China and the United States in Civil-Commercial Air and Space: Specialist cultures and international relations in high-technology sectors

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy

Department of Political Science
University of Toronto

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Abstract

Why are some high-technology sectors trans-nationally integrated while others are sites of interstate competition? This dissertation explores this question through a comparison of China-U.S. relations in two strategic, high-technology sectors: civil-commercial aircraft manufacture and civil-commercial spacecraft manufacture. Between 1989 and 2009, China-U.S. relations took strikingly different trajectories in these two sectors. In the aircraft sector, the two countries’ industries traded and integrated their activities and their civil agencies cooperated. By contrast, in the space sector, their industries did not trade or integrate, their civil agencies did not cooperate, and the two countries engaged in a form of technological competition. The divergent trajectories taken by China-United States relations in these two sectors are puzzling because both sectors present similar incentives and disincentives for both transnational integration and interstate competition. Theories of international relations do not fully explain this sectoral variation. This research indicates that this variation is traceable to underlying differences in how specialists in each sector, including technical and policy experts, implicitly reason about and represent technologies in general. In both countries, the air and space specialist communities each hold distinct understandings of the relationship between humans and technology.
Performing representational practices that reflect these distinct assumptions, aeronautic and space specialists discursively constitute each sector and its technologies as distinct objects of policy, requiring different forms of state action. In air, these include policies adopted by both countries to enhance bilateral trade, industrial partnership, and technical cooperation. In space, these include measures to inhibit bilateral trade and cooperation while preparing for a coming bilateral confrontation.
Acknowledgements

This dissertation would not have been possible without the help of many individuals.

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Note on Translation

With the exception of certain titles of articles and books, all translations herein are the author’s own, unless otherwise indicated.

Readers may notice that the translations to English often do not read smoothly. This reflects deliberate choices about the translation and exposition of the material. I performed the analysis of the Chinese-language discourses for this research on the Chinese-language originals, rather than on their translations to English. In order to give readers of this text who do not read Chinese characters a window into this process, I aimed to provide translations that conveyed the original terms, including specific words, as directly and literally as possible. This approach came at the expense of conveying the larger meaning of the Chinese-language passages in a more natural-sounding English.
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<tr>
<th>Acronym</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>A&amp;R</td>
<td>Automation and robotics</td>
</tr>
<tr>
<td>AIA</td>
<td>Aerospace Industries Association (USA)</td>
</tr>
<tr>
<td>AIAA</td>
<td>American Institute for Aeronautics and Astronautics</td>
</tr>
<tr>
<td>AMS</td>
<td>Academy of Military Sciences, PLA</td>
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<tr>
<td>APSCO</td>
<td>Asia-Pacific Space Cooperation Organization</td>
</tr>
<tr>
<td>Avic</td>
<td>Aviation Industries Corporation of China</td>
</tr>
<tr>
<td>Beihang</td>
<td>Beijing University of Aeronautics and Astronautics (China)</td>
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<tr>
<td>C4ISR</td>
<td>Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance</td>
</tr>
<tr>
<td>CAAC</td>
<td>Civil Aviation Administration of China</td>
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<tr>
<td>Calt</td>
<td>China Academy of Launch Vehicle Technology</td>
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<tr>
<td>CAS</td>
<td>Chinese Academy of Sciences</td>
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<tr>
<td>Casc</td>
<td>China Aerospace Science and Technology Corporation</td>
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<tr>
<td>Casic</td>
<td>China Aerospace Science and Industry Corporation</td>
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<tr>
<td>CASS</td>
<td>Chinese Academy of Social Sciences</td>
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<tr>
<td>CCL</td>
<td>Commerce-Controlled List</td>
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<tr>
<td>CICIR</td>
<td>China Institutes for Contemporary International Relations</td>
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<td>CIIS</td>
<td>China Institute of International Studies</td>
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<tr>
<td>CLEP</td>
<td>China Lunar Exploration Program</td>
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<td>CMSEO</td>
<td>China Manned Space Engineering Office</td>
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<td>CNSA</td>
<td>China National Space Administration</td>
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<tr>
<td>Comac</td>
<td>Commercial Aircraft of China</td>
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<tr>
<td>Costind</td>
<td>Commission for Science, Technology and Industry for National Defense (China)</td>
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<tr>
<td>CRS</td>
<td>Congressional Research Service, U.S. Congress</td>
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<tr>
<td>CSIS</td>
<td>Center for Strategic and International Studies (USA)</td>
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<tr>
<td>CSSAR</td>
<td>Center for Space Science and Applications Research, CAS</td>
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<tr>
<td>ESA</td>
<td>European Space Agency</td>
</tr>
<tr>
<td>FFRDC</td>
<td>Federally funded research and development center (USA)</td>
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<tr>
<td>GAD</td>
<td>General Armaments Department, PLA</td>
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<tr>
<td>GAO</td>
<td>Government Accountability Office, U.S. Congress</td>
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<tr>
<td>GE</td>
<td>General Electric Company (USA)</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System (USA)</td>
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<tr>
<td>Great Wall</td>
<td>China Great Wall Industry Corporation</td>
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<tr>
<td>ISS</td>
<td>International Space Station</td>
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<tr>
<td>ITAR</td>
<td><em>International Traffic in Arms Regulations</em></td>
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<tr>
<td>ITU</td>
<td>International Telecommunications Union</td>
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<tr>
<td>LEO</td>
<td>Low-Earth orbit</td>
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<tr>
<td>MOST</td>
<td>Ministry of Science and Technology (China)</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration (USA)</td>
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<td>NDRC</td>
<td>National Development and Reform Commission (China)</td>
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<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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NRC  National Research Council (USA)
NUDT  National University of Defense Technology (China)
OSTP  Office of Science and Technology Policy in the Executive Office of the President (USA)
OTA  Office of Technology Assessment, U.S. Congress
PLA  People's Liberation Army (China)
PNT  Position, navigation, and timing
R&D  Research and development
RMA  Revolution in Military Affairs
Sastind  State Administration for Science, Technology and Industry for National Defense (China)
SIIS  Shanghai Institutes for International Studies
U.S.ML  U.S. Munitions List
ULA  United Launch Alliance (USA)
UTC  United Technologies Corporation (USA)
Part I:
Question, theory, and methods
Part I: Chapter 1

Research Question

Introduction

In some high-technology manufacturing sectors, research, development, and production are seamlessly global processes. In others, they are confined by country borders to national systems that compete with each other. Why are some high-technology sectors transnationally integrated while others are sites of interstate competition? This dissertation explores this general question through an examination of relations between China and the United States in two strategic high-technology sectors: the civil-commercial air sector and the civil-commercial space sector. The air sector consists of activities related to the development, production, and operation of small and large commercial aircraft or their parts by national aeronautic agencies and by public or private firms. The space sector consists of activities related to the development, production, and operation of civil and commercial satellites, launch vehicles, and their parts by national space agencies and by public or private firms.

The air and space sectors share features that make them equally probable sites of transnational trade, industrial integration, and technical cooperation. The two sectors also share features that make them equally likely sites of international suspicion and competition for technological capabilities. Yet, after the end of the Cold War, China-U.S. relations in these two sectors followed strikingly different trajectories. In air, the two countries’ industries rapidly integrated their activities. Chinese and U.S. agencies also engaged in civil aeronautic cooperation. In contrast, in space their firms did not trade or integrate their activities. Their programs did not cooperate. Instead, tensions grew between the two countries over their

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1 The air sector excludes the air transportation business, i.e. airlines.
respective technology development programs. This dissertation examines why and how China-U.S. relations evolved differently in these two sectors between 1989 and 2009.

Theoretical approaches brought to the study of these and related subjects in international relations emphasise different factors to explain when states will cooperate or compete in a given domain. The most important among these factors are the international distribution of power, the economics of transnational integration, national economic development agendas, international prestige motives, and domestic politics. Realists, liberals, and modernist constructivists of different schools each emphasise factors among these to explain when international relations are cooperative or competitive. However, their approaches account for neither the variation across the air and space sectors nor for particular features of China-U.S. relations in one or the other sector.

Drawing on theory and research in international relations and in science and technology studies, this thesis examines whether and how contrasting specialist cultures account for the different bilateral outcomes observed in air and space. A specialist culture is shared among the national and transnational groups of professionals who participate in any given technical sector. These include engineers, scientists, policy experts, and business leaders. Sectoral specialists share technical knowledge and certain basic philosophical understandings from which they reason and act. They express this common background knowledge in representational practices. Together, these common understandings and practices constitute a sector’s internal specialist culture.

During the two decades under study, experts in the air and space sectors constituted two distinct transnational communities, each held together by a specialist culture. Within each of these communities, members shared background knowledge comprising a set of basic assumptions about the human-technology relationship. These included common understandings
about human nature, relations between humans and their machines, and relations between nation-states. In other words, each sector had a distinct culture rooted in and expressing a specific anthropology, sociology of technology, and theory of international politics. Experts expressed these shared background knowledge in common habits of speech, writing, and illustration.

During the two decades following the end of the Cold War, participants in the Chinese and U.S. air sectors shared a specialist culture. Aeronautic experts in both countries drew on this culture when they described and explained their sector to their national policymakers and decisionmakers. Through their depictions, specialists discursively created and produced their sector and their technologies as objects requiring particular policies. They represented aircraft technologies as inherently commercial and civil and as products of a global supply chain. They represented global markets as offering irresistible opportunities for their national companies. They represented trade and industrial integration with foreign firms as natural, as desirable, and as posing modest, manageable risks. They characterised cooperation between their two countries’ civil aeronautic programs as mutually beneficial. Chinese and U.S. specialists constituted their sector to their national policymakers in ways that supported the adoption of policies fostering trade, industrial integration, and technical cooperation between the two countries.

Experts in the space sectors of both countries shared a different specialist culture, rooted in a distinct philosophy of the human-technology relationship and expressed in distinct representational practices. Space specialists represented their technologies to policymakers and decisionmakers as inherently strategic and as having dual civil and defense applications. They characterised trade between firms in the two countries as posing technology transfer risks that could not be managed. They represented technical cooperation in civil space as jeopardizing national security and as bringing scant benefit to their countries. Through these representational practices, space specialists constituted policies limiting and blocking bilateral trade and
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cooperation as prudent and feasible to policymakers. At the same time, their representations supported the adoption of policies fostering the autonomous development of space capabilities in each country. The central argument of this dissertation is that, through their representational practices, aeronautic and space experts in China and the United States made possible the adoption of policies fostering the distinct bilateral outcomes observed in the two sectors.

The first part of this chapter examines the distinct trajectories followed by China-U.S. relations in the air and space sectors. The second part discusses the theoretical significance of this sectoral variation, highlighting the similarities that predisposed these sectors to similar bilateral outcomes. The third part explores how theories of international relations can shed light upon this sectoral variation or aspects of it, concluding that the most influential perspectives in the field fail to account for the variation and for important aspects of Chinese and U.S. conduct. The final part outlines the structure of this dissertation and its chapters.

1. China and the United States in the air and space sectors

In this account, trade refers to transnational purchase and sale of aircraft-related goods and services. Industrial integration refers to collaborations in research, development, and production activities between firms from different countries. It includes the establishment of transnational joint ventures or mergers and acquisitions of firms in one country by those in another. Technical cooperation refers to intergovernmental collaborations between civil agencies in different countries. In both the air and space sectors, industry-led commercial activities and government-led civil activities are closely related.

Between 1989 and 2009, China-U.S. relations in the air and space sectors evolved in opposite directions. The air sector saw bilateral trade, industrial integration, and technical civil cooperation deepen and grow. The space sector saw neither trade, integration, nor cooperation
flourish, but rather security tensions and competition for new systems between the two countries worsen.

1.1. Bilateral trade, industrial integration, and technical cooperation in air

Following the end of the Cold War, aircraft manufacture became a global and transnational activity. The major manufacturers of finished aircraft consolidated into a few large companies with production networks that spanned the globe. The sector differentiated itself into several segments, including one for large aircraft dominated by Airbus and Boeing Commercial Airplanes (hereafter in the air sector, Boeing) and others for smaller airliners, defense aircraft, rotorcraft, sub-systems, and components. These firms developed among the most sophisticated and integrated worldwide supply chains of any high-technology manufacturing industry. China-U.S. relations reflected this trend toward global trade, industrial integration, and technical cooperation. Bilateral trade and partnerships in aircraft manufacture deepened and broadened over time.

By the late 1980s, leading U.S. firms, such as Boeing and McDonnell Douglas, had already begun partnerships with manufacturers of aircraft components in China and other emerging markets. Initially, these collaborations produced relatively small aircraft parts. As in other countries with rapidly growing demand for aircraft, in China the government tied foreign manufacturers’ sales to the localisation of production and the transfer of technology to local

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firms. This localisation took the form of joint ventures between foreign and Chinese firms for the production of parts and components. Major North American and European aircraft manufacturers competed for sales in the Chinese market by moving more and more of their production activities to China.

Transnational partnerships of this type grew in scope and in the sophistication of their products. By the 2000s, these collaborations had expanded to include not only the production of technically demanding items, but also joint research and development into new products. By 2011, major U.S. firms were partners in no fewer than 28 joint ventures initiated in China. During this same period, the Chinese government implemented plans for Chinese companies to produce finished aircraft of their own. These included a regional jet and a large passenger jet. With this change, Chinese firms went from suppliers to buyers of aircraft components from U.S. firms. Bilateral industrial integration deepened as these projects advanced throughout the late 2000s.

Transfers of technology and capacity were inherent in the integration of the Chinese and U.S. aircraft industries. These transfers provoked mounting regulatory and political concerns in the United States throughout this period, but integration grew in spite of them. During the two decades after 1989, the U.S. government regulated, but did not block, trade or industrial partnerships between U.S. and Chinese firms. This situation obtained even while a Chinese firm

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6 Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies.”

entered the strategically important large-carrier segment of the industry as a maker of finished aircraft, taking the first step toward becoming a competitor to U.S. champion Boeing in Chinese and international markets. Nor did this approach change when, in the late 1990s, evidence of illegal transfers of U.S. aeronautic technologies to Chinese defense programs surfaced.\textsuperscript{8} The response to these developments by U.S. policymakers was subdued and slow. Neither the Administration nor Congress took measures to restrict integration between Chinese and U.S. firms in the sector.

China-U.S. aircraft industrial integration was also unaffected by signs of progress in China’s military aircraft programs.\textsuperscript{9} Aeronautic experts indicated that advances in defense aviation were accelerated by Chinese manufacturers’ civil-commercial activity. In spite of these changes, bilateral industrial integration and technical cooperation proceeded unfettered during these two decades.\textsuperscript{10}

1.2. No bilateral trade or cooperation, but mounting tension in space

During the same period, bilateral relations in the space sector took a different course. Firms from both countries engaged in only limited trade and did not integrate their research, development, or production efforts. The two countries’ civil space agencies did not cooperate. Instead, tensions grew between the two governments over their respective space technology programs.

\textsuperscript{8} 2010 Report to Congress of the U.S.-China Economic and Security Review Commission.
Although the U.S. space program was more familiar to international observers, China had also established multi-faceted civil, defense, and commercial space activities following World War II.\textsuperscript{11} In both countries, space activities were increasingly commercial by the late 1980s. U.S. firms dominated commercial satellite manufacture and applications, such as communications and remote sensing. During this time, China also developed a commercial space sector, including rockets capable of delivering commercial satellites to orbit.\textsuperscript{12} China’s leading space industrial group began to make available competitively priced launch services for commercial satellites on global markets.

Beginning in the early years of the Cold War, the U.S. government regulated certain exports of space items as exports of defense articles. These and other restrictions on launch purchases prevented U.S. satellite manufacturers from using Chinese launch services. By the late 1980s, however, the U.S. space industry faced a shortage of launches, which harmed the competitiveness of its satellite manufacturers. Facing these circumstances, the administration of President Ronald Reagan and, later, his successors authorised nearly thirty launches of U.S.-manufactured commercial satellites from China. The launches from China continued even after the 1989 Tiananmen crackdown, when the U.S. government implemented sanctions that restricted trade with China in defense items.

This limited bilateral trade came to an abrupt end in 1999, when the U.S. Congress banned the export of space technology to China in the National Defense Authorization Act for year. The passage of this law was triggered by a congressional committee’s investigation into

\textsuperscript{11} On the origins of China’s space industry under Chairman Mao Zedong, The Capital Aerospace Engineering Corporation [首都航天机械公司], \textit{Wide Road, Long Journey [大道远行]} (Beijing, China: China Astronautics Publishing House, 2011).
allegations, still under federal investigation at the time, of illegal defense technology transfers to China by U.S. satellite manufacturers. In a report titled *U.S. National Security and Military/Commercial Concerns with the People’s Republic of China*, the committee identified a pattern of successful efforts by the Chinese government to acquire U.S. technologies with defense and security applications. In particular, it found that Chinese entities had acquired restricted technical data from U.S. satellite companies, which could have led to improvements in China’s dual-use launch vehicles and ballistic missiles.\(^\text{13}\) The U.S. Congress responded to the report by legislating a tighter sector-wide prohibition on the export or transfer of any space item to China. This prohibition extended to the deemed export of satellites containing U.S. parts to Chinese launch sites. Because almost all commercial satellites sold worldwide contained U.S. parts, this prohibition quickly decimated China’s budding launch industry.

Over the years that followed the 1999 rule change, the China-U.S. relationship took a turn that marked a sharp contrast from relations in the aircraft sector. In space, commercial ties and civilian-scientific relations between the two countries all but disappeared. Mutual hostility and suspicion over space activities grew. Defense analysts in both countries expressed alarm at the implications of revived U.S. interest in a space-based missile defense system, China’s 2007 test of anti-satellite technology, and the U.S. conduct of a similar procedure a year later. Chinese observers became preoccupied with what they regarded as efforts by the U.S. military to control or limit its access to and use of space. Defense experts in the United States worried about Chinese efforts to develop weapons they feared would target their military’s Achilles’ heel, the fragile space systems on which it had grown dependent. Experts in both countries emphasised

\(^{13}\) *U.S. National Security and Military/Commercial Concerns with the People’s Republic of China* (Select Committee, United States House of Representatives, 1999); Michael M. May et al., *The Cox Committee Report: An Assessment* (Center for International Security and Cooperation, Stanford University, 1999); Gregory Kulacki and Joan Johnson-Freese, “Significant Errors in Testimony on China’s Space Program” (Union of Concerned Scientists USA, May 20, 2008).
the military potential of space technologies developed by the other country for primarily civil and commercial applications.\(^\text{14}\) By the end of the decade, not only had the potential for space cooperation and commerce between the two countries evaporated, but a growing chorus of observers also announced the start of the second international space race.\(^\text{15}\)

### 2. Theoretical significance:

**Why are the different outcomes in air and space interesting?**

The divergence in China-U.S. relations across air and space is interesting because the two sectors shared a similar mix of both incentives and disincentives for bilateral trade, industrial integration, and technical cooperation.

Several factors made trade, industrial integration, and technical cooperation between the two countries likely outcomes in both sectors.

First, *economic incentives for transnational integration and international cooperation existed in both sectors, including economies of scale and cost- and risk- sharing opportunities*.\(^\text{16}\) National firms and programs benefitted from integrating their research, development, and production activities with suppliers and partners abroad. In air, these factors drove the integration of aircraft manufacture across Chinese, European, and U.S. firms.\(^\text{17}\) In space, these

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\(^{15}\) E.g. Erik Seedhouse, *The New Space Race: China Vs. the United States* (Chichester, UK: Springer Praxis, 2009).


\(^{17}\) Esposito, “Strategic Alliances and Internationalisation in the Aircraft Manufacturing Industry,” 443–444.
factors were behind the consolidation of several national space programs into the European Space Agency (ESA).\textsuperscript{18}

Second, \textit{U.S. supply and Chinese demand were complementary in both sectors}. U.S. firms sold competitively priced aircraft and satellites, while China’s demand for air travel and space-based services was growing. Actors in both sectors stood to benefit from bilateral trade.

Third, \textit{in both sectors, U.S. firms faced competition from European companies eager to trade and cooperate with Chinese firms}. In air, these rivals included aircraft manufacturer Airbus and engine maker Snecma. In space, European competitors included major satellite manufacturers. For example, the company Thales Alenia Space began producing a satellite free of U.S. components for the express purpose of launching inexpensively from U.S. export-controlled destinations, such as China. Because economies of scale obtained in both aircraft and spacecraft manufacture, European firms that increased their total volume of sales by selling to the large Chinese market also made their products more competitive in other export markets.

Several other factors also made bilateral trade, integration, and cooperation unlikely outcomes in both sectors.

First, \textit{in each sector, civil-commercial technologies were closely related to defense technologies}. In air, civil-commercial and defense products and production techniques were similar or identical for both types of aircraft.\textsuperscript{19} Computer-aided design and manufacturing, precision machining, composite materials, high-bypass turbofan engines, and flight-control systems were among the commercial aeronautic technologies with defense applications.\textsuperscript{20} Even when specific commercial aircraft products did not have direct defense applications, the


\textsuperscript{19} Author interviews with a U.S. government official responsible for export control compliance verification and with Chinese aviation specialist in a subsidiary of Avic, Beijing, 2011.

\textsuperscript{20} Roger Cliff, Chad J.R. Ohlandt, and David Yang, \textit{Ready for Takeoff: China’s Advancing Aerospace Industry} (Santa Monica, CA: The Rand Corporation, 2011), 120.
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capabilities required to engage in the research, development, and production of commercial aircraft could be applied to defense programs. In space, civil-commercial space items and manufacturing capacity were also applicable to defense programs. Civil and commercial weather and imaging satellites, positioning, navigation, and timing (PNT) satellites, and manoeuvrable spacecraft used in civil missions could perform military and intelligence functions. Chinese policymakers and policy specialists stressed the goal of civil-military integration in both the air and space sectors because, in each sector, a common industrial and technical base produced both types of items.

Second, the U.S. government knew of illegal defense or dual-use technology transfers from U.S. firms to Chinese entities in both sectors. These cases cast doubt on whether regulation was sufficient to prevent such transfers in trade with China. Federal agencies and congressional committees investigated export control violations in both sectors. In air, U.S. manufacturer McDonnell Douglas exported to China precision machining tools that could be applied to both commercial and military production in violation of the Export Administration Regulations. In space, U.S. satellite makers Hughes and Space Systems Loral disclosed controlled technical data about space items to their Chinese launch provider without the required export license from the Department of State.

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Third, maintaining an advantage over China in defense technologies in both air and space was important to the U.S. government during this period. Throughout those two decades, the most likely site of a military confrontation between the United States and China was the Taiwan Strait, a setting in which air and space systems would perform important functions for both sides. U.S. defense analysts expected air operations to be decisive in such a conflict. China’s defense aircraft modernisation threatened to deny the U.S. military access to the Taiwan Strait and the waters off China’s coast. As in other distant theatres, in the Taiwan Strait U.S. forces would also rely on space-enabled command, control, communications, intelligence, surveillance, and reconnaissance capabilities. China’s development of anti-satellite weapons and civil space capabilities with counter-space applications threatened the space assets on which the U.S. military would depend for operations in such a conflict.

Fourth, the Chinese defense industry made significant progress on defense technologies in both of these sectors during this period, raising concerns about an erosion of U.S. advantage in both domains. In air, this progress was indicated by the development of new indigenous fighter aircraft platforms, including a reported stealth variant, several of which test flew by 2011. U.S. experts at the time also expected the Chinese military to soon test a new indigenous fighter engine. Analysts attributed these developments in part to the Chinese air industry’s progress in commercial manufacture. In space, China’s defense industry also made progress toward developing military and intelligence space systems. The People’s Liberation Army (PLA) tested its first ground-based kinetic anti-satellite weapons and in-space rendez-vous and capture capabilities after 1999. The PLA also deployed new space intelligence assets and space systems that could enhance battlefield communications, command, and control. As in the air sector, in space defense programs advanced in step with civil-commercial programs.
Fifth, both sectors featured industries of strategic value to their national economies and products that had become integral to vital national infrastructures. These features made both air and space improbable sites of trade and cooperation between countries in tense security relationships. The air and space industries both generated positive externalities and produced intermediate goods and services critical to the rest of their national economies. In both countries, the development of air and space brought spin-off applications to other sectors and supported the development of other high-technology sectors and regional economies. Similarly, commercial space applications and products supported the development of industries outside the space sector and of remote areas. Space assets provided weather data and PNT signals also integral to the two countries’ infrastructures.

These factors made the air and space sectors equally likely sites of China-U.S. trade, industrial integration, and technical cooperation. A similar mix of both incentives and disincentives for transnational trade, integration, and cooperation gave outside observers reason to expect similar bilateral outcomes in the two sectors.

3. A puzzle for theories of international relations

The contrasting developments in air and space pose a challenge not only to common sense, but also to theories of international relations. Two different patterns of interstate relations developed within the same bilateral relationship and in sectors exhibiting otherwise similar characteristics. Existing theories of international relations explain aspects of these developments, but fall short of adequately accounting for the variation across these two sectors. Most of the

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international relations approaches that help explain developments in one or the other sector predict similar outcomes for both. The remainder of this section considers theoretical perspectives that each emphasise one of the following factors as determinants of international trade, cooperation, and/or competition: the distribution of power in the international system; the economics of transnational integration; international institutions; the pursuit of national prestige; economic development strategies; and domestic politics and institutions within each state.

### 3.1. Distribution of power

In realist theories of international politics, the distribution of power in the international system is the main variable determining when states will compete and when they will cooperate. The systemic distribution of power is often assessed as a comparison of different states’ individual measures of aggregate national power.\(^{26}\) This understanding of power makes realism insensitive to variation across areas or sectors of state activity that bear similarly upon relative national strength.\(^{27}\) outside of alliances, states should engage in cooperation only when it affords them greater gains than their partners and resist cooperation when they might incur relative losses. For this reason, realists who regarded China as threatening U.S. strength in the 1990s and 2000s warned against *all* forms of technical and commercial cooperation in which China accrued gains relative to the United States. In their view, the U.S. government should have equally restricted industry partnerships with China in all sectors that afforded opportunities for technology transfer. The U.S. government, then, should have blocked integration between U.S. and Chinese firms in both the air and space sectors. The outcome realists expected was no bilateral trade, industrial


\(^{27}\) Waltz, *Theory of International Politics*, 131.
integration, or technical cooperation in either sector. Realists would also have predicted worsening tension and suspicion between the two countries and their respective technology development programs advanced in both sectors.

Some realists accept that states occasionally forego small relative gains in the short term in order to reap economic benefits or larger relative gains in the long term. However, both air and space were important enough to U.S. and Chinese security that even such nuances to the realist perspective cannot explain the courses their relations took in these two sectors.28 While U.S. conduct was consistent with realist predictions in the space sector, it ran counter to them in the air sector. In aircraft manufacture, the U.S. government allowed its firms to help build up a Chinese industry expected to rival its own. In the same process, the U.S. government allowed U.S. firms, including its major defense contractors, to develop the defense-industrial base of the most likely challenger to U.S. interests.

The relative gains to China from the integration of its air industry with U.S. firms unsettled U.S. realists. Realists observing China-U.S. relations regularly cited the modernisation of the PLA, perhaps the most substantial military transformation in world history, as among the greatest threats to U.S. interests and U.S. global leadership.29 Security analysts expected China’s air force modernisation to benefit from the development of the country’s commercial aircraft-manufacturing industry.30

The strength of China’s defense aircraft programs and aircraft industry concerned realist analysts because they regarded air power and air dominance as essential to winning contemporary

wars. They observed bombers and fighters decide major wars during the 1990s and 2000s.\textsuperscript{31} Moreover, during those two decades, U.S. defense, foreign policy, and academic observers agreed that the greatest likelihood of major war faced by the United States was with China in the Taiwan Strait, a setting in which air operations would play a crucial role on both sides.\textsuperscript{32}

During most of those two decades, the strongest constraints on the technological upgrading of the PLA Air Force were technical and fiscal.\textsuperscript{33} That the U.S. government allowed U.S. firms to strengthen China’s dual-use aircraft industrial base therefore ran counter to realist expectations.\textsuperscript{34} At minimum, the development of China’s integrated commercial-defense air industry enhanced China’s capacity to build large numbers of military aircraft at lower cost, loosening the fiscal constraint on the PLA’s technological modernisation. At maximum, U.S. firms transferred advanced defense technologies developed with U.S. taxpayers’ dollars to Chinese firms in exchange for short-term market access. Thus, to realists, the integration of production activities by U.S. and Chinese firms was descriptively puzzling and prescriptively imprudent.

When China-U.S. relations in the space sector are considered in isolation, a realist perspective appears more persuasive. If China was the most significant challenger to U.S. military and technological leadership, then it follows that the two countries should not have cooperated, but competed, to acquire space technologies. Nevertheless, aspects of both U.S. and Chinese conduct in the space sector during this period were inconsistent with realist expectations.

\textsuperscript{31} E.g. Roger Cliff, \textit{The Development of China’s Air Force Capabilities: Testimony Presented before the U.S.-China Economic and Security Review Commission} (Washington, DC, 2010).


Balance-of-power realisms predicted China’s pursuit of some advanced space capabilities with defense applications. Scholars in this school expect states to aim for and preserve a balance of capabilities among major powers. China lagged far behind the United States in defense space technology during this period. To correct this disadvantage, it would have been rational for Chinese policymakers to focus scarce space resources on achieving a minimal deterrent capability vis-à-vis the United States. The pursuit of minimal deterrence would also have been consistent with China's nuclear posture and conduct toward arms control. Rather than attempting to match the numbers and size of U.S. and Soviet nuclear weapons, Chinese policymakers decided on a small nuclear arsenal sufficient to deter their country’s enemies from attacking. Given the need to achieve a balance of defense capabilities in space, then, it was not rational for China’s leaders to implement costly programs that reproduced U.S. achievements in civil space, including human spaceflight and exploration, as they did. Balance-of-power realisms cannot explain the expansion of Chinese activities in space to these areas and China’s pursuit of capabilities beyond those necessary for deterrence.

If achieving strategic, not absolute, parity with the United States was China’s goal, then we should not have observed Chinese decisionmakers divert scarce resources away from defense-related space activities to a risky, costly, and conspicuous human spaceflight program of no military value. The contention that China’s human spaceflight program was a smokescreen for a military space program is equally unpersuasive, since human spaceflight capabilities had very few, if any, defense applications. A smokescreen for a military program should have taken the

35 Martel and Yoshihara, “Averting a Sino-U.S. Space Race.”
form of a far less costly and less visible program oriented toward civil and commercial applications, activities that could have been presented and justified as serving economic modernization goals.

Realists also assert that states do not and should not seek conflicts they cannot win. China was unlikely to win against the United States in an overt space competition of the type that opposed the United States and the Soviet Union. Instead, the greatest threat China posed to the United States in space was ‘asymmetrical,’ meaning that it relied on relatively simple, low-cost, but high-impact technologies, used against a more powerful but unsuspecting adversary. Asymmetrical capabilities, however, could not deter or outdo an adversary by their ostensible strength or numbers, since their very affordability and attainability depended on their technical ‘backwardness’ and smaller scale. Given this situation, it puzzles realists that China deliberately undertook activities that exacerbated tensions and hostility with the United States. No variant of realism can explain why the Chinese government stoked the fires of an overt space competition that the country lacked the resources to win by provocative activities, such as dazzling the sensors on U.S. satellites with ground-based lasers and testing a kinetic anti-satellite system.

Moreover, realist expectations are inconsistent with Chinese spending and activities in space. The realist argument that China developed anti-satellite weapons to target strategic vulnerabilities in U.S. defenses cannot account for China’s own investments in space systems. During this period, China pursued a range of space technology development programs with defense applications. Chinese space specialists’ writings of the time emphasised the need to

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39 Handberg and Li, *Chinese Space Policy*; Johnson-Freese, *Space as a Strategic Asset*; Harvey, *China’s Space Program: From Conception to Manned Spaceflight*; Erickson and Walsh, “National Security Challenges and Competition.”
41 One account of these developments is found in Ren Zhong, *Challenging the Blue Sky: Radar and Space Electronic Technology Expert Zhang Luqian* [挑战蓝天: 雷达与空间电子技术专家张履谦] (Beijing, China: China
follow the United States in developing networked military forces enabled by space-based information and communications technologies.\textsuperscript{42} These hardware investments and changes in strategic thought set China on a course to develop the same reliance on space systems that realists claimed it sought to target in U.S. defenses. The Chinese government also increased its overall investment in the space domain with the pursuit of a large-scale human spaceflight program and exploration programs.\textsuperscript{43} With so many assets of its own in space vulnerable to retaliation, China’s strategic advantage in space began to erode. As China developed into a space-dependent power, it began to lock itself into a relationship of mutual vulnerability with the United States that would deny it the benefits of asymmetric deterrence.

Realist perspectives also fail to account for some U.S. policies. Realist theories positing a need to ‘contain’ China’s rise appeared to both explain and inform U.S. restrictions on space technology exports. However, these perspectives do not account for why the U.S. government adopted a strict policy of technology denial in the space sector, but not in other important sectors featuring dual-use technologies, such as aircraft manufacture. Equally unclear is why the U.S. government continued to adopt this approach toward China in the space sector when its broader experience of bilateral relations since the 1980s had shown that it was ineffective and costly.\textsuperscript{44} In a range of areas, attempts by other countries to deny China new technologies were met with

\textsuperscript{42} Reviews of these writings are found in Cheung, Fortifying China, 250; Andrew S. Erickson, “Beijing’s Aerospace Revolution: Short-range Opportunities, Long-range Challenges,” in Chinese Aerospace Power: Evolving Maritime Roles, ed. Andrew S. Erickson and Lyle J. Goldstein (Annapolis, MD: Naval Institute Press, 2011), 3–18.

\textsuperscript{43} Di, Dreams of the Road to Heaven: Surveying China’s Human Spaceflight Engineering (梦圆天路 - 纵览中国载人航天工程); Chinese Academy of Spaceflight Technology (中国空间技术研究院), Beacons on the Sky Road: Legendary Stories of China’s Satellite Spacecraft (天街明灯:中国卫星飞船传奇故事) (Beijing, China: China Astronautics Publishing House, 2008); Ningfeng Deng, Oneirromancy of the Milky Way [天河圆梦] (Beijing, China: China Astronautics Publishing House, 2004); Faren Qi and Yili Li, Shenzhou Overview: Uncovering the Secrets of Manned Spacecraft (巡天神舟 - 揭秘载人航天器) (Beijing, China: China Astronautics Publishing House, 2010).

\textsuperscript{44} E.g. James A. Lewis, Export Controls / Dual Use Technology and Technology Transfer Issues: Testimony for the United States-China Security Review Commission (Washington, DC, 2002).
successful Chinese efforts to develop the same technologies indigenously.⁴⁵ Space experts in the late 1990s and early 2000s recognized that this form of substitution was occurring in their sector. By that time, it was apparent to them that China was autonomously developing comprehensive space capabilities.⁴⁶ As this progress reduced China’s interest in U.S. space products, it deprived the U.S. government of negotiating leverage toward China on technology transfer and space security issues.⁴⁷ From the perspective of a balance-of-power theorist, a more promising U.S. approach would have been to prevent, delay, and/or disincentivise the Chinese space industry from developing indigenous space capabilities by strategically supplying users in China with the civil and commercial products they sought.⁴⁸ However, the U.S. government did not attempt this strategy.⁴⁹

Variants of realist theory account for aspects of U.S. policy toward China, but they do not explain why the U.S. government continued to implement realist strategies when it saw them fail and alternatives were available.

### 3.2. Economics of transnational integration

Some liberal theorists of international relations emphasise countries’ shared economic interests as drivers of international trade, industrial integration, and cooperation. Their approaches do not explain the divergent trajectories taken by China-U.S. relations in air and space. Theoretical perspectives emphasising the two countries’ economic interests in trade and technical cooperation predict similar outcomes in both sectors of the bilateral relationship. Liberal-economic theories predict bilateral trade in both sectors, the integration of the two

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⁴⁵ Handberg and Li, *Chinese Space Policy*; Shambaugh, *Modernizing China’s Military*.
⁴⁷ Handberg and Li, *Chinese Space Policy*; Johnson-Freese, *Space as a Strategic Asset*.
⁴⁸ Private remarks by former U.S. administration official responsible for space policy.
⁴⁹ Johnson-Freese, *Space as a Strategic Asset*. 
countries’ research, development, and production activities in both sectors, and technical cooperation by the two countries’ civil agencies in both sectors. These predictions would be consistent with broader, global trends toward transnational trade, industrial integration, and technical cooperation observed in both sectors, but they do not explain China-U.S. relations.

In the two decades following 1989, aircraft manufacture became a transnational activity. As the largest aircraft system and sub-system integrators specialised and faced offset requirements in international markets, they integrated their research, development, and production with suppliers and partners all over the world. U.S. firms followed this course in China.

During this time, circumstances in the space sector also induced the transnational integration of research, development, and production activities by firms and public agencies. Important economies of scale and incentives to pursue cost-sharing and risk-spreading arrangements existed in all the major segments of civil and commercial space. These included launch vehicle, satellite, and component manufacture. Observing these trends, space experts in 1994 expected that “the future in space will be marked, by necessity, by an increasing international cooperation. The major space programs will most probably be mutually dependent.” By 2009, their prediction held true for the programs and industries of close allies, but not for those of China and the United States. Chinese and U.S. space agencies did not cooperate, nor did their major space firms trade.

The U.S. policy that limited bilateral trade, industrial integration, and technical cooperation with China was costly for the U.S. space sector. U.S. satellite manufacturers and operators were not able to take advantage of competitively priced Chinese launchers, while

50 Peter, “The Changing Geopolitics of Space Activities.”
launch costs in the United States remained high.\textsuperscript{52} U.S. companies also lost opportunities to sell satellites to China. By 2006, one analyst estimated that losses to U.S. firms resulting directly from the tightened export controls totalled as much as six billion US dollars.\textsuperscript{53} The U.S. government maintained the export controls even while competing European firms began to procure inexpensive Chinese launches, giving them an edge in the competitive global satellite market. The controls remained as these European concerns’ trade with China grew and as European civil programs expanded cooperation with Chinese partners, becoming less reliant upon and interested in their traditional U.S. partners. Recognising this situation, critics of U.S. export controls sought reforms that would allow U.S. firms to trade with Chinese firms in commercial items like their European competitors. In spite of these efforts, policymakers and decisionmakers kept the strict controls in place, justifying them as necessary to protect national security and on the terms of the Tiananmen sanctions.\textsuperscript{54}

Theories emphasising economic factors predict a convergence in the air and space policies within each country that did not occur. In particular, if economic interests influenced the likelihood of bilateral trade, industrial integration, and technical cooperation in air and space, then U.S. policies for the two sectors would have converged, rather than diverged.

3.3. International institutions

Some liberal theorists of international relations argue that international institutions explain why states cooperate and trade in some areas but not others. They argue that institutional factors, such as the presence, robustness, and other features of institutions, are independent

\textsuperscript{52} An influential and controversial report that attempted to assess these costs is Guy Ben-Ari and Pierre Chao, \textit{Health of the U.S. Space Industrial Base and the Impact of Export Controls} (Washington, DC: Center for Strategic and International Studies, February 19, 2010).
\textsuperscript{54} Handberg and Li, \textit{Chinese Space Policy}. 
variables making cooperation or trade between states in particular policy areas more or less likely. Their theoretical perspectives fall short of adequately explaining China-U.S. relations in air and space. Institutional factors do not predict the variation in bilateral relations across the two sectors, although institutional theories elucidate particular aspects of each sector’s outcome.

Perhaps the most important institutional factor expected to increase the likelihood of cooperation and trade between states is their joint participation in international institutions. This factor fails to explain the variation across sectoral outcomes in the bilateral relationship. In air, China and the United States did not jointly participate in multilateral institutions, but cooperated bilaterally. In space, the two countries did jointly participate in multilateral institutions, but did not cooperate bilaterally.

Institutional perspectives also suggest that the stronger the international institutions in a policy area, the more likely countries are to trade and cooperate. These approaches suggest that integration in air owed to the presence of robust institutions in that sector and that non-integration in the space sector owed to the absence of international institutions for space. In fact, both sectors featured high levels of multilateral institutionalisation.

In air, international institutions were numerous, capable, and powerful. The World Trade Organization, the International Civil Aviation Organization, and many other ad hoc multilateral arrangements removed barriers to sectoral trade and ensured the coordination and safety of flight operations and aircraft worldwide. For most of the 1989-2009 period, however, China, was not a party to the General Procurement Agreement on Trade in Civil Aircraft or its successor, the Agreement on Trade in Civil Aircraft, the main international mechanisms designed “to provide a

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comprehensive basis for free and fair trade in the aircraft sector.”

In spite of this situation, the two countries managed to reach bilateral agreements on reducing tariffs, eliminating quotas, and limiting other barriers to trade in aircraft items. The joint participation of China and the United States in robust multilateral institutions does not explain why trade, industrial integration, and cooperation were possible in this sector.

In space, international organisations also played important roles. Institutionalised space cooperation had been the norm, not the exception, since the start of the space age. The most important and durable space institutions were established under the United Nations (UN) system within two decades of the first satellite launch, although this process stagnated as the Cold War wore on. Following the end of superpower competition, as space activities spread to new parts of the world, states agreed to establish new global and regional space institutions. By 2005, space analyst Linda Billings observed that national and multinational space agencies “entered hundreds of bilateral and multilateral agreements over the past half century to pursue increasingly costly and complex space initiatives.” Some of these created robust institutions that allowed substantial technical cooperation and program integration between major spacefaring states. The most striking examples were the arrangements that nineteen (by 2013) states created to build the International Space Station (ISS). With astronauts’ lives and billions of dollars directly at stake,

57 Ibid.
58 Examples include the European Space Agency, the International Space Exploration Coordination Group, the Asia-Pacific Multilateral Cooperation in Space Technology and Applications (AP-MCSTA), the Asian-Pacific Space Cooperation Organization (APSCO), the Space Conferences of the Americas (CEA), Eumetsat in Europe, Arabsat in the Middle East, and the Inter-Islamic Network on Space Technology. Peter, “The Changing Geopolitics of Space Activities,” 107–108.
this project required governments to agree to institutions with the authority to intervene in the management and operation of their national space assets.\textsuperscript{60}

Both China and the United States joined a range of multilateral space institutions and projects,\textsuperscript{61} but they did not cooperate and at times overtly opposed each other within these fora. The two countries participated in several UN institutions, including the International Telecommunications Union (ITU), the Committee on the Peaceful Uses of Outer Space (UNCOPUOS) under the UN Office of Outer Space Affairs, and the UN Conference on Disarmament (UNCD). At the ITU, China and the United States negotiated tensely over allocations of satellite signal spectrum. At the UNCD, the two countries opposed each other on space security issues. The United States blocked a decade-long Chinese and Russian effort to pass a draft treaty on \textit{Preventing the Placement of Weapons in Outer Space}. The two countries’ joint participation in these UN institutions did not facilitate their cooperation or trade as institutionalist theories would suggest. Instead, these institutions became new sources of and settings for antagonism.

Outside the UN system, China and the United States each participated in space institutions that excluded the other. China led the establishment of the Asia-Pacific Space Cooperation Organization (APSCO), in which the United States was not a member. The United States was a lead partner in the ISS, but blocked Chinese participation. The two countries established no major new institutions that they both joined. Even if the absence of robust space institutions did explain why China and the United States did not cooperate or trade in space, it

\textsuperscript{60} Howard E. McCurdy, \textit{The Space Station Decision: Incremental Politics and Technological Choice} (Baltimore, MD: The Johns Hopkins University Press, 2007).

would only raise the question of why the two states did not both participate in the sector-wide trend toward institutionalisation in the first place.

Institutional variables do not explain the variation in bilateral relations across the air and space sectors. The joint participation of China and the United States in international institutions does not explain why they traded and cooperated in air, but not space. Both sectors exhibited high levels of institutionalisation, a factor that should have facilitated trade and cooperation in both.

3.4. The pursuit of international prestige

Some rationalist and modernist-constructivist theories of international relations point to actors’ interests in achieving prestige as explaining state behaviour. Lilach Gilady, for example, argues that prestige motivated the “first space race,” the conspicuously costly “international race to measure the precise distance from the earth to the sun through the observation of the transits of Venus in the 18th and 19th centuries.” Similarly, some China specialists cite national prestige as a motive for the country’s space activities from the 1980s onwards. They argue that prestige explains the Chinese government’s diversion of scarce resources to a conspicuous human spaceflight program of no security value. Analysts also invoke this motive to explain government spending choices in the space sector that ran counter to leaders’ stated economic development goals.

Although space programs may have conferred the greatest national prestige when they were autonomous, China and the United States each had a long history of cooperating with other

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62 Lilach Gilady, “Conspicuous Waste in International Relations” (PhD, Yale University, 2006).
63 Chinese space experts also refer to the prestige value of national space systems, as in Dou Changjiang (窦长江), “China’s Beidou, China’s Pride (中国的北斗中国的骄傲),” Aerospace China (中国航天), January 2007.
64 An example of this type of perspective is found in Martel and Yoshihara, “Averting a Sino-U.S. Space Race”; Handberg and Li, Chinese Space Policy.
countries in space. Arguments emphasising prestige motives do not explain why the two did not cooperate with each other, while they cooperated with others, including strategic rivals, in this sector. Moreover, the two countries’ pursuit of prestige in space does not explain why they cooperated in aircraft production, research, and development, equally prestige-laden pursuits.

Arguments of this type also raise further questions about whether and how international prestige factors can explain relations between countries in space. Why should space have been the arena in which China and the United States pursued prestige? In particular, why should China have sought prestige by reproducing Soviet and U.S. achievements of the 1950s and 60s, including placing humans in orbit and sending vehicles to the moon? Biotechnology, nanotechnology, computer science, and the life sciences offered more contemporary opportunities to trail-blaze and make the sort of notable ‘firsts’ and discoveries that earn countries a place in history and lasting national prestige.

Space was also a peculiar area in which to pursue prestige for a country facing China’s challenges. Unlike other high-technology sectors, in which the process of trial and error could be confined to the laboratory, conspicuous space activities entailed very real risks of national humiliation. The Apollo 1 fire that killed three astronauts early in the U.S. civil program was a tragic example.65 China also experienced major setbacks, including one that involved human casualties.66 It remains unclear why Chinese policymakers would determine that space was the best domain in which to win prestige.

Paradoxically, China’s space activities may have inflicted net damage on its international standing. While China’s space achievements may have earned it some ‘soft power’ with respect

66 Harvey, China’s Space Program: From Conception to Manned Spaceflight. These casualties were not on board a spacecraft, but on the ground in a village downrange from the launch site.
to its East Asian neighbours and some developing countries in other regions, they did not earn China the support of states that were not already seeking closer ties with it for economic reasons. Worse, some of China’s space activities alarmed India and Japan, which both responded by enhancing their own defense space capabilities, and strained relations with the United States. Furthermore, the mass of space debris caused by China’s 2007 test provoked worldwide criticism, including in international fora, compromising the country’s reputation as a ‘responsible’ and capable power.

Finally, even if China’s space achievements were met with international acclamation, to what ends could China use the prestige it acquired in space? Was there any single international objective that China could not meet but for the prestige it derived from its space program? For China’s space activities to have been worth their costs in foregone economic opportunities and deteriorated foreign security relations, they would have had to translate into substantial gains, which were not apparent.

Even if answers to these questions were found, prestige-focused explanations would still fail to explain the variation in bilateral outcomes across the air and space sectors. Both these sectors are prestigious. Chinese and U.S. conduct in both of these sectors was prestige-driven, so this motive does not explain the divergent sectoral outcomes. Moreover, if country leaders are motivated to pursue international prestige through technological achievement, then U.S. and European governments should have sought to block the emergence of a Chinese aircraft industry, which would compete with their own. Instead, these governments adopted policies that allowed their champions Boeing and Airbus to nurture their own Chinese rival.

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67 Handberg and Li, Chinese Space Policy.
3.5. Economic development

Because technology programs can accelerate economic growth and modernisation, scholars often cite economic development as a rationale for Chinese air and space programs. 69 Although development was among the objectives guiding China’s air and space policy, this factor does not account for the variation in relations with the United States across the two sectors. Cooperation with U.S. producers would have facilitated China’s development of capacity in both sectors. Chinese leaders at certain points sought cooperation with the United States on both air and space programs. A concern with the developmental impact of China’s air and space programs does not explain why the U.S. government blocked trade and cooperation with China in space, but not air, after 1998. Moreover, China’s space activities were inconsistent with a primarily developmental agenda. Chinese leaders made policy and programmatic choices that reflected other priorities. This fact suggests that developmental motives cannot explain bilateral relations in both sectors.

In some respects, Chinese leaders treated both air and space programs as means to economic development. China’s air and space activities served the goals of developing domestic

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technical capacity and producing high value-added goods for export to foreign markets. Chinese officials cited these factors as rationales for the programs. Their goals for the air and space sectors were consistent with elements of Deng Xiaoping, Jiang Zemin, and Hu Jintao’s technocratic developmental ideologies. These ideas were expressed in documents outlining aerospace development strategies, such as the State Council’s 1986 *State High-Technology Development Plan* (国家高技术研究发展计划) and 2006 *Medium- and Long-Term Plan for the Development of Science and Technology* (国家中长期科学和技术发展规划纲要).

Despite these stated priorities, the Chinese government’s spending on space activities between 1989 and 2009 reflected other priorities. Leaders allocated only modest sums on space activities that made direct contributions to economic development. The greatest developmental impact of building capacity in the space sector came from utilising space assets for terrestrial applications. For example, applications of communications, weather, and environmental monitoring satellites generated the greatest pay-offs by improving productivity, efficiency, and sustainability in agriculture and other sectors. In spite of this situation, the Chinese government dedicated an overwhelming portion of China’s space spending after 1992 not to these relatively productive areas, but to an ambitious human spaceflight program. The expenditure required specifically to support a crew in space was substantial and did not yield the same level or quality of developmental benefit as investment in these other space activities. Space experts, 

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70 Wu, “China’s Outer Space Activities.”
73 See discussion of national priorities with respect to earth observation systems in Peter, “The Changing Geopolitics of Space Activities,” 105.
policymakers, and other decisionmakers understood these issues when they made decisions about these major programs. According to individuals familiar with the human spaceflight program, critics of public investments in such large space hardware engineering programs made their views known before these initiatives were adopted, but they were outnumbered and ignored.

Moreover, when the larger opportunity costs of China’s space spending on the whole are considered, the risky and expensive civil space program appears even less economic. Insights from welfare and development economics suggest that comparable expenditures on healthcare, education, and basic infrastructure would have generated greater social returns than China’s investments in space.

That the Chinese government’s space choices did not reflect the priority of economic development is further suggested by differences between the space activities of China and those of other countries. For example, Japan’s space program produced civil-scientific and military applications, while nurturing internationally competitive commercial space firms. When compared to the policies adopted by the archetypal developmental state, the Chinese approach to space directed a far smaller portion of the space budget to the areas showing the greatest promise of developmental benefit. Explanations for China’s autonomous pursuit of space capabilities that attribute major policy choices to a developmental agenda fail to account for the government’s record of resource allocation.

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75 Martel and Yoshihara, “Averting a Sino-U.S. Space Race”; Handberg and Li, Chinese Space Policy.
In the air sector, the Chinese government arguably also made choices reflecting non-economic priorities. For example, it adopted policies aimed at pushing its firms to enter system integration, the most prestigious but also arguably the most saturated and least profitable segment of the industry. I consider related arguments for the Chinese government’s aeronautic policies and programs in the second chapter of Part III, which focuses on the air sector. In short, at minimum, economic development goals are insufficient to explain Chinese choices in the space sector. It follows that developmental motives do not explain the bilateral outcomes in air and space and that other factors are at play.

3.6. Domestic politics and institutions

Scholarship examining national high-technology programs, industries, and innovation systems suggests possible insights into international outcomes, such as transnational industrial integration. Studies of this type identify domestic factors, such as the features of national institutions and competition among political elites, as causes of science and technology policy outcomes. Experts who have studied China’s space program argue that domestic factors, beyond the developmental agendas discussed above, shaped its course. Fractional in-fighting, ideology, and the personalities of China’s leaders explain the origins of the program in Mao’s era,

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its stagnation during the Cultural Revolution, and the decision to pursue human spaceflight.  
Many studies of the U.S. space sector also trace policy choices to domestic factors.

While domestic-level variables explain specific developments in the Chinese and U.S. air and space sectors, they do not account for the divergence in bilateral relations across these two sectors. National institutions and the configuration of the industrial base in both states did not vary substantially enough across sectors – although they varied across the two states – to explain the two contrasting outcomes. For instance, within China and within the United States, procedures for making policies on technology transfers and trade rules in both these sensitive sectors were similar enough in their content, process, and degree of politicization and centralisation that they do not explain the variation across these two areas.

In both sectors of both countries, commercial interests and state agencies played substantial roles. The air and space industries were both public-private hybrids. Firms in both sectors were motivated to seek new markets abroad. Chinese and U.S. firms in both the air and space sectors would have benefitted from bilateral trade and industrial integration. The integration of research, development, and production activities would have brought gains to

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80 Prominent examples include Harvey, *China’s Space Program: From Conception to Manned Spaceflight*; Handberg and Li, *Chinese Space Policy*; Feigenbaum, *China’s Techno-Warriors*.


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major producers in both sectors. In particular, both the U.S. air and space industries stood to benefit from the market access that bilateral partnerships made possible. U.S. firms also benefitted from joint ventures with Chinese state-owned enterprises because these received generous support in various forms from the Chinese government.\textsuperscript{84}

New markets were especially attractive the U.S. space industry for several reasons. U.S. government spending on space had declined since the end of the Apollo program and of the Cold War, impacting U.S. spacecraft manufacturers. Meanwhile, their European competitors had begun to benefit from their from partnerships with China by access to inexpensive launches and contracts on new civil space projects between Chinese and European agencies.\textsuperscript{85} In spite of these circumstances, U.S. firms were unable to effectively pursue their interests in reforms that would allow them to trade and partner with Chineseentreprises. Locally clustered and with notoriously strong ties to elected office-holders,\textsuperscript{86} U.S. space concerns should in principle have had as much influence on policymaking as the aircraft firms that successfully sought looser restrictions on trade with China. In fact, some of the strongest proponents of tight export controls were congressional representatives elected in districts with important satellite-manufacturing industries.

Because interest groups in both the air and space sectors of each country were equally motivated to pursue integration, their interests alone cannot explain why policies supporting transnational integration were adopted in air but not in space. In the following chapters, I argue that theoretical perspectives emphasizing domestic variables account for only part of the outcomes we observe between China and the United States in these two sectors.


Part I: Chapter 1

Conclusion

This thesis explores the conditions that foster transnational trade, industrial integration, and technical cooperation in high-technology sectors through an examination of China-U.S. relations in the air and space sectors between 1989 and 2009. These sectors share features that should have made them equally probable sites of bilateral trade and cooperation. These sectors were in principle equally prone to China-U.S. competition. In spite of these similarities, relations between China and the United States followed divergent trajectories in the two sectors. In air, the two countries traded and their industries integrated their activities. Chinese and U.S. agencies also engaged in civil aeronautic cooperation. In the contrasting space sector, the two countries did not trade regularly or at all after 1998. Their industries did not integrate their activities. Their agencies did not cooperate. Instead, tensions grew between China and the United States over their respective technology development programs. This dissertation examines why and how bilateral relations evolved differently in these two sectors.

Influential theoretical approaches brought to related subjects suggest some insights into this research problem. These theoretical perspectives emphasise different factors to explain when states will cooperate or compete in a given domain. The most important approaches stress factors such as the international distribution of power, the economics of transnational integration, international institutions, national economic development agendas, international prestige motives, and domestic politics. However, these factors do not adequately account for the variation in bilateral relations across the two sectors. Nor do they explain particular features of bilateral relations or specific national policies in one or the other sector.

This dissertation proposes another account of why and how China-U.S. relations followed divergent courses in air and space. This account draws on theory and research in other areas of
Part I: Chapter 1

international relations and in science and technology studies. The next chapter introduces the
theoretical framework underpinning this account.
Theoretical Framework

Introduction

This chapter introduces a theoretical framework for explaining why and how China-U.S. relations followed distinct courses in the air and space sectors in spite of their similar features. I argue that the variation in the bilateral outcomes in air and space owes to the representational practices of Chinese and U.S. technical experts in these two sectors. These experts explained and described each sector to their national policymakers. Based on experts’ authoritative representations, policymakers in both countries adopted policies that fostered bilateral trade and technical cooperation in the air sector, but limited them in the space sector. This argument draws on theoretical ideas developed in the fields of international relations and of science and technology studies.

The first part of this chapter introduces the basic theoretical argument of this dissertation. The second part explains the basis for this argument in theoretical concepts from studies of epistemic communities and communities of practice in international relations and from investigations of technological artefacts in science and technology studies. The third part applies these theoretical concepts to the research question. The fourth part explains how the air and space sectors constituted two distinct communities of specialists. The fifth part describes background knowledges and practices shared within each of these communities. The sixth part explains how aeronautic and space specialists participated in the production of distinct international orders in their sectors through their respective representational practices.
1. Theoretical argument

Existing scholarship and the research for this project suggest a theoretical explanation of international outcomes in technically specialised sectors. This argument applies to high-technology sectors, such as aircraft, spacecraft, and perhaps other specialised areas of manufacture. In this view, international outcomes, such as trade, industrial integration, and technical cooperation between countries, depend on sectoral cultures shared among experts who contribute to policymaking in these domains. These cultures are configurations of background knowledges and professional practices particular to communities of specialists in given sectors. The variation in international outcomes observed across sectors is in part traceable to differences in the specialist cultures of those sectors. In other words, international outcomes in high-technology sectors are made possible and structured by national policies, which influential communities of experts help produce, maintain, or change through their culture-bound practices.

The constitutive effects and functions of expert practices upon international outcomes are apparent in the distinct bilateral orders that evolved between China and the United States in the air and space sectors. In each of these sectors, experts from both countries belonged to a single transnational specialist community. Within each of these communities, members shared distinct habits of speech and writing, which they used to describe and explain aspects of their sector. These habits constituted representational practices. In each case, these representational practices expressed the common background knowledge shared by members of the specialist community. This background knowledge consisted in tacit philosophical assumptions about the relationship between humans and technology. These assumptions comprised implicit understandings of human-machine interaction, of the relationship between society and technology, and of technology’s role in international politics. Individual experts conveyed these common understandings through their representations of the sector to policymakers and decisionmakers.
As specialists represented their sector to these audiences, they also imparted their philosophical assumptions and policy prescriptions called forth by these assumptions.

These modes of representation expressed each specialist community’s most basic philosophical assumptions about the relationship between humans and technology. Aeronautic experts’ representational practices reflected their individualistic and agential conceptions of human beings. They also reflected their instrumental view of technology and their view of the international environment as benign. These representations implicitly and explicitly characterised aircraft technologies as commercial, as relatively mundane, and as posing risks manageable through regulation. Aeronautic specialists and policymakers in both countries adopted, circulated, and reproduced these representational practices and the assumptions they carried. In the process, they also translated these commitments into policy prescriptions that reflected this underlying specialist culture. These included recommendations for policies that fostered trade, industrial integration, and technical cooperation, which policymakers in both countries adopted.

In contrast, space specialists’ representational practices reflected their deterministic view of technology’s impact on society. Space experts conveyed a related structural and holistic view of the individual and society in representations of their sector to policymakers. They described space systems as threatening, as necessary, and as posing risks unmanageable through regulation. Space experts in both countries absorbed, diffused, and reproduced these representational practices and the philosophical commitments underlying them. In the process, these experts produced the space domain as a distinct object of policy, requiring policies that limited or blocked bilateral trade, industrial integration, and technical cooperation. Through their representational practices, experts in both countries also prescribed policies to develop
autonomous national space systems and counter-space systems and to maintain self-sufficient space industrial bases.

Through their representational practices, specialists defined and produced technologies in their sector as objects of policy to policymakers and to other members of their community. In particular, experts defined how their state should control, limit, supervise, support, or compel the manufacture and/or transfer of technologies. Specialists achieved these effects by representing technologies and technical processes as subject to human manipulation or as eluding deliberate control by humans. For example, specialists represented innovation as driven by creative individuals or represented the diffusion of advanced technologies to new countries as automatic and inevitable. Experts also prescribed what policies suited their sector in depictions that situated specific items of technology in their social contexts, connecting these articles to national interests and policy goals. Finally, experts defined technologies themselves: they characterised artefacts and knowledges through their representational practices. Specialists attached meanings to hardware. They endowed articles with the very technical properties that their community and non-specialists alike regarded them as having. Experts naturalised and maintained prevalent understandings of particular technologies in their practices, producing their features as technical givens.

By performing representational practices that constituted their sectors as requiring certain forms of intervention but not others, specialists prescribed specific policies and programs. Their acts of representation made possible the adoption of these policies by Chinese and U.S. policymakers. In air, aeronautic specialists’ representational practices produced the sector as requiring policies that fostered bilateral trade, industrial integration, and technical cooperation. In the space sector, experts’ representational practices implicitly recommended policies limiting
or blocking bilateral trade, industrial integration, and technical cooperation. These policies in turn made possible the distinct bilateral outcomes observed in air and space.

2. Theoretical context

This argument draws on theory and research in three major bodies of scholarship. The first of these is the study of epistemic communities in international relations. The second is the study of communities of practice in international relations. The third is cultural research and theory in science and technology studies.

2.1. Epistemic communities and international cooperation

Studies of epistemic communities by international relations specialists have established that transnational communities of scientific and technical experts can influence the prospects for international cooperation in issue-areas that demand specialised knowledge of their participants. These studies have also shown that technical expertise itself is an important resource that affords

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figures such as scientists and engineers the authority to shape international policymaking to their own normative ends.

The concept of epistemic communities in international relations owes to studies of arms control by Emanuel Adler and environmental regimes by Peter Haas. In these accounts, epistemic communities consist of networks of experts who share knowledge and beliefs, including causal understandings and normative commitments. These communities of specialists can become agents of international policy change, particularly when the complex nature of transnational problems faced by policymakers requires their advice and expertise. In their issue areas, specialists who share knowledge and beliefs can form the epistemic basis for international cooperation, such as the building of international regimes. The epistemic communities approach is consistent with other international theories that stress the power of ideas and beliefs in international affairs, such as accounts of how ideas impact states’ foreign policies.

Studies of epistemic communities provide insights into how networks of specialists function. Empirical and theoretical work on epistemic communities introduces them as both new actors in international politics and as structures providing settings for action by individual experts. In this approach, experts in any given field constitute a distinct community, recognised as such from within and from without. This recognition affords them the authority to influence developments outside their specialist communities, including in the international policymaking arena. However, the extent to which particular ideas become influential within policymaking circles depends on which individual experts advocate for and against them.

The epistemic communities literature provides two fundamental theoretical insights into China-U.S. relations in air and space. First, this literature demonstrates that communities of

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experts share not only specialised technical knowledge, but also often share normative commitments and basic philosophical assumptions. We will return to these issues in the latter part of this chapter. Second, the literature on epistemic communities demonstrates that communities of specialists can influence policymaking and international relations. They influence these processes and outcomes for two reasons. The first is that they provide substantial formal and informal input into policymaking, since their expertise is needed by policymakers in particular issue-areas. The second reason is that experts who are scientists and engineers enjoy authority and credibility in their areas by virtue of the social status of their professions and of regard for science in general. Policymakers typically trust their experts.

Studies of these communities assume a particular understanding of the epistemic in international politics. They tend to emphasise the causal power of ideas, as opposed to their constitutive effects. The ideas that matter for international outcomes are policy-relevant beliefs about cause-and-effect relationships and norms about conduct. Changes to intersubjectively held knowledges bring about international policy changes. For example, changes in expert beliefs made possible cooperation between states to establish an international environmental regime. Epistemic shifts may occur because networks of experts transform widely held beliefs by propagating new ones. Knowledge, in this view, is a set of disembodied ideas transmitted between individual minds. Agency resides in individual actors who act in and through the knowledge-sharing communities to which they belong. Experts can exercise this agency by authoritatively acting upon prevailing understandings and beliefs.

Research in this vein also tends to adopt an implicit understanding of technology and technological artefacts. Scholars taking an epistemic perspective present technologies as material entities external to the human mind and which actors can perceive objectively and directly. However, epistemic theorists add that prevailing beliefs exist within communities about how
technologies can or ought to be used or handled. Some studies of epistemic communities examine norms around the use and control of nuclear weapons and environmentally hazardous substances. The ideas that these accounts emphasize as shapers of policy are not about what the objects are, but about their use and their status as targets of policy. These ideas are about technologies and their use, but not ideas of the technologies themselves. In other words, expert discourses conveying these ideas represent technologies, but do not produce them as the objects we know them to be. For instance, when epistemic theorists examine changing norms about the control and use of nuclear weapons, they do not go as far as to study how nuclear weapons are constituted and reconstituted as different objects over time in practices. They focus instead on ideas about when and how these weapons were or should be used. In this respect, the epistemic approach is distinct from the work in the other two reviewed perspectives, which emphasise the production of technologies in actors’ representational practices.

Studies in the epistemic vein tend to assume that the normative commitments shared by scientists and technical experts are liberal, progressive, and cosmopolitan. They regard these figures as pursuing normative agendas that reflect the universal and humanistic values of their work. In some ways, these suppositions underlie accounts of epistemic communities as fostering international cooperation on nuclear arms control and climate change. Critics of this position contend that scientific and technical specialists’ value commitments are embedded in history and culture, rather than derived from transcendent norms internal to scientific practice and institutions (Peking Man, Science and Dissent in China on lysenkoism, etc.). Scientists and engineers are then just as likely to be conservative, nationalistic, or otherwise parochial. They can either promote international cooperation or stoke the fires of international competition. The theoretical framework adopted for this study is sensitive to the content and origins of the commitments and knowledges that specialists within a community share. This approach does not presuppose that
the content of these common epistemes is benign. Instead, it focuses on their particular, situated, and historical character, their evolution over time, and their expression in concrete practices.

2.2. Communities of practices in international relations

Another body of research in international relations examines how the daily practices of individuals make up world politics. Studies of this type demonstrate how communities of professionals produce, maintain, or change international relations through their daily routine-like activities. As Emanuel Adler and Vincent Pouliot explain, “the complex pictures of world politics are made up of a myriad of everyday practices.” A focus on practices illuminates how the patterned actions of individuals create the large-scale phenomena observed in the interstate system. In this sense, Adler and Pouliot argue that practices stabilize social structures and fix ideas and subjectivities in people’s minds (or determine the dominant ideas that corporate actors focus on at a given point in time), thus constructing agents and agency. Our theory, in a kernel, is that practices structure and congeal thought and language into regular patterns of performance and turn contexts or structures into (individual and corporate) agents’ dispositions and expectations. […] frames as the micro-foundations of the macro effects of practices.

Although studies of international practices are diverse, they tend to agree on an understanding of practice itself. Adler and Pouliot define practices as “competent

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92 Ibid., 20.
performances.” Practices are general classes of patterned, habituated individual actions familiar to other members of the practitioner’s community. Like routines, practices are “repeated or at least reproduce similar behaviors with regular meanings.” Practices both reflect and carry the community’s common stock of understandings.

Practices are socially meaningful patterns of action, which, in being performed more or less competently, simultaneously embody, act out, and possibly reify background knowledge and discourse in and on the material world.

This common knowledge is a fundamental aspect of practice. As Adler and Pouliot explain, “practice rests on background knowledge, which it embodies, enacts, and reifies all at once.” Shared background knowledge is an “embodied stock of unspoken know-how, learned in and through practice, and from which deliberation and intentional action become possible,” they write. This knowledge is “located ‘behind’ practice, in the form of intentions, beliefs, reasons, goals, etc.” Background knowledge is also “bound up” in the very execution of a practice. For the seasoned practitioner, write Adler and Pouliot, “knowledge does not precede practice but is ‘enclosed’ in its execution.” One may “conceive of the social as bundles of ideas and matter that are linguistically, materially, and intersubjectively mediated in the form of practices.” Culture, then, “is not only in people’s minds, discourse, and interactions, it is also

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93 Ibid., 4.
94 Ibid., 5.
95 Ibid., 6.
96 Ibid., 4.
97 Ibid., 7.
98 Ibid., 18.
99 Ibid., 17.
100 Ibid.
101 Ibid.
102 Ibid., 14–15.
in the very performance of practices.”\textsuperscript{103} In short, “Practices turn common knowledge into deeds; the latter becomes part not only of what communities of practice know, but also do together.”\textsuperscript{104}

Actors are not born capable practitioners, but acquire their practices. Because practices are “embedded in particular organized contexts,” they are “articulated into specific types of action and are socially developed through learning and training.”\textsuperscript{105} Moreover, “social recognition” is an integral part of an individual’s performance of a practice: “its (in)competence is never inherent but attributed in and through social relations.”\textsuperscript{106}

International practices are performed by and within communities. Communities of practice are both a type of agent in international relations and a structure within which individual agents act. Practice is inherently intersubjective, explain Adler and Pouliot:

\begin{quote}
While performed by individual human beings, practices are possessions of collectives insofar as their meanings belong to communities of practice. ‘Suspended’ between structure and agency, practices are simultaneously enacted (agency) and inserted within a social context or political order (structure).\textsuperscript{107}
\end{quote}

Practitioners who share these meanings form communities. “Practices develop, diffuse, and become institutionalized in such collectives,” write Adler and Pouliot.\textsuperscript{108} “A community of practice is a configuration of a domain of knowledge that constitutes like-mindedness, a community of people that ‘creates the social fabric of learning’, and a shared practice that embodies ‘the knowledge the community develops, shares, and maintains’.”\textsuperscript{109} It is not only

\begin{footnotesize}
\begin{itemize}
\item[\textsuperscript{103}] Ibid.
\item[\textsuperscript{104}] Ibid., 23–24.
\item[\textsuperscript{105}] Ibid., 5.
\item[\textsuperscript{106}] Ibid., 6.
\item[\textsuperscript{107}] Ibid., 16.
\item[\textsuperscript{108}] Ibid., 18.
\item[\textsuperscript{109}] Ibid.
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repetition that structures practice, but also, and mainly, “that groups of individuals tend to interpret its performance along similar standards.”110

Communities of practice in a sense act collectively, functioning as coordinated, but not unitary, groupings capable of bringing about change or maintaining stability in international affairs.111 For example, communities of deterrence specialists reproduce and maintain deterrence as the foundation of international security arrangements.112 At the same time, communities of practice provide the settings from which their individual members reason and act. In this role, the community takes on the functions of a structure by conditioning, constraining, and enabling agents. Adler and Pouliot describe these aspects of practices.

When ‘disaggregated’, practices are ultimately performed by individual social beings and thus they are clearly what human agency is about. Collectively, however, we understand practices as structured and acted out by communities of practices, and by the diffusion of background knowledge across agents in these communities, which similarly disposes them to act in coordination.113

Yet practices also attach to agents, since they are not only “performed by individuals and communities of practice, but also because they frame actors, who, thanks to this framing, know who they are and how to act in an adequate and socially recognizable way.”114 Communities mediate between agents and structures.

Theoretical work on international practices provides a lens through which to examine stability and change in international affairs. Actors’ practices are not epiphenomenal, but carry effects: “Practice typically does something in the world, and thus can change the physical world

110 Ibid., 6.
112 Adler, “The Spread of Security Communities.”
114 Ibid.
as well as the ideas that individually and collectively people hold about the world.”115 Practices are the micro-level mechanisms through which macro-level international orders are constituted and maintained. In this view, international structures are not givens. Rather, in order to exist and persist, structures require actors to continuously reproduce them; practices are the “vehicle” of this reproduction.116 For Adler and Pouliot, the “performance of practices in socially recognizable ways is the source of ontological stability in social life.”117

Practices can also be sources of structural change. Practices always afford individual actors some wiggle room, within which they may exercise agency. As actors use these opportunities, both tapping into accepted practices and modifying them, they instigate change in the larger structures of international politics. Practitioners, then, are “not passive performers of discursive scripts or texts, but are active agents of both stabilization and change.”118 International structures endure or evolve in actors’ practices.

Actors fix meanings upon the world around them in and through practices. These include discursive practices.119 Actors create their social and natural environments as they perform practices in them, conferring and attaching meanings to them. As Adler and Pouliot explain of actors in general, “Recursively, in and through practice, agents lock in structural meaning in time and space.”120 Not only are the settings and situations that actors face practically constituted, but it is through practices that actors learn and maintain a more fundamental sense of who they are and what they want. Adler and Pouliot advocate a study of international practices that explores

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115 Ibid., 15.
116 Ibid., 18.
117 Ibid.
118 Ibid., 23.
“the role of practices in the attainment of preferences or practices’ constitutive effects on subjectivity.”

Practices, then, constitute actors’ identities and interests.

Practices fix common understandings of what actions are feasible or desirable in given contexts. Past performances serve as guides to actors encountering situations both familiar and new. Records of practice spell out the choices before actors and how they should make decisions. For example, when practices function as focal points, they supply different actors with similar scripts or frames to guide their behaviour. In these contexts, practices “affect actors’ dispositions and expectations,” sometimes nudging them toward similar or coordinated forms of action. Actors’ practical contexts also inform how they make choices: “practices help construct a practical and mediated understanding of what is rational in given situations.”

Within communities of practice, habituated performances implicitly define what are normal or default courses of action, even when members do not explicitly communicate these.

As individuals perform practices guided by their shared background knowledge, they spread and reinforce agreement on their understanding of the world around them within their community and beyond. In policymaking, communities of experts render intelligible and, thus, create the objects of government policy in practices. For example, communities of specialists can produce and constitute targets of policy such as demographic groups, environmental outcomes, and technical devices in discursive practices. Practices are the background work that sustains agreement among policymakers on the ends and means of policy in a given issue-area.

Because practices matter for policy outcomes in these ways, they are both an expression and a source of power. The fixation of meanings through practice is political and practices can

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121 Ibid., 28.
124 Ibid., 23.
become objects of contestation. Certain practitioners have the power to impose dominant meanings. In given issue-areas, influential communities or individuals define what is true through their authoritative practices. Adler and Pouliot also explain that dominant knowledges become reified and institutionalised in international practices, while other knowledges do not.

The practice turn is not only concerned with meaning and language, but also with the material dimension of actors’ habituated performances. Because practices are embodied and corporeal, they are “of” the physical world and leave traces upon it. Actors’ practices are observable in their tools and materials. For example, representational practices can be observed in Powerpoint slides, maps, and data-sharing programs. Keyboards, cameras, and modeling software are implicated in other international practices, ranging from border policing to disaster management. Methodologically, then, the material entities implicated in actors’ representational acts are sites and objects in which to observe and study these practices.

Insights from research and theory on international practices form a theoretical basis for my argument about China-U.S. relations in air and space. First, this scholarship introduces a concept of practice that illuminates the role of specialists communities in policymaking. Second, the literature on international practices elucidates the concept of background knowledge, which guides how I represent sectoral cultures. Third, this literature theorises communities of practice. This work sheds light on how aeronautic and space specialists act as two distinct collectives, each spanning national borders and sharing background knowledge. Fourth and most important, scholarship on international practices provides theoretical insights into the practical constitution

125 Ibid., 29.
126 Ibid., 30.
127 Ibid.
128 Ibid., 29.
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of reality. Adler and Pouliot’s discussion of this process provides a basis from which to argue that communities of aeronautic and space specialists differently constitute the means and ends of policy for their sectors through their practices.

2.3. Cultural studies of science and technology

Cultural approaches to science and technology are concerned with the interpretation of shared knowledges, discourses, and practices. These approaches were developed in cultural studies of science and technology, or the cultural strand within science and technology studies. Although approaches in this family present no unified perspective, they tend to share distinctive ideas about technology and expertise. Studies in this field emphasise the role of expert knowledges, which they tie to discourses and practices in constitutive explanations.

The cultural perspective consists in loose agreement around several basic propositions about scientific and technical knowledge and practice. Science is not a timeless institution or a body of abstract knowledge, but a set of historically and culturally bound practices. Science has no essential features that unify it or distinguish it from other cultural formations. Scientific and technical norms and practices not only vary across history but, at any given time, are also culturally variant across localities and sites, even within the same field. No general explanation of scientific and technical knowledge is therefore possible. Scientific and technical knowledge is not a set of “free-floating ideas” detachable from the circumstances that produced them. Scientific and technical practice is local, material, and discursive. Instruments, such as

130 For example, Andrew Pickering, The Mangle of Practice: Time, Agency, and Science (Chicago, 1995).
131 Statements of this position are found in Rouse, “What Are Cultural Studies of Scientific Knowledge?,” 57–94; Hess, Science and Technology in a Multicultural World, 18–53.
microscopes and satellite sensors, shape the production of knowledge in particular settings. Technological artefacts themselves are also made and remade in discourses and practices. Discourses do not merely represent technological objects but constitute them. Science produces its realities as well as describing them; scientific and technical experts not only discover but also make facts.\(^{133}\)

Cultural studies of technology share assumptions about knowledge and the constitution of reality with studies of international practices. These approaches are complementary. Among the communities of practice envisioned by international relations scholars are the communities of scientists and engineers that cultural scholars investigate. Among the international practices that the first group examines are trans-nationalised technical practices studied by the second. Both groups of scholars are interested in international affairs, the first to explain international outcomes, the second to understand how expertise and global order co-produce each other.

Cultural theories of technology part ways with approaches that treat scientific and technical practice as a unique domain separate from the rest of society. A cultural approach instead assumes the “openness” of scientific and technical work, or its embeddedness in broader social and cultural contexts. According to Rouse, “any distinctions between what is inside and outside of science, or what is scientific and what is social,” are unstable constructions.\(^{134}\) Scientific and technical practice is not governed by universal laws, but culturally bound and context-specific. Cultural studies of technology insist upon the locally rooted character of technical practice. They reject any program to arrive at general explanations of scientific knowledge or technological change, preferring instead to focus on the plasticity of scientific and


technical practices across settings. Scientific and technical practice is not inherently progressive. Instead, any concept of progress is itself an intellectual construct deserving of scrutiny by social scientists.

The cultural approach also provides a distinct concept of the technological artefact. Technological artefacts are at once material and cultural entities. They do not exist in any relevant way independently from the human experience of them, which is mediated by language and culture. This combination of views is why these perspectives are termed “material-semiotic.” Artefacts are produced not only in laboratories and factories but also in discourses and practices. The properties and features we assume these devices to have are defined in their use and in language.

Although technological artefacts are discursively constituted, they are not reducible to discourses or other intangibles. Rather, technological artefacts have a material dimension that scholars cannot ignore. In this view, technology is inseparably intertwined with nature, culture, language, and politics in assemblages that constitute the social. These elements hang together in different configurations, composing different social orders. Technologies are not conceptually distinct from these social orders but participate in them. Investigating how social orders are produced and sustained is the aim of social science. The object of explanation in such

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accounts is the ordering of the social, a continual process of becoming, maintenance, and contestation.

In the study of international politics, the social orders to be examined are global or transnational. “What makes the world hang together?” is the crucial question for studies adopting a cultural perspective. Some technologies play an indispensable role in the making of order. For example, networks of fibre-optic cable, which connect people from all over the world and help create a sense of global oneness, participate in the making of global order. The software and hardware systems that network financial markets across the world are in this sense implicated in order-making practices. Other technologies that perform a similar function include scopic devices, such as satellites and software generating images of Earth. These visually produce the planet and its climate as a single system and as an object of global governance. “Representational” technologies and techniques are implicated in actors’ constitution of international relations. These objects are not merely instruments or media, but in a sense actively participate in, constitute, and transform human actors’ practices. Humans and their tools shape each other. Scientists and engineers interact with non-human actants, both recruiting them toward their ends and adapting to their influence.

Insights from cultural studies of technology provide another theoretical basis for my argument, reinforcing theoretical concepts from the study of international practices and contributing distinct theoretical perspectives on the technical. These insights provide a theoretical vocabulary for understanding the constitution of hardware and technical processes in

practices. The cultural perspective also sheds light on the historicity and particularity of knowledges and practices shared within communities of specialists. This recognition, in turn, points the way to examining the unique origins of the background knowledges shared within specialist communities and their expression in distinct practices. Following these insights, I examine the historical sources of the aeronautic and space specialist communities’ internal philosophies of the human-machine relationship. Finally, cultural studies of technology focus on and develop the concept of social order. This concept offers a useful way to conceive of bilateral trade, industrial integration, and technical cooperation, since it is possible to conceive of bilateral processes and outcomes in a given sector as making up an evolving international order. Chinese and U.S. policies, participants, and technologies come together in two distinct sectoral orders, which support distinct processes and outcomes.

3. Applying this framework to the research question

Studies of epistemic communities, communities of practice, and the cultural production of technological artefacts provide the foundations and building blocks of a theoretical framework through which to understand and explain China-U.S. relations in air and space. The theoretical vocabularies developed in these three bodies of scholarship help characterise the research problem, describe the two outcomes, and identify conditions responsible for the variation across the two cases.

The practical and cultural approaches provide concepts that guide how the objects of this inquiry are represented. The international phenomena to be explained – the persistence or absence of bilateral trade, industrial integration, and technical cooperation in each sector between 1989 and 2009 – are distinct international orders, consisting of configurations of the two countries’ policies, underpinned by rationales and logics for these policies. Participants in these
orders range from policymakers and regulators, through industry engineers, to academic experts. Following the literature on international practices, this study aims to explain the emergence and maintenance of these two different international orders.

The main agents of stability and change in these bilateral orders were specialists belonging to communities of practice. The air and space sectors within which China-U.S. relations unfolded were two domains of specialised activity. Experts in the air and space sectors consisted in two distinct specialist communities, each bound by common background knowledge and practices. Aeronautic specialists and space specialists formed two distinct communities of practice. Diverse U.S. and Chinese participants belonged to each of these sectoral communities, their common knowledge and practices uniting them in spite of national differences and physical distance. Shared background knowledge expressed in representational practices formed the particular specialist culture of each sector.

The process through which these specialist communities made their impact on bilateral outcomes felt was their practical constitution of the air and space sectors as sites requiring particular types of policies. In both China and the United States, sectoral specialists defined and constituted their sectors as targets of policy. They achieved this effect by representing their sector to policymakers and decisionmakers in their words. Specialists in each sector relied on common representational practices, reflecting their shared background knowledge. As experts repeatedly performed these representational practices, they diffused and fixed the meanings associated with the objects of their depictions. Their practices were particularly important because, in Ann Swidler’s words, they “anchored” other practices, such as regulatory practices.  

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144 Miller, “Epistemic Communities in the Space-policy Arena.”
In their representational acts, communities of specialists constituted their sectors as sites requiring certain forms of state intervention, but not others. Their acts of speech and illustration were not merely representational, but also productive of the sectors themselves. Moreover, experts’ descriptions of these settings carried implicit prescriptions for policies. Aeronautic specialists in both countries represented their sector as requiring policies fostering bilateral trade, industrial integration, and technical cooperation. Space specialists in both countries represented their sector as requiring policies to limit or even block bilateral trade, industrial integration, and technical cooperation. These understandings constituted the two distinct bilateral orders that evolved in air and space.

4. Communities of practice in the air and space sectors

Membership in the aeronautic and space specialist communities was fluid and diverse. Each of these communities brought together individuals of various educational and occupational backgrounds and nationalities. Engineers, scientists, entrepreneurs, managers, lawyers, policy analysts, and civil servants were among the professionals who belonged to the aeronautic specialist community. A similarly diverse cast constituted the space specialist community. In each case, participants in these sectors shared technical knowledges and philosophical commitments.

The specialist community in each sector comprised distinct sub-communities. The most influential of these was involved in sectoral policymaking. In both China and the United States, this sub-set formed a core of leading specialists in each sector. This core comprised a range of professionals. Among them were government decisionmakers who had developed subject-matter expertise in their sector and their specialised staffs. This core also included functionally specialised civil servants in major agencies and departments. This sub-set brought in senior
industry participants who regularly interfaced with government officials, testifying before lawmakers, meeting with and briefing decisionmakers, or writing reports for policymakers. Academic and think-tank experts also joined these circles. They participated in policy through several channels, including as members of committees appointed to study policies and programs in each sector.

Individuals in this core of sectoral specialists often had formal technical training in their sector, but had over the course of their careers migrated to the management side of their companies or to positions in administration and government. By the time these individuals participated in policymaking, they were more likely to wear business suits than clean suits. In each sector, these senior figures formed the element of the specialist community that had the greatest role in shaping bilateral relations.

Membership in a specialist community was not defined by individuals’ location, but by their participation in the sector. Because common interpretation is what structures practice, Adler and Pouliot define communities of practice as “based on what people actually do rather than by where they happen to live.” When vectors exist to diffuse and transmit a specialist community’s background knowledge and practices, it transcends its local setting and even national borders. The air and space specialist cultures circulated between continents because such channels for their transnational movement existed. As a result, aeronautic specialists in China and their counterparts in the United States shared a single specialist culture that tied them into a single transnational community of practice. Space specialists in both countries belonged to a single transnational community of practice in the same way.

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Specialists from different countries who participated in a given high-technology sector constituted a distinct community of practice, even though many of them never met in person. Emails, print, and podcasts carried representational practices across continents, diffusing them throughout the specialist community, even while its members remained dispersed. Membership in the specialist community was defined by the performance of common representational practices based on shared background knowledge, rather than person-to-person relationships, occupational similarities, shared goals, or even common language.

Despite their members’ broad common background knowledge and practices, specialist communities were heterogeneous and fragmented. Contestation and disagreement were ubiquitous within these communities. Controversy, not consensus, was the norm among these experts. They disagreed and debated particular facts, theories, and policies. Yet many of these substantive disagreements were premised upon agreement on a more basic common understanding of the world. This background consensus on the human-technology relationship defined the scope of sectoral specialists’ debates and the policy positions considered plausible within these communities in the first place.

Even this bedrock of basic philosophical commitments was not accepted by all the specialists in a sector. Within every community, certain experts did not share the dominant stock of background knowledges and its practices. Although detractors and dissidents existed and persisted within both air and space, a mainstream specialist community, bound by a common culture, was identifiable and observable in each sector. In a sense, as sectoral participants on the

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margins expressed alternatives to the dominant meanings and practices, they made it possible to discern the contours of the mainstream specialist community’s culture.¹⁴⁹

5. **Background knowledges and specialist practices**

Differences in the representational practices of aeronautic and space specialists reflected differences in the background knowledges shared within each of these communities. These background knowledges comprised not only technical knowledge, but also tacit philosophical commitments about the relationship between humans and technology. The commitments comprised several layers of inter-related assumptions about humans, their tools, and the international environment.

Most aeronautic and space professionals were engineers and technologists by training and title. In practice, however, their daily work also called for them to reason, act, and express themselves as anthropologists, sociologists, and international relations theorists. Developing and applying informal theories of the social world was an integral part of technical work in air and space, from system design through manufacture to operation. As Michel Callon and John Law observed of defense aircraft manufacture, aeronautic engineers were also sociologists, since their performance of engineering practices relied on often unstated judgments and theories about social relations.¹⁵⁰ Aeronautic and space specialists sharing their expertise with policymakers and decisionmakers also expressed tacit understandings about humans and society.

More specifically, specialists within each community shared an unstated philosophy of the relations between humans and their technologies. At the core of this philosophy was a

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conception of how agency was distributed across humans and technologies in the world around them. This basic and fundamental understanding differed between aeronautic and space specialists. Aeronautic specialists expressed a background philosophy in which agency resided with the humans, rather than technologies, which they characterised as passive instruments. Space specialists, in contrast, expressed a background philosophy in which both humans and technologies possessed forms of agency. In some instances, space experts attributed greater agency to the technical than to the human elements of the assemblages they described.

Derived from this basic and abstract view of agency in the human-technology relationship was a conception of how humans relate to their tools and to each other. This included an informal theory of human-machine interaction. It also comprised a tacit model of how individuals related to society and an implicit understanding of human nature. This grouping of philosophical commitments constituted an informal “anthropology” shared among members of a specialist community.

In addition to this theory of the individual, specialists in a community shared a theory of how society writ large relates to technology. In other words, they shared a model of the society-technology relationship. This model also derived from their understanding of how agency was distributed across humans and technologies. It included assumptions about whether societies respond to or shape their technologies. It also comprised beliefs about the sources of technological change and related ideas about the determinants of societal conditions. This grouping of theoretical commitments constituted an informal “sociology of technology” shared among members of a specialist community.

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The final layer of the specialist community’s shared background knowledge consisted in an informal theory of international politics. This theory was made up of assumptions about the role of technological factors in the rise and fall of nation-states in the international system. These assumptions also reflected the community’s underlying view of the human-technology relationship. Specialists expressed their community’s theory of international politics in representations of their sector and the international environment they faced.

**Figure 1. Content of background knowledge shared among members of a specialist community**

Drawing on their community’s background knowledges, specialists in a given sector tended to represent their world in similar ways. When experts performed representational practices recognised as competent and intelligible by other members of their community, they established and reinforced their membership in this group. Each specialist community was itself maintained in countless such acts performed by its constituent members. For example, specialists engaged in this process when they represented their programs at conferences or reported the results of their work in trade journals. Propagated and repeated over time, representational practices produced and perpetuated the specialist community and its internal culture. At the same time, any individual specialist’s performance of a practice derived from their community and its
common stock of background knowledge. This background knowledge was a historical product, the result of currents of thought and practice that influenced the specialist community and its sector over time.

Figure 2. Differences in content of air and space specialists’ background knowledges

<table>
<thead>
<tr>
<th>Sector</th>
<th>Air</th>
<th>Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontology 1: society</td>
<td>Society is a collection of individual agents.</td>
<td>Society is a holistic system.</td>
</tr>
<tr>
<td>Sociology of technology</td>
<td>Human choice produces technical change.</td>
<td>Technological change causes social change.</td>
</tr>
<tr>
<td>Ontology 2: objects</td>
<td>Objects are aggregates of labour processes.</td>
<td>Objects are inherently effectual; objects have fixed properties.</td>
</tr>
<tr>
<td>Theory of international politics</td>
<td>Production and trade across borders are manageable.</td>
<td>Technological competition between states is inevitable.</td>
</tr>
<tr>
<td>Expected international order</td>
<td>Regulated transnational integration</td>
<td>No integration, emerging interstate competition</td>
</tr>
</tbody>
</table>

6. The constitution of international order in specialist practices

Through their representations, specialists constituted the international orders that fostered bilateral trade and cooperation in the air sector, but constrained them in the space sector. However, the impact of specialist cultures was not straightforwardly causal. Specialist performances of representational practices were not a direct cause of the bilateral outcomes in air and space. Nor did specialists’ representational practices exert a discrete, unidirectional influence upon sectoral policy. A specialist community’s internal culture is not a variable that
causally explains any specific event, such as government’s adoption of a policy, its choice of one policy over another, or the timing of a policy decision. “Specialist culture” does not constitute an independent variable competing with other possible independent variables to explain these sectoral outcomes.

Instead, specialists’ practices indirectly, distantly, and diffusely contributed to the bilateral outcome in each sector. Through their representational practices, aeronautic and space experts created the conditions of possibility for the outcome that prevailed in each sector. Specialists defined the range of policies and outcomes that decisionmakers and policymakers in their sector considered plausible and feasible, in the process setting the parameters of what was possible in the bilateral relationship. As Albert Yee explains, shared understandings or social facts “quasi-causally affect certain actions not by directly or inevitably determining them but rather by rendering these actions plausible or implausible, acceptable or unacceptable, conceivable or inconceivable, respectable or disrespectful, etc.”

Without the intersubjective meanings that specialists fixed in practices, the international orders that structured bilateral outcomes in air and space could not have emerged in the ways that they did and with the rationales that they did.

As specialist cultures functioned in these ways, they were not rigid structures compelling or constraining actors from without. Specialist cultures, comprising knowledges and practices, only existed as and could only be observed as patterned action by individuals. Specialist cultures did not have an ontological status of their own. Nor were they in any other sense independent of the agents that created and reproduced them in concrete acts. Specialist cultures did not operate upon agents, but through them.

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Conclusion

Research and theory about epistemic communities and communities of practice in international relations and about the cultural production of technology provides the basis for a theoretical framework addressing my research question. Drawing on insights from these areas of scholarship allows for conceiving of China-U.S. relations in the air and space sectors as two evolving bilateral orders. These distinct orders were produced and sustained in the representational practices of technical specialists, who in both countries influenced policymaking. Within each sector, specialists formed a community, sharing background knowledge expressed in common practices.

In each case, this background knowledge consisted in a set of basic philosophical assumptions about the relationship between humans and their technologies. At their core, these assumptions characterised the distribution of agency between humans and devices. Within each community, this philosophical assumption about the agency of humans and their tools translated into a series of slightly more focused theories. These included the specialist community’s tacit anthropology, sociology of technology, and theory of international politics. These tacit theories were conveyed in experts’ representations of their sector to policymakers and decisionmakers. As specialists represented their sector drawing on these tacit theories, they not only described their sector, but also implicitly prescribed policies compatible with their basic philosophical commitments. In the air sector, these theories called forth policies fostering bilateral trade, industrial integration, and technical cooperation. In the contrasting space sector, experts’ representations implicitly prescribed and reinforced agreement on policies limiting or blocking bilateral trade, industrial integration, and technical cooperation.

Although expert practices did not directly cause the Chinese and U.S. governments to adopt these policies, they created the circumstances within which their adoption became possible.
and likely. Through their representational practices, specialists produced and created agreement on the ends and means of policy in their sector. They characterised their sectors as a targets of policy in ways that rendered some classes of policies feasible and desirable, while locating others outside the range of policies under consideration. Experts in each sector defined the spread of policy options from which policymakers and decision makers would then choose. Because experts’ representations produced their sectors as objects of policy, they were also constitutive of the policies themselves.

Within each sector, Chinese and U.S. policies, each underpinned by logics and rationales, combined to form a bilateral order that either fostered trade and cooperation or hindered them. In the air sector, specialists’ representations conveyed their background assumption that humans and individuals and agents, that technologies are instrumental and passive, and that the international environment is benign. These assumptions called forth policies that regulated and managed bilateral trade and cooperation, but did not block them. In space, experts’ representations communicated that humans are part of structural wholes and systems in which their agency is constrained, that technologies are intrinsically potent and menacing, and that the international system is hostile and competitive. These assumptions were compatible with policies that blocked or tightly limited bilateral trade and cooperation and instead fostered the autonomous development of national capabilities in each country.
Research design and methods

Introduction

This chapter introduces the research design and methods for this project. The design of this study is driven by an empirical research question, qualitative, and comparative. I collected data for this project using several methods developed by qualitative political scientists, scholars of science and technology studies, and sinologists. Applying the insights of qualitative methodologists, I tailored these methods to my research question and needs and to the realities of my research environments. This approach allowed me to analyse and interpret my observations into evidence lending support to, disconfirming, or refining my theoretical argument. The end product of this research and analysis is an analytically structured and comparative historical reconstruction of bilateral relations in the air and space sectors.

The first part of this chapter recalls the research question and objectives that guide this project. The second part discusses the meta-theoretical issues raised by the theoretical framework introduced in the previous chapter. The third part explains the study’s research design. The fourth part describes the methods and sources used to collect data. The fifth part explains how these data were analysed and interpreted into evidence for or against my argument.

1. Research question

This research project is driven by a specific empirical question: Why and how did China-U.S. relations evolve differently in civil-commercial air and space between 1989 and 2009? In particular, this research examines why and how the two countries engaged in trade, industrial integration, and technical cooperation in air, but not space. It also examines why and how the two countries developed separate space national programs and industries and why and how
mutual suspicion and competition grew between their two governments in the space sector. Given this goal, I designed the research to develop a theoretical framework answering the research question, provide evidence of its plausibility, and then demonstrate where possible the distinct value that this framework adds above and beyond existing approaches.

However, as noted in the first chapter, this specific empirical puzzle is one facet of a larger theoretical question about international relations. In addition to answering the concrete question about the particular cases, a secondary objective of this research was to develop theoretical constructs that could in the future be applied to other questions in international relations, including about other specialist sectors and/or countries. The specific research question is one expression of this more general question: why do states trade, integrate their industries, and cooperate in some high-technology sectors, but not in others? Put differently, this broader question is about why and how research, development, and production is transnational and global in some high-technology sectors, while it is fragmented by national borders in others. The study of the two sectors proceeded with a view to these larger theoretical issues in international relations.

2. Metatheoretical issues

This research design also derives from metatheoretical assumptions underpinning the theoretical framework described in the preceding chapter. These assumptions are about the nature of knowable reality and how knowledge is produced. These assumptions underlie the scholarship on international practices and on the cultural production of technological artefacts reviewed in the preceding chapter. These perspectives carry three methodological implications for this research project: a focus on constitutive explanation, an interpretivist orientation, and an attempt to convey the ontological conjoining of matters and meanings.
The concept of explanation that underlies the theoretical framework carries methodological implications. Guided by scholarship on international practices and in technology studies, I base the design of this research on a loosened understanding of explanation. This view of explanation encompasses constitutive claims, rather than restricting it to causal claims. Constitutive accounts describe and explain how social reality is produced in discourses and practices, rather than identifying relationships of variables to uncover general laws about the social world. Constitutive accounts often explain the “how,” “how possible,” or “what” of phenomena under study, while causal accounts aim at explaining the “why” of these phenomena. As Alexander Wendt explains, the objective of constitutive theories is “to account for the properties of things by reference to the structures in virtue of which they exist.”

Some scholars in international relations and in technology studies go a step further and reject any attempt to seek causation understood as a linear relationship of one variable acting upon another at a point in time. For example, Bruno Latour argues that social science should aim for description, not causal explanation. In his view, careful descriptions of how the social is ordered and evolves are also accounts of why things are the way they are and, therefore, have an explanatory function without assuming point-to-point causality. The design for this research project draws on these diverse insights to generate descriptive and constitutive accounts of the two cases. These accounts describe the phenomena under study, identify the conditions of possibility for these phenomena, and illuminate constitutive processes through which these conditions arose.

155 Latour, *Reassembling the Social*. 
Another methodological consequence of the theoretical framework is the interpretivist orientation of this project. The theorists I draw upon assume that knowable reality is neither objectively given nor directly apprehended, but produced in human practices. This view rests on an internalist theory of mind, within which the duality between subject and object – or between social scientists and the entities they study – collapses. The analyst’s task, then, is to understand and represent, as best as possible, the phenomena under study from the perspective of the actors involved. This approach assumes that academic researchers, analysts, and other observers of these phenomena do not simply study them from without, but become involved in the constitution of the phenomena themselves. Scientists do not discover facts, but create them. Thus, neither engineers perceive their hardware as an objective given, nor do social scientists observe these engineers at work from some neutral perch. These metatheoretical assumptions preclude a quasi-experimental design aimed at testing competing explanatory variables. It is implausible within this framework to identify one variable as a more potent sole determinant of the outcomes than others. As suggested in the first chapter, the potential variables themselves are entities whose constitution to and by actors requires scrutiny.

A third methodological implication of the theoretical framework relates to ontology. In particular, it relates to whether the world under study is made of matter or ideas and to how artefacts may be studied. Following cultural theorists of technology, this project assumes that knowable stuff is dually material and meaningful. Material entities, such as oceans and typewriters, are known to us as and in both matters and meanings: there is no knowledge of matter that is unmediated by constructed meanings, and meanings are shared between subjects through material vectors. The world known to us is a shifting assemblage of these elements. In

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their epistemologies and ontologies, cultural theorists of technology draw no line between matter and meaning.

In contrast, for modernist constructivists like Wendt, the world is also made of both matter and ideas, but the two are distinguishable. Ideas do not go all the way down, but rather hit a bedrock of material “reality” that they cannot penetrate. These material conditions exist independently of the human mind and have some objective knowability, i.e. some measurable correspondence to the truth. This material bedrock comprises existing technologies, which constrain and allow what is possible in the social world.

From these ontological and epistemological differences flows a methodological nuance. The technology scholar’s approach examines the cultural constitution of technological artefacts “through and through,” while recognising the material dimension of both the artefacts and of constitutive processes. Inquiry of this type situates these technological artefacts in larger webs and configurations of related matters and meanings. In contrast, Wendt’s constructivism is best suited to investigating the constitution of “social facts” relating to or surrounding technological artefacts, but not the constitution of the artefacts as known entities in and of themselves. Thus, in this respect this project parts ways with Wendt’s vision of constitutive explanation to focus instead on explaining the cultural production of technological artefacts and the international orders within which they exist.

3. Research design

In order to shed light on why and how bilateral relations evolved differently in air and space, the design of this project is qualitative, comparative, and inductive.

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Part I: Chapter 3

The design of this research is qualitative because answering the research question required the intensive, thickly empirical study of two particular cases, the air and space sectors. These cases were selected for their variation on outcomes, which are the phenomena to be explained by this study. ‘Bilateral outcome’ here is analogous to a ‘dependent variable.’ This research design was the best means to answering the specific research question and developing theoretical insights applicable to other cases. Selection on the ‘dependent variable’ is recognised within political science as a suitable approach to developing theoretical constructs, but not to testing or verifying theoretical propositions.\(^{158}\)

This research design provides for the semi-structured comparison of the two sectors. The comparability of the two sectors is discussed in Chapter 1. In short, while the air and space sectors are not identical, their similarities warrant comparison. The two sectors are similar in aspects that major theories of international relations highlight as significant. At the same time, the variation in the sectors’ bilateral outcomes is pronounced and substantial enough to make these cases interesting to compare. This comparison was partly structured by the systematic and explicit analysis of features of the two sectors that bore upon their likelihood to become sites of bilateral trade, industrial integration, and cooperation (found in Chapters 5 and 9). In other words, the structure of this comparison ‘held constant’ sectoral conditions expected to influence bilateral outcomes. This form of sectoral comparison made it possible to contrast and isolate the distinct constitutive processes implicated in the two sectors’ bilateral outcomes.

In order develop general theoretical insights into this type of question, I followed the guidance of China specialist Kevin O’Brien and adopted an inductive research design. In practice, this approach consisted in an iterative process of alternating inductive and deductive inquiry in order to formulate theoretical constructs. In this project, I began with initial theoretical suppositions derived from the secondary literature relevant to my topic. After conducting some empirical research, I revised these theoretical suppositions to more closely correspond to my observations. I then conducted more research on new sources in order to determine whether my revised theoretical framework was empirically supported. I performed this cycle several times. Because of this process, this research cannot test or verify the theoretical framework. Rather, this approach is suited to developing or refining theoretical concepts, which are likely to be of bounded generalizability.

The end-product of this approach is an analytically structured historical reconstruction of the processes that made possible the outcomes observed in air and space. For each sector, this reconstruction consists of four segments, each allocated its own chapter. The first part is a systematic consideration of the factors making bilateral trade, industrial integration, and technical cooperation either likely or unlikely in the sector at the start of and during the period under study. The second part is an interpretation of the culture shared among specialists within the sector, including its content as a tacit philosophy of human-technology relations performed in practices and its origins in other domains of practice. The third part traces the cultural processes through which specialists constituted the sector as an object of policy in China and the United States, creating the underlying conditions of possibility for the observed outcome.

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159 O’Brien, “Discovery, Research (Re)design, and Theory Building.”
These analytically structured accounts are based on data collected using methods developed in qualitative political science and in science and technology studies. These approaches rendered specialist cultures observable as patterns in aeronautic and space experts’ representations of their sectors. The next section explains the methods and sources used to collect these observations.

4. Empirical methods and sources

I collected data for this project through extensive on-site research in China and the United States. At these sites, I gathered observations of discourses about human-technical configurations from participants in each sector using several methods. The specific methods used to collect data for this analysis were of three types: interviews; the analysis of texts; and the participant-observation of conferences and meetings.

4.1. Semi-structured interviews

Interviews with air and space specialists in China and the United States provided substantial data for this project. These interviews served two objectives. The first objective was to collect data that was not available elsewhere about developments in air and space. This data provided the basis for the historical reconstructions of developments in the two sectors. The second objective was to elicit participants’ representations of human-technical arrangements in their sector, in order to detect their implicit assumptions about the human-technology relationship.

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Asking participants questions and initiating conversation about their sector and work that related to my research question elicited these discourses from them.

Following O’Brien’s example, I adopted a semi-structured interview style that evolved during the course of the research. I settled on an approach that involved preparing both general and specific questions tailored to each interviewee based on their position and experience. In the course of interviews, however, these questions often gave way to the interviewees’ own preferences and direction, a mode that O’Brien likens to encouraging “guided monologues.”

This approach was suited to the technical and corporate elites I consulted, who spoke from positions of authority and offered their most candid insights when they were not constrained by a rigid question-and-answer format. This mode of interviewing readily elicited interviewees’ representations of sociotechnical assemblages in their sector. It also prompted them to share their insights into issues unsettled in the secondary literature, such as the magnitude of technology transfers in aircraft manufacture at U.S.-invested joint ventures in China and the long-term goals of the Chinese central government’s “indigenous innovation” strategy.

4.1.2. Interviewees

In order to identify and approach interviewees in China for this project, I followed the practices of experienced sinologists, who recognise the limitations of the Chinese research environment and the challenges inherent in discussing sensitive topics with research participants. To access interviewees, I relied primarily upon my institution of affiliation in China and diverse networks of personal contacts. The Institute of World Economics and Politics (世界经济与政治研究所) at the Chinese Academy of Social Sciences (CASS) (中国社会科学院) provided me

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162 O’Brien, “Discovery, Research (Re)design, and Theory Building.”
with letters of introduction and arranged meetings with individuals throughout China’s academic institutions. For most of my interviews, I drew upon a diverse network of contacts including academics, diplomats, think-tank experts, consultants, corporate leaders, and other benefactors who introduced me to potential interviewees. From there, my interviewees introduced me to other interviewees. I also met interviewees at conferences. Finally, I identified interviewees from articles and books about China’s air and space sectors that I had read. I sought interviewees from all the major units and organisations in the two sectors and, while my access fell short of this ideal, I nevertheless managed to collect perspectives from a broad and relatively representative swath of the Chinese air and space sectors.

I interviewed over 70 air and space specialists in several of China’s major air and space hubs: Beijing, Shanghai, Shenyang, Tianjin, and Xi’an. These interviewees included current and former officials specialising in air and space in government agencies and the military, including the China National Space Administration (CNSA) (中国国家航天局), the Ministry of Science and Technology (MOST) (中华人民共和国科学技术部), the Ministry of Foreign Affairs (中华人民共和国外交部), and the Ministry of Post and Telecommunications (part of which later became the state-owned enterprise ChinaSat). Within the military, I interviewed senior figures who had served in the General Armaments Department (GAD) (中国人民解放军总装备部) and Academy of Military Sciences (AMS) (中国人民解放军军事科学院) of the PLA and the astronaut training facility under the People’s Liberation Army Air Force (中国人民解放军空军).

Among interviewees were also participants in state-owned and private enterprises. These included subsidiaries of Aviation Industries Corporation of China (Avic) (中国航空工业集团公司), including Shenyang Aircraft Corporation and Xi’an Aero-Engine Corporation. Interviewees
also came from different organisations within the China Aerospace Science and Technology Corporation (Casc) (中国航天科技集团公司), the country’s largest space industrial group. Among Casc subsidiaries, I interviewed individuals leading the China Great Wall Industry Corporation (Great Wall). I consulted technical specialists at the China Aerospace Science and Industry Corporation (Casic) (中国航天科工集团公司), the other of China’s two space industrial groups. Although China’s air and space sectors are dominated by the large state-owned defense conglomerates, there are also rapidly growing small and medium-sized enterprises that engage in manufacture in these areas. I interviewed the founder of China’s then-largest private aircraft components manufacturer. Among my interviewees were employees at China Eastern, one of the country’s three major airlines and an important customer of the equipment manufacturers.

Finally, Chinese interviewees included academics in technical universities and policy-oriented research institutions. These included the Beijing University of Aeronautics and Astronautics (Beihang) (北京航空航天大学), Tsinghua University, Peking University, the China Institutes for Contemporary International Relations (CICIR) (中国现代国际关系研究院), the China Institute for International Studies (CIIS) (中国国际问题研究所), the China Arms Control and Disarmament Association (中国军控与裁军协会), and the Shanghai Institutes for International Studies (SIIS) (上海国际问题研究院). I also interviewed individuals within the Chinese Academy of Sciences (CAS) (中国科学院) and CASS, bodies tasked with performing research in support of policymaking and which reported directly to the State Council. Within CAS, I interviewed titled academicians, professors, and other experts in the Graduate School of Technology Policy and Management and in the Center for Space Science and Applications Research (CSSAR). I interviewed a leading figure at the Chinese Society of Astronautics (CSA),
a Casc entity that represents the Chinese professional space community at international conferences and in connection with academic cooperation efforts. Finally, I consulted professors at the China University of Politics and Law, who participated in preparations of the draft of China’s first space legislation, a significant document with policy and institutional ramifications for the country’s entire space sector.

While in China, I also seized opportunities to interview other professionals and specialists in the Chinese air and space sectors based in Beijing and elsewhere. These included a director at the APSCO, a regional space institution headquartered in Beijing. I interviewed representatives of U.S. and other foreign companies operating in China, including in particular individuals then or formerly at GE Aviation, Boeing, Airbus, Textron, Pratt & Whitney, and Bombardier. I interviewed military personnel, diplomats, and other officials responsible for the air and space sectors posted to the U.S., Canadian, French, and Italian embassies in Beijing. To get more context and background, I also consulted journalists based in China, who focused on or covered the air and space industries. Among these were correspondents for U.S. and Brazilian publications. In the course of this research, I also had several opportunities to visit manufacturing facilities in connection with specific interviews. For example, I visited the Airbus Tianjin Final Assembly Line and test flight range and a large private aircraft component maker in Shenyang.

The U.S.-based stage of this research entailed over 50 interviews of U.S. air and space policy specialists in Washington, DC, Cape Canaveral, FL, and Colorado Springs, CO. I conducted these interviews across several government agencies, industry, think tanks, and academia.

The majority of interviewees were in agencies of the U.S. federal government. They included air and space specialists in the Departments of State, Defense, and Commerce. Some of
these individuals were in the Directorate of Defense Trade Controls, the unit in charge of implementing export licensing procedures within the Department of State. I also interviewed State Department officials responsible for space security diplomacy and civil space cooperation. Interviewees at the Department of Commerce were then or formerly responsible for aircraft manufacture, commercial space, and export control implementation. Among them were individuals who attended launches of U.S. satellites from China on behalf of the U.S. Government, including attendees at one launch failure that occasioned a technical investigation within which controlled information was transferred. Within the Department of Defense, I consulted space policy specialists. I consulted a former analyst at the National Air and Space Intelligence Center who was familiar with China’s anti-satellite test of 2007.

I consulted individuals responsible for aeronautics and international space cooperation within the headquarters of the National Aeronautics and Space Administration (NASA). In Cape Canaveral, I interviewed a technical specialist who was responsible for international payloads on the U.S. Space Shuttle and ISS programs. My interviewees included an expert familiar with bilateral space-data cooperation with China in the National Oceanic and Atmospheric Administration (NOAA).

Government interviewees also included an aerospace industry specialist in the International Trade Commission, a body that studies U.S. industries and foreign compliance with trade agreements. In addition, I consulted commissioners and staff focused on aerospace at the U.S.-China Economic and Security Review Commission, a body that reports to the U.S. Congress on developments in the bilateral relationship.

The second group of U.S. interviewees consisted of air and space industry specialists. These included representatives of major original equipment manufacturers, including Boeing and Raytheon, smaller firms, and consultancies. I also consulted specialists at the Aerospace
Industries Association (AIA) and at other trade organisations representing companies in the air and space sectors.

The third group of individuals I interviewed in the United States consisted of air and space experts based at universities and think-tanks. I consulted sectoral specialists involved in policymaking at the Space Policy Institute and other departments of the George Washington University. I drew on the expertise of specialists on air, space, and China at the Heritage Foundation, the Rand Corporation, Defense Group Inc., and the Nonproliferation Policy Education Center. Among these individuals were several who, earlier in their careers, had been political appointees in agencies responsible for air and space or involved in the Cox committee’s investigations.

Finally, I consulted individuals outside China and the United States whose expertise in air and space was relevant to this project. These included individuals responsible for China and U.S. cooperation within ESA. Among them was a former chair of UN COPUOS. I also consulted individuals employed at major Canadian satellite manufacturers familiar with the U.S. export control regime. I interviewed a professor of transportation economics with knowledge of the U.S. export control and China’s aircraft manufacture at the Université de Montréal.

The individuals I consulted were at different stages of their career. Some were junior professionals, while many had already become leading, senior figures in their sector. Many of the U.S. participants had moved between government, industry, and research positions. In addition to these interviews, I engaged in dozens of additional informal consultations at international conferences and other gatherings, discussed below.
4.2. Close reading of texts

The second method used to collect data for this analysis was the study of specialised texts. I observed specialist discourses by examining policy documents, official statements, and writing in aerospace technical and trade journals. I studied these official and technical publications on air and space in English and Mandarin, including sources available only in China and Taiwan. As in the interviews, examining these documents allowed me to collect observations of how air and space specialists represented the sociotechnical systems in their sector.

4.2.1. Texts

In China, this research focused on four main types of texts: policy documents; academic journals in aeronautics and space engineering; specialised trade periodicals; and books.

I consulted the major air and space policy documents issued by the Chinese central government from approximately 1986 onward. These were mostly policy and programmatic statements outlining long-term sectoral strategies and technology development programs. They ranged from white papers on space activities to Five-Year Plans targeting specific areas of science. Among China specialists, there is consensus on what are the major texts that define and explain policies and programs, so these were straightforward to identify.

The collection of Chinese academic journal articles was performed by my China-based research assistant. I instructed him to perform searches of major inter-disciplinary databases for the hundred most relevant original articles on my topics during the time period under study using a list of search terms I provided. He provided me with electronic image files of these articles and filled a matrix I had provided with the bibliographic information for these articles and a one- or two-sentence summary of each in English. I then performed the analysis and translation of these texts.
The collection of trade periodicals was performed in the same way by my China-based research assistant. In this case, he eliminated items that the search returned if they were very short. Because many trade publications in China have an explicit affiliation with a major industrial group or an institution, it was straightforward to determine that this method of selecting texts identified relevant articles. I performed the analysis and translation of these items.

I collected books for this research through diverse means. I visited specialised bookstores and presses in Beijing to buy most of the publications that pertained to air and space programs and policies from the 1980s onward. I found relevant texts at the National Library (国家图书馆), at the library of China’s premier technical university, Tsinghua University, and at the library of the Center for the History and Philosophy of Natural Science at CAS. I also obtained books in Taiwan.

I focused on programmatic histories, studies of aeronautic and space technology and society, theoretical and analytical studies of strategic and tactical issues in air and space, and technical texts, such as engineering textbooks, when these provided rationales or explanations for programs. I also consulted biographies and collected writings of elite Chinese scientists and engineers who are known to have enjoyed influence over major policy and programmatic decisions since 1949. I performed the analysis and translation of these texts in the same way as for the academic and trade publications.

Following the practice of specialists who study China’s air, space, and defense industries, including Dean Cheng, Tai Ming Cheung, Roger Cliff, and Kevin Pollpeter, I chose these books based on several indicators of their significance and likely circulation among policy-relevant communities. These indicators included the issuing press, the standing and affiliation of the

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author or committee of authors, the author of the foreword, and any other particular attention or mention that item had received in other authoritative sources.

Within the United States, I also studied several types of documents. I chose to focus on U.S. texts that were not of the same type or format as the Chinese texts, but which were the most likely to express the views of an equivalent community of influential technical experts. The volume of U.S. texts addressing air and space policy, programs, and strategy was unmanageable, so I selected sources written by recognised authorities and published by influential institutions, often with explicit connections to policymaking. These texts were of three main types: reports and studies written for policymakers by appointed committees of air and space experts; policy documents; articles in publications affiliated with major government or military units in the air and space sectors; and texts written by individual specialists of high standing in their sectoral community.

I identified and analysed the relevant research reports on air and space by committees of technical experts released during the 1988-2012 period. Many of these documents were published by the National Research Council (NRC). I also consulted authoritative reports produced by other professional research organisations, such as Federally Funded Research and

Development Centers (FFRDCs) and think tanks. Other influential reports that I analysed included those produced by professional associations and industry associations.

A second set of U.S. sources consisted of major air and space policy documents issued during this period. These included the U.S. national air and space policies. Among them were also sectoral studies, program studies, implementation strategies, and related documents released by major government agencies in air and space. These included the Federal Aviation Administration (FAA), NASA, agencies within the intelligence community and other parts of the Department of Defense, and certain other major government departments. The Congressional Research Service (CRS) and Government Accountability Office (GAO) also produced studies on specific air and space policy topics.

The third set of sources consisted in books and articles about air and space policy, programs, and technology-society issues by leading contemporary and historical aeronautic and space specialists. This selection was restricted to books by influential air and space thinkers known to professionals in these two sectors and to books by individuals with specific sectoral policy experience. In addition to these sources, I consulted aeronautic histories and biographies of early aviation pioneers and innovators.

The final set of sources I consulted consisted in articles and chapters related to air and space policy in journals and books affiliated with major defense-intellectual centers, including the Air Force and the National Defense University. I focused specifically on contributions that addressed international trade, industrial integration, technical cooperation, and strategic competition, that offered broad perspectives on the society-technology relationship or international relations, or that introduced theoretical or doctrinal perspectives on the air and space domains.
4.3. Participant-observation of conferences and meetings

The third method used to collect data for this project was the participant-observation of expert conferences and meetings. Most of these meetings brought together sectoral specialists from different countries and often from different areas of specialisation and occupations. Joining these gatherings allowed me to observe how a transnational specialist culture is produced and maintained in interaction. It also revealed how a common culture circulates through encounters between sectoral specialists from different countries. At these gatherings, I collected observations of specialists’ representational practices similar to those gleaned through interviews and from texts. In addition, I conducted countless informal consultations about my research on the sidelines of these conferences with individuals in Chinese, U.S., Canadian, and other government agencies, multilateral organisations, and companies.

4.3.1. Conferences and meetings

In China, I participated in and observed conferences gathering sectoral professionals in Beijing, Xi’an, and Shanghai. I presented on my research in English and Chinese at conferences and companies in different localities. The conferences I attended focused on aircraft manufacture, air transportation economics, avionics technology, foreign-invested manufacturing joint ventures, and U.S. and Chinese export controls. I also joined a meeting of participants in the Aviation Cooperation Program of the American Chamber of Commerce in China.

In the United States, the conferences I joined as a participant-observer included the Air Force Association’s annual meeting, the National Space Symposium (NSS) held annually in Colorado Springs, an international meeting of the heads of national space agencies, and dozens of conferences, hearings, and presentations about U.S. space policy and programs. I presented on my research at conferences on international space cooperation and security and space policy.
Outside China and the United States, I also participated in and observed the 2011 International Astronautical Congress (IAC) in Capetown, South Africa. The IAC is the largest annual meeting of international space professionals from government, industry, and academia. At the IAC, I was able to informally draw on the expertise of individuals from other NASA centres that I did not have the opportunity to visit while in the United States and officials from other countries. In Montreal, I joined a “track-two” dialogue on space security between Chinese and U.S. officials and representatives organised by the Eisenhower Center for Air and Space Studies of the U.S. Air Force Academy.

In addition to attending conferences as a participant-observer, I had opportunities to informally observe and interact with air and space specialists in other contexts. For example, I joined a group of U.S. aerospace industry executives on a trip to Beijing and Shanghai as an interpreter under the auspices of a major industry organisation. On this trip, I participated in technical meetings and visits of facilities. These included launch vehicle assembly lines at the Chinese Academy of Launch Vehicle Technology (CALT), satellite assembly, integration, and testing facilities at the Chinese Academy of Space Technology (CAST) and the Shanghai Academy of Space Technology, ground stations at China’s largest satellite operator, ChinaSat, and facilities at the National Center for Remote-Sensing and Space Applications. During this trip, I also joined a meeting with a specialist from the Chinese human spaceflight program and was able to informally consult him about developments in the bilateral relationship in space. I twice participated in the NSS as an interpreter-facilitator for several Chinese industry delegations in attendance. On these occasions, I informally consulted industry and government figures from both countries about my research. For example, I was able to seek the thoughts of former astronauts and other participants in the ISS program about the possibility
of Chinese participation in missions to the station. I also consulted media figures involved in advocacy for China-U.S. space cooperation about their work.

5. Analysis and interpretation of the data

I used simple and easily replicable analytical and interpretive procedures to turn these raw and unstructured observations of specialist representations into evidence for or against my argument. To detect whether or not specialist cultures existed and functioned as I postulated, I analysed the collected observations of aeronautic and space experts’ acts of representation. Analysing these individual observations allowed me to detect regularities and systematic differences in these representations indicating that specialists of the same sector shared underlying philosophical assumptions.

The items I observed consisted in acts of written or spoken representation by individual specialists (or committees of specialists). The referents of these representations were sociotechnical systems in the air and space sectors, depicted in some state of activity. These observed “units” of discourse were as short as a single verb-subject phrase or as long as a description spanning several pages in a book. Their defining feature was not length or form, but content: all represented an interaction between humans and technology.

For example, I observed aeronautic specialists represent configurations of technologies and humans in action. Their depictions located particular aeronautic artefacts in their practical settings, comprising human operators, organisations, facilities, policies, and other institutions. An aeronautic expert could represent the international flight of a large commercial jet in spoken and written words, a photograph on a PowerPoint slide, or a three-dimensional miniature. This expert would describe the moving aircraft as a passenger vehicle, comprising an airframe, wings, and engines, specialised on-board equipment, pilots, crew, travellers, operating procedures,
regulations, national airspace policies, and international treaties. In the process, the specialist would establish connections between these diverse elements. Representing the relationships between the human and technical elements of the large commercial jet in flight, the aeronautic expert produced it as a system in action. As they described relationships between these parts, experts tended to rely on habits of representation shared throughout their community.\textsuperscript{164}

I examined the particular representational acts I had observed one by one to detect regularities and patterns among them. Closely reading individual specialists’ acts of speech and writing about their sector, I drew out the conceptual relationships between the human and technical elements of their compositions. This process provided purchase on the underlying philosophy of human and technological agency that these acts conveyed. Simple examples of representations in speech help explain this approach. In the paragraph below, the quoted sentences are analysed for the underlying philosophical assumptions they express. In these cases, the subject and object positions in the sentence indicate whether it is the humans or the machines in the sociotechnical system that act or are acted upon.

“The pilot flew the plane.” //
The human agent operated the machine. //
\textit{Agency belongs to the human, not the machine.}

“The space shuttle lifted the astronauts.” //
The machine acted upon the human subjects. //
\textit{Agency belongs to the machine, not the humans.}

More complex acts of representation modified the subjects and objects with layers of additional information about them, added more meaning and content to the action verbs, and rendered the sociotechnical systems as evolving in time. When more and more features and

processes related to the sociotechnical system were added in these ways, the representations grew in length. They also conveyed additional background assumptions about actors, society, devices, and how they related to each other.

“Dreams of conquering the sky in their hearts, intrepid visionaries invented the technologies of flight.” // Acting upon intentions, human agents created machines. // *Agency belongs to the humans, not the machines. Humans are intentional actors.*

“The only things standing between us and nuclear winter were luck and early-warning satellites.”// Early-warning satellites and luck protected humans from nuclear winter. // Machines and abstract impersonal forces acted upon the human subjects. // *Agency belongs to the machines, not the humans. Structures act upon humans.*

The empirical chapters of Parts II and III illustrate this mode of analysis with specific examples.

Examining hundreds of such representations, it became possible to identify regularities in the conceptual relationships they expressed. I interpreted each processed item of data – the analysed act of representation – as an individual specialist’s performance of a representational practice. Considered together, these observations indicated two distinct modes of representational practice performed by two sectoral specialist communities. These practices conveyed and were structured by each community’s particular philosophy of human and technological agency. Encapsulated in concrete acts of representation, this tacit philosophy formed a sectoral culture. Having identified two distinct specialist cultures, I explored their origins (Chapters 6 and 10), drawing on secondary and, later, primary sources. I then examined and traced how, through their reproduction and circulation among sectoral professionals, these specialist cultures constituted the two sectors as requiring distinct policies to decisionmakers in each country (Chapters 7 and 11).
Conclusion

The research design and methods of this project were dictated by two goals. The first of these was to answer an empirical question about particular sectoral cases within the China-U.S. relationship. The second was to formulate theoretical constructs with a view to developing a theory of why and how states trade and cooperate in some high-technology sectors but not others. Metatheoretical issues associated with my theoretical framework imposed constraints upon what type of research and explanation were possible. Given these circumstances, the research design best suited to my goals was an inductive, qualitative, thickly empirical semi-structured comparison of both sectors. The methods best suited to collect and analyse data for this project derived from theory and research in cultural studies of technology, from insights into interpretivism and discourse analysis, and from qualitative research in China studies. Adapted to the specific demands of this project, these approaches offered means to examine whether sectoral cultures existed and functioned as I proposed in the previous chapter. These approaches made it possible to assemble empirical evidence to lend support to or disconfirm my account. Incorporating explicit consideration of alternative explanations for the outcomes under study into the analysis of the cases allowed for greater confidence in my conclusions.
Part II:
Air
The politics of China-U.S. relations in air:
Trade, industrial integration, and cooperation

Introduction

Between 1989 and 2009, China and the United States traded, integrated their industrial activities, and cooperated in the air sector. In the commercial air segment, Chinese and U.S. firms traded in aircraft products and related services. They also integrated their research, development, and production activities by forming joint ventures in China and other collaborations. In the civil segment, Chinese and U.S. agencies cooperated on technical projects. Over the course of those two decades, this bilateral trade, industrial integration, and civil cooperation deepened and broadened to new areas. Both governments maintained and even strengthened national policies that supported this bilateral order throughout this period. By 2009, integration of the two countries’ respective air sectors’ was an all but irreversible tendency.

This chapter examines the policies that the two governments adopted to establish the bilateral order that fostered these outcomes in the air sector. These are the phenomena to be explained in this sector by this thesis. The first part of this chapter surveys Chinese and U.S. policy in the air sector. The second part recounts the course that bilateral trade and industrial integration took during the two decades following 1989. The final part reviews technical cooperation led by the two countries civil aviation agencies.

1. Air policy in China and the United States

China and the United States adopted vastly different policies and programs in the air sector during the 1989-2009 period. Although these policies and programs reflected distinct national priorities and institutions, they were based on similar basic understandings of aircraft
manufacture and aeronautic technology. They were also based on a common view of bilateral trade, industrial integration, and civil cooperation as beneficial. Both countries’ policies, in their respective ways, allowed and fostered these outcomes.

1.1. Air policy in China

During the 1990s and 2000s, China’s leaders approached making policy for the air sector as the implementation of a multi-decade technology development strategy. Several state and government organs participated in these processes, some as makers of policy and others as makers of hardware. Policy and programs for the air sector engaged diverse interests throughout the Chinese state, evolving with economic reforms and policymakers’ and corporate leaders’ assessments of international opportunities.

Strategies for developing the air sector lay at the intersection of interests and goals espoused by several Chinese government actors. Diverse entities contended to influence policy and were involved in implementing the sectoral strategies devised at the top. These entities fostered trade and bilateral industrial integration on the ground by attracting and supporting U.S.-invested joint ventures.

At the central-government level, policies and programs for the sector were designed to serve the goals of building a knowledge-based economy and increasing China’s share of worldwide high-value added exports.1 Chinese specialists cited as a central motive for top policymakers reducing the expected foreign exchange burden of importing increasing numbers of aircraft as projected demand would surge through 2030.165 Requiring the foreign manufacturers that equipped Chinese airlines to localise production also served this goal. Once they were

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165 Interview with Lu Feng, Professor in the School of Government and Director of the Lee Kuo-Guan Institute for Business and Government at Peking University, Beijing, China, 2009.
established, joint ventures in aircraft manufacturing enjoyed strong support from the central government. For example, they enjoyed financing on soft terms and preferential access to land for facilities.

Aeronautic technology development strategies intersected with reform agendas targeting specific industries and firms. The National Development and Reform Commission (NDRC) led the reform of the largest state-owned enterprises, including Avic, as part of a strategy to build export-competitive Chinese firms and brands. It had a role in approving Chinese airlines’ purchases of foreign aircraft, giving it a lever on U.S. firms’ access to the Chinese market. In this role, the NDRC could induce and compel the establishment of U.S.-invested joint ventures. The Commission for Science, Technology and Industry for National Defense (Costind) and the State-owned Assets Supervision and Administration Commission (Sasac, established 2008) directed and oversaw sweeping reforms and restructuring of China’s ten defense industrial groups, which included Avic. The goal of these reforms was the transformation of Avic into a modern, profit-driven, global high-technology corporation. A step in this process was imbricating Avic units into the global manufacturing networks of the world’s leading aircraft firms. These diverse interests and actors coalesced to implement the center’s long-term visions for aeronautic development in specific policies and programs.

They were joined by yet other government organs involved in designing and implementing policy under the 1986 and 2006 strategies. For most of the two decades following 1989, the main state organ involved in policy for the air sector was Costind. Guided by the long-term strategies, this body designed and coordinated the implementation of policy between large

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166 Interview with manager at one of China’s three major airlines, Interviewee 00-00-00, Xi’an, China, 2010.
strategic SOEs, military and other government end-users, research facilities, and concerned ministries. In 2008, Costind was succeeded by a weaker entity, the State Administration for Science, Technology and Industry for National Defense (Sastind). Together with Costind, the main government entities implementing policy for the sector during this period included ad hoc leading small groups, coordinating the execution of technology programs by other organs and ministries. In aviation, a unit of the Ministry of Transportation, the Civil Aviation Administration of China (CAAC), regulated aircraft safety, airlines, and airports.

Air policy also engaged local and regional interests. Governments at these levels saw the sector as an engine of local economic growth and trade. They pursued policies to attract joint ventures to their areas. Some led the way in creating industrial parks and other facilities dedicated to the sector, often becoming direct stakeholders in commercial manufacturing and service projects. The Shanghai municipal government, for example, owned 30 per cent of Commercial Aircraft of China (Comac). The government of Tianjin, through the Tianjin Free Trade Zone, was invested in the city’s Final Assembly Line Company joint venture with Airbus. In addition, governments in remote localities saw airports, with their attendant foreign-invested aircraft repair and maintenance facilities, as sources of growth and backbone infrastructures that would integrate their communities into China’s vibrant coastal economy. They also sought to attract airports and related joint ventures.

The main industrial players in the sector belonged to the large state-owned defense industrial group Avic. Avic comprised factories and research and development facilities throughout China. Most of these were clustered around Beijing, Shanghai, Chengdu, Jingdezhen,

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167 Evan Medeiros et al., A New Direction for China’s Defense Industry (Santa Monica, CA: RAND Corporation, 2005); Interview with senior Canadian diplomat responsible for Canadian aircraft industry interests in China and familiar with the Chinese aircraft manufacturing industry, Interviewee 16-16-00, Beijing, China, 2009.
168 Interview with executive and founder of a Chinese manufacturer of aircraft components, Interviewee 07-17-07, Shenyang, China, 2010.
Tianjin, Shenyang, and Xi’an. Avic companies included system integrators, sub-system integrators, sub-system suppliers, and makers of components. These units produced both commercial and defense items, often in the same facilities. In 2004, Comac was spun off as a separate entity at arm’s length from Avic. Comac became the system integrator and marketer for the ARJ21 and C919 programs.

In 2008, a reformed Avic adopted an overarching strategy aimed at integrating its firms into the global aircraft industry. The new vision would guide Avic’s ongoing internal reforms and long-term business decisions. This developmental strategy was known as “Two integrations, three creations, five development objectives.”169 “Two integrations” referred to integration into the global aircraft market and into the regional aircraft-manufacturing economy.170 “Three creations” referred to developing new “core competencies” based on creating brand value, creating a business-oriented model, and creating an integrated framework for the group.171 The “five development objectives” were market-oriented reform, consolidation according to specialisation, capital-market-inspired operations, international expansion, and industrialised development.172

Avic President Lin Zuoming elaborated on corporate strategy in 2012, explaining that the group sought “to create a global industrial chain promoting the healthy development of the Chinese and global aviation industries.”173 Avic modeled itself after globally networked

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Part II: Chapter 4

companies such as Boeing and Airbus. Such “modern aerospace companies,” Lin explained, “cannot operate alone; they have operations in many countries working together developing systems and building parts.” Avic’s leaders and policymakers were committed to seeing Avic entities enter the top tier of the global aircraft industry.

The Chinese government’s sectoral strategy used industrial partnerships between domestic and more established foreign aviation firms to develop a national base of scientific, technical, and manufacturing capacity in the sector. The main mechanism through which government and industry actors pursued this goal was requiring foreign aviation firms to offset their sales in China by localising their manufacture of aircraft hardware. Most of these arrangements took the form of joint ventures between domestic and foreign firms that produced aircraft components and sub-systems. As foreign firms located their activities in China and partnered with local firms, they helped build a Chinese aircraft industrial base.

Although many other countries had offset policies, in China several factors facilitated the process of inducing localisation. First, this strategy leveraged the enormous size of China’s internal market for aircraft products. Foreign firms were prepared to pay a high price for access to this market. Chinese experts were aware of their industry’s unique position. As a manager within the Shenyang Aircraft Corporation put it, “market and demand provide the momentum behind the [bilateral commercial] cooperation.”

Second, Chinese airlines were state-owned entities whose major purchases were subject to formal approval by

176 For example, the requirement that overall domestic content must equal 51% of the aircraft value was expressed by the predecessor to Avic, the Ministry of Aerospace Industries, at the outset of the competition process for the prime contract on the Trunkliner program of the early 1990s. Paul Proctor, “Chinese Nearing Decision on Trunkliner Program,” Aviation Week & Space Technology, November 12, 1990, 41.
177 Interview with Professor Liu Feng, Peking University, Beijing, China, 2010; see also Interviewee 8-4.
178 Interview with Shenyang Aircraft General Aviation Corporation manager with experience at Shenyang Aircraft Corporation, Interviewee 12-26-25, Shenyang, China, 2010.
government organs. Airlines submitting purchase order proposals that did not accord with central
government priorities expected to get their proposals rejected and to resubmit their requests until
they conformed to directives from the center.\textsuperscript{179} This process ensured that airlines did their part
to implement the offset policy. Third, imports of foreign aircraft by Chinese airlines required
substantial movements of foreign exchange, which could be blocked by the Ministry of
Commerce if it objected to the transactions. Finally, the ARJ21 and C919 national aircraft
programs came to both be run by Comac, a state-owned enterprise established to implement the
government’s sectoral strategy. Comac implemented the offset policy by restricting the bidding
for contracts to supply the sub-systems on its aircraft to China-based joint ventures.

Statements and writings about these strategies emphasised their goal of indigenisation and
“localisation (本地化).” While these programs aimed to harness foreign capabilities and
contributions toward China’s aircraft development in initial stages, their explicit long-term goal
was to increase the indigenous content on the ARJ21 and C919 vehicles.\textsuperscript{180} This meant growing
the proportion of technologies with “intellectual property rights (知识产权)” owned by Chinese
entities on the aircraft, gradually substituting them for foreign-origin items. In this plan, sub-
systems that Chinese companies could not produce, such as engines, were initially supplied by
foreign-invested joint ventures, but they would be later replaced with Chinese engines as these
became available.\textsuperscript{181} In addition to the content of Chinese-developed technologies on the
finished vehicles themselves, the indigenisation strategy encompassed equipment and tools used
throughout the research, development, and production processes. The projects initially relied on

\textsuperscript{179} Interview with manager at one of China’s three major airlines, Interviewee 00-00-00, Xi’an, China, 2010;
Interview with Lu Feng, Professor in the School of Government and Director of the Lee Ko-Guan Institute for
Business and Government at Peking University, Beijing, China, 2009.

\textsuperscript{180} Lu Feng [路风], “Research Report on China’s Large Aircraft Development Strategy [中国大型飞机发展战略研究
报告],” Business Affairs Weekly [商务周刊], March 20, 2005.

\textsuperscript{181} Yu Dawei [于达维], “国产大飞机发动机预2014年首飞[First Domestic Large Aircraft Engine Flight Test by
foreign technologies at each of these stages, but Chinese technologies to replace them were in development. This sectoral strategy reflected the long-term goal of fostering “indigenous innovation (自主创新)”\textsuperscript{182} in China.

The indigenisation strategy aspired to a relative increase of Chinese content in select areas, not a total substitution of foreign for local content, although views varied on the target level of indigenisation. Chinese aeronautic and technology policy specialists argued that the critical subsystems on these aircraft should be Chinese, but they accepted a long-term role for foreign suppliers of non-essential or less complex components and other smaller elements. Initially, the target for local content on the C919 was 10 per cent, but gradually increased to 30 per cent. As experts envisioned the successor to the C919, sometimes called the C929, they expected this figure to rise.

This view of indigenisation as relative, not total, also applied to the share of the domestic market that the ARJ21 and C919 would satisfy. Between 2006 and 2009, Chinese industry specialists and official statements placed this share at between 10 and 30 per cent for the C919 in its segment of the market (which included the Boeing 737 and the A320) and at approximately 10 per cent for the ARJ21. Chinese airlines and government planners did not see an interest in completely excluding major manufacturers, such as Airbus and Boeing, from the domestic market. Rather, the goal of the sectoral strategy was to reduce the overall reliance on imports and to break into world markets with Chinese aircraft exports.\textsuperscript{183}

As China’s leaders formulated and implemented sectoral policy, they also aimed to promote civil-military integration. This concept referred to “harnessing the technological and

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\textsuperscript{182} This term is sometimes translated as “independent innovation.”
\textsuperscript{183} Interview with Lu Feng, Professor in the School of Government and Director of the Lee Koo-Guan Institute for Business and Government at Peking University, Beijing, China, 2009.
As an expert on the Chinese aircraft industry, Tai Ming Cheung, testified to the U.S.-China Economic and Security Review Commission,

Instead of relying on its own resources, the aviation and defense industry seeks to make use of commercially available technologies and manufacturing processes as a suitable substitute. CMI [civil-military integration] advocates argue that most of the technological needs of the military can be met through commercially available channels.  

Enhancing capacity in commercial aircraft manufacture served the strategy of civil-military integration. Policymakers saw civil-commercial programs as a means to supporting defense aircraft development and manufacture. Imports and foreign partnerships were among the strategies through which civil-military integration could be pursued in the air sector.

Together, these long-term strategies for capacity building and industrial reform, evolving principles, and specific programs composed Chinese air policy. Diverse sectoral entities, comprising units across government and industry, devised or implemented air policy measures.

1.2. Air policy in the United States

In contrast to China, U.S. policy for the air sector was not guided by a single overarching strategy. Rather, throughout the post-World War II period, sectoral policy remained fragmented. A range of policies and programs addressed different aspects of aviation, aeronautic research and development, and the aircraft industry. Various government organs implemented these agendas, acting in related but distinct areas and roles.

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185 Ibid.
Major sectoral policies and programs were decided by the office of the President and his appointed agency leaders. Depending on the issue and the administration, the National Science and Technology Council, the Office of Science and Technology Policy (OSTP), the National Security Council, or other entities formulated the President’s main policies related to aeronautics and aviation. Programs implemented by federal agencies were shaped in a negotiated process with the Congress. Within the legislative branch, several influential committees of the House and Senate had overlapping responsibilities for the budgets and oversight of agencies acting in the air sector. Together, these institutions created the policy landscape facing the U.S. aircraft industry.

The U.S. aircraft industry was the world’s largest and most sophisticated. It formed a tiered pyramid of over 15,000 firms, most of which produced both commercial and defense items. At the top, two large system integrators produced and delivered finished aircraft to customers. Boeing produced most commercial aircraft systems and Lockheed, later Lockheed-Martin, produced most defense aircraft systems. These companies managed global supply chains producing sub-systems and components, which they integrated with the airframes they manufactured. The second tier consisted of major integrators of sub-systems, such as engines and avionics systems. Numbering in the tens, these companies included General Electric (GE), Honeywell, Rockwell Collins, Pratt & Whitney (U.S.), Rolls Royce (U.S.), and BAE Systems (U.S.). The third tier was made up of hundreds of suppliers of major components or small systems to the sub-system integrators. At the base of the pyramid were thousands of firms supplying the upper tiers with specialised components. These different types of companies were tied into global production networks through their sub-contracting relationships. Of the various products these U.S. firms made, nearly each was exported.

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188 Ibid.
Although no single long-term national strategy shaped the sector in which these firms operated, the basic goals of U.S. air policies and programs were constant throughout those two decades. The first was maintaining U.S. leadership in commercial and defense aeronautic technology. Experts and policymakers described leadership as dominant global market share in key commercial products and as the operation of technologically unmatched defense capabilities. The second goal was ensuring that the sector made the greatest possible contribution to the economy. This objective required regulating the industry for safety and sustainability and promoting aircraft exports.

These goals were pursued through policies and programs that fostered transnational trade, industrial integration, and civil cooperation, including with China. Government responsibilities in the sector spanned four main areas: supporting cutting-edge research and technology development; ensuring safe flight operations, including through regulation of vehicle airworthiness and air traffic management; promoting U.S. exports; and regulating exports of sensitive U.S. aircraft technologies.

The main organs implementing aeronautic research and technology development programs were NASA, through its Aeronautics Research Mission Directorate, and agencies within the Department of Defense. In 2006, President George W. Bush issued the first comprehensive inter-agency aeronautics policy addressing research and development. This document was produced in response to the release of a long-term European strategy for strengthening aircraft manufacture. Like the European plan, the U.S. National Aeronautics Research and Development Policy outlined a strategy to 2020. This policy built on and

190 National Aeronautics Research and Development Policy.
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incorporated the recommendations of earlier studies of the U.S. industry and aeronautics research by specialists in government, industry, and academia. The 2006 plan directed agencies to pursue programs toward long-term, forward-looking research and technology development priorities identified by these aeronautic experts. The goals included advanced vehicles, such as supersonic civil transports, the safety and environmental sustainability of flight, and next-generation air traffic management.

The Department of Transportation’s Federal Aviation Administration (FAA) undertook flight vehicle certification and civil aviation responsibilities, including the upgrading of the national air traffic control system.

Several government agencies promoted and regulated U.S. exports of aircraft items. The export-financing arms of the government, including organs of the Department of Commerce and Eximbank, facilitated foreign sales of U.S. aircraft, both commercial and military. The International Trade Administration studied the sector and investigated alleged violations of trade agreements by foreign competitors.

Government agencies also controlled exports of aircraft items whose foreign sale or transmission affected national security or foreign policy interests. Under the export control regime, controlled aircraft items were classified as either dual-use or defense items. Dual-use items were those deemed designed for commercial purposes, but which had secondary defense applications. Defense items were items deemed designed for military or intelligence purposes. To export items of both classes, U.S. firms needed licenses specifying different conditions for the transactions. Pursuant to the Export Administration Regulations, the Department of Commerce issued licenses for exports of dual-use aircraft items. These items were scheduled on the

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Commerce Control List (CCL). Further to the Arms Export Control Act and the International Traffic in Arms Regulations (ITAR), the Department of State licenced exports of defense aircraft items, scheduled on the U.S. Munitions List (U.S.ML). Exports of defense items to China were prohibited by law after the Chinese government’s crackdown on the Tiananmen Square protests of 4 June 1989. The controlled aircraft items licensed for export to China were dual-use items on the CCL. These relatively permissive export controls on aircraft items allowed U.S. firms to export to and establish industrial partnerships in China.

2. Bilateral trade and industrial integration in air

Throughout these two decades, the Chinese and U.S. governments adopted policies and programs that permitted and fostered growing trade and the deepening integration of the two national industries. Their policies also expanded civil cooperation on flight safety, vehicle certification, and aircraft management.

Between 1989 and 2009, China and the United States became major trade partners in commercial aircraft items. As sectoral trade between the two countries’ grew, their national industries integrated their production, research, and development activities. U.S. manufacturers of aircraft items significantly expanded their presence in China. They brought Chinese firms into their global supply chains.\(^\text{192}\)

Throughout these two decades, the Chinese government adopted measures to attract and grow U.S.-invested joint ventures and to integrate Avic units into U.S. firms’ manufacturing networks. In parallel, the U.S. government regulated, but did not block, these arrangements between U.S. and Chinese firms. Permissive export rules allowed the licensed export to China of

\(^{192}\) Bowen Jr., “Global Production Networks, the Developmental State and the Articulation of Asia Pacific Economies in the Commercial Aircraft Industry.”
commercial dual-use aircraft items, while prohibiting only exports of aircraft items explicitly designed for defense uses. Commercial aircraft items remained classified as dual-use articles whose export to China was licensed by the Department of Commerce. Supported by both government’s policies and programs, bilateral commerce and industrial integration grew.

**Early aircraft trade and joint ventures in China**

Under the rule of Deng Xiaoping, China’s policymakers made the country’s entry into export-oriented manufacture a priority. Commercial aircraft manufacture became an area in which the government fostered trade with the United States and European countries. Program 863 mandated developing aeronautics and building an industrial base capable of producing modern aircraft. As China’s imports of commercial aircraft and related items grew in the 1980s, the Chinese government made offsets a condition of foreign firms’ access to the Chinese market.

Over several decades, U.S.-invested joint ventures in China increased in scale, scope, and in the sophistication of the products they made. Beginning with the manufacture of simple parts in the 1980s, these partnerships evolved to produce larger and more technically demanding components and even to research and develop new products for eventual sale in export markets.

When the first joint ventures were established in China, they built basic parts.\(^{193}\) For example, they made brake pads for aircraft landing gear. Early joint ventures also assembled pre-manufactured systems, such as engine kits for Pratt & Whitney, which opened China’s first foreign-invested aerospace facility in the 1980s.\(^ {194}\) During this phase, joint ventures also began to produce leading edges on wings, nacelle components, and tail fin elements.

\(^{193}\) Interview with executive and founder of a Chinese manufacturer of aircraft components, Interviewee 07-18-07, Shenyang, China, 2010.

\(^{194}\) Interview with former manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 19-01-00, Beijing, China, 2010.
When the Chinese government cracked down on protesters at Tiananmen Square in 1989, the U.S. Congress passed the Tiananmen Sanctions Act, a law that prohibited the export to China of any article classified as a defense item on the U.S.ML. This change had far-reaching implications for bilateral trade, but did not affect trade in aircraft items. Classified as dual-use items, airliner technologies remained subject to the licensing authority of the Department of Commerce. Bilateral trade and industrial partnerships in commercial aircraft items continued.

**China’s defense modernisation and growing demand for aircraft**

When the Jiang administration came to power after the Tiananmen Square crackdown, it continued Deng’s integration of China into the global economy and accelerated many of the technology development efforts initiated under Program 863. Arguably the most technocratic of China’s post-revolutionary leaders, Jiang initiated in practice the last of Deng’s four modernisations: the technological modernisation of the PLA. With Jiang at the helm, the military began to transform from a bloated Maoist People’s Army into a disciplined and capable force equipped with advanced hardware.

Costind designed and began implementing sweeping upgrades of the services’ defense systems. At the start of the decade, China’s aircraft industry was the weakest of all the major defense industries and unable to meet the PLA Air Force’s equipment needs. Facing this constraint, the defense establishment imported hundreds of advanced aircraft and anti-aircraft systems, mainly from teetering post-Soviet defense industrial behemoths. In parallel, the Costind began reforms of the major defense industrial groups, including what would become Avic, aimed at making them into producers of modern and technologically sophisticated defense systems.

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195 Cheung, *Fortifying China*. 
The 1990s also saw China’s demand for commercial aircraft grow rapidly. This made it a bright spot on a map of largely depressed global aerospace markets. The end of the Cold War had brought a contraction of defense budgets across the advanced industrial economies. Newly consolidated U.S. and European aircraft manufacturers competed fiercely in emerging markets. Already an important market because of its size, China in the 1990s became a strategic battleground for major manufacturers of aircraft products.

As Chinese airlines’ demand for imported aircraft grew and competition between foreign manufacturers intensified, the Chinese government’s leverage relative to these foreign firms grew. Determined to build up a domestic aircraft industrial base and to promote manufacturing exports, China’s economic planners and decisionmakers negotiated more substantial offsets with foreign aircraft equipment makers seeking access to the Chinese market. U.S. and European companies localised more of their production through joint ventures in China.

The Chinese government’s policy of tying market access to offsets was explicit and familiar to observers both within and outside the industry. Boeing's top official for international development, Lawrence Clarkson, plainly stated in 1996: “'If we hadn't moved work to China, […] we wouldn't have got orders.” Lewis M. Simons quoted him in Time magazine, explaining that China refuses to buy planes “unless the American manufacturers agree to establish more factories there, transferring precious technology and skills.”

In the United States, the Clinton administration came to power promising a renewed focus on the economy and trade. The Cold War over, expectations of a peace dividend ran high. Government defense spending dropped. The Department of Defense’s large technology and acquisition programs slowed. Adjusting to this new environment, the defense industry underwent

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197 Ibid.
a period of consolidations and reorganisations. The country’s major manufacturers of aircraft items, from system integrators to component makers, were forced to reinvent themselves to survive. No longer primarily contractors to a government customer with deep pockets, many of these companies reoriented their business toward commercial aircraft manufacture.

Under the Clinton administration, export promotion became a central pillar of U.S. foreign policy. The Department of Commerce’s mission remained to promote U.S. trade interests, and this priority guided the Department’s execution of its export control responsibilities, including its processing of export licenses for aircraft items. Commerce continued to license exports of aircraft items, aircraft-manufacturing equipment, and technical information sharing that allowed trade and industrial integration with China to proceed.

Congressional investigation of export control violations

In 1999, a special committee of the House of Representatives conducted a far-reaching investigation of illicit transfers of sensitive U.S. technologies to China. This committee became known after its chair, Representative Christopher Cox, as the Cox committee. In its final report, the committee found that U.S. firm McDonnell-Douglas had illegally exported precision-machining equipment with defense-industrial applications to its joint venture partner in China. The exported equipment was found at a Chinese facility manufacturing missiles, a transfer that violated the end-user conditions on the item’s export license. The committee found that, in spite of evidence of these breaches, federal regulatory and enforcement agencies had neglected to thoroughly investigate the case and enforce penalties against the U.S. company for several years.

Although the Cox investigation was highly influential, especially because of its analysis of space and nuclear technology transfers, U.S. policymakers took no action in response to the committee’s findings about aeronautic technology transfers. Decisionmakers in the executive branch reacted slowly to the committee’s allegations that the violator had not been adequately investigated or sanctioned. The Congress undertook no legislative action to reduce the likelihood of future aeronautic technology transfers. Despite learning of significant illegal transfers of aeronautic technology, U.S. policymakers and decisionmakers took no significant measures to restrict integration between Chinese and U.S. firms in the sector.

When the second Bush administration came to power in 2000, it continued its predecessors policies on promoting exports of aircraft items to China. Bilateral trade on the whole grew as China acceded to the World Trade Organisation in 2001. The Bush administration led several trade delegations with aircraft industry representatives to China, cementing agreements for Chinese airlines’ major purchases of Boeing aircraft and paving the way for more U.S.-invested joint ventures to supply the Chinese market.

**China’s airliner programs and deepening industrial integration**

Throughout the 2000s, bilateral industrial partnerships gradually expanded to more demanding technical areas, such as the co-production of composite-material elements. For example, one of the largest joint ventures, the Boeing Tianjin Composite Company, manufactured composite structures for several airliners.\(^2\) Foreign-invested joint ventures continued to grow in size and in the scale of their work. Chinese industry experts responsible for

\(^2\) Backgrounder: Boeing in China (Beijing, China: The Boeing Company, updated 2012 2009), 2.
international cooperation at Shenyang Aircraft Corporation described joint ventures expanding “from components to sub-systems (从零部件到大部件).”\textsuperscript{201}

In 2006, the Chinese government accelerated the country’s domestic aircraft development effort. With the ARJ21 and C919 programs, China’s aircraft industrial groups became aspiring producers of finished aircraft for sale at home and abroad. This new role transformed their relationship with U.S. firms. Once merely suppliers to U.S. aircraft manufacturers, Chinese firms became major clients of these U.S. companies. As U.S. firms competed for contracts to supply these programs, they located even more of their production in China.\textsuperscript{202}

The presence of U.S. firms in China grew throughout this period. U.S. firms met the Chinese government’s offset requirements by localising the production of aircraft components in joint ventures with manufacturers in China. For this reason, “Boeing’s equity investment in China’s aviation industry [was] considerable, with Boeing being the leading commercial purchaser” of components made in China and related services.\textsuperscript{203} These arrangements incorporated Chinese facilities into U.S. firms’ global supplier networks. As a Boeing statement illustrated,

Some 6,000 Boeing airplanes fly throughout the world with parts and assemblies built by China. China has a role on every one of Boeing’s commercial airplane models — 737, 747, 767, 777, and the newest and most innovative airplane, the 787 Dreamliner.\textsuperscript{204}

Facing the same offset requirements, European and other foreign companies also established joint ventures in China. Europe’s Airbus, Canada’s Bombardier, Brazil’s Embraer,

\textsuperscript{201} Interview with executive and founder of a Chinese manufacturer of aircraft components, Interviewee 07-17-07, Shenyang, China, 2010.
\textsuperscript{202} Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies.” Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009; Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
\textsuperscript{203} Backgrounder: Boeing in China, 1.
\textsuperscript{204} Ibid.
Japan’s Mitsubishi, and French and German sub-system producers all broke ground on facilities in China during this period. In 2007, Airbus opened a joint venture with Avic and the government of Tianjin to assemble the A320 regional jet. The Tianjin Final Assembly Line performed the integration of pre-manufactured sub-systems and airframes that arrived from abroad.\textsuperscript{205} Such initiatives placed pressure on U.S. firms seeking access to the Chinese market to also expand their local activities.\textsuperscript{206}

Chinese and U.S. firms not only co-produced components and sub-systems, but also engaged in research and development as partners. GE Aviation and Boeing led this trend. In 2009, GE Aviation established a joint venture with Avic Avionics to develop and produce new avionics systems. The new company planned to base these new products on an open-architecture model, a type of avionics platform developed for Boeing’s 787 program and implemented in other forms in U.S. defense aircraft.\textsuperscript{207} The two companies agreed that the intellectual property rights to these innovations would belong to the joint venture itself.\textsuperscript{208} The company aimed to supply the Chinese market and export. As an individual familiar with the project explained, “the joint venture is not just for China, but for the world.”\textsuperscript{209} Under the arrangement being negotiated in 2009, GE would relocate all of its commercial avionics activity from the United States to China.\textsuperscript{210}

\textsuperscript{205} Interview with China-based senior manager at a European aircraft manufacturer with joint ventures and facilities in China, Interviewee 19-22-00, Tianjin, China, 2009.
\textsuperscript{206} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
\textsuperscript{207} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
\textsuperscript{208} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
\textsuperscript{209} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
\textsuperscript{210} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
During this time, Boeing also began joint research and development projects with Chinese partners. The company established “Boeing Research & Technology – China, a part of Boeing’s advanced central research and development organization.” Under the program, Boeing and its partners in the CAS and Chinese universities established “three joint research laboratories and a joint research center” to conduct “collaborative research” in the areas of “the environment, advanced materials, and advanced computing technologies for aviation and industry design.” Boeing also collaborated with Air China and the China National Aviation Fuel Company to research and develop next-generation aviation fuels. The parties agreed that the joint venture established under this initiative would own the intellectual property rights to the technology it developed. Building on these efforts, in 2012 Boeing agreed to collaborate with Comac on a joint center to support “research to improve aviation industry fuel efficiency,” the Boeing-Comac Aviation Energy Conservation and Emissions Reductions Technology Center.

Throughout the 2000s, trade in aircraft items between the two countries was substantial. Boeing, the single largest U.S. exporter, measurably reduced the U.S. trade imbalance with China every time it collected for delivery on a Chinese airline’s order of aircraft. By 2012, Chinese airlines had ordered over 900 Boeing airplanes. In addition to purchases of finished aircraft, Chinese airlines bought major sub-systems and other aircraft products and services from U.S. firms. In 2009 alone, Chinese imports of aircraft items from the United States totalled USD

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211 Backgrounder: Boeing in China, 2.
212 Ibid., 2–3.
214 Backgrounder: Boeing in China, 2.
215 Commercial Aircraft Corp. of China and Boeing Sign Collaboration Agreement to Partner in Areas Advancing Commercial Aviation Industry Growth (Beijing, China: The Boeing Company (Boeing China Communications), March 6, 2012).
216 Backgrounder: Boeing in China, 1.
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4,593,207,000 and represented 48 per cent of China’s total imports in this sector.\(^{217}\) By 2011, there were no fewer than 28 joint ventures between U.S. and Chinese aircraft manufacturers in China either in operation or in the process of being established.\(^{218}\) These included virtually all the major U.S. firms, among them Boeing, GE, Pratt & Whitney, Honeywell, Rockwell Collins, Goodrich, and Parker Hannifin.\(^{219}\) Their facilities clustered around China’s major aircraft-manufacturing hubs.

**China’s advances in defense aircraft manufacture**

In defense aircraft manufacture, Avic made concurrent strides. By the end of the decade, Avic companies had demonstrated several major advances in the defense systems they developed and produced. As several defense aircraft and anti-air programs reached maturity, the industry revealed this progress in a series of test flights and other operational firsts. These are discussed in greater detail in the next chapter. Despite observing Avic firms’ concurrent innovation in commercial and defense products, U.S. policymakers did not evaluate the connection between the foreign-assisted commercial programs and defense technology advances. For the U.S. government during this period, exports and transfers of U.S. aircraft technology to China never acquired the urgency of space technology transfers.

**3. Bilateral technical cooperation in civil aviation**

As the Chinese and U.S. aircraft-manufacturing industries grew intertwined, the two countries’ civil aviation agencies also began to cooperate in specific areas. CAAC became a


\(^{218}\) Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies.”

\(^{219}\) Ibid.
bilateral “aviation partner” to the FAA during this time. In the 1990s, their cooperation focused on aircraft and flight safety. It later expanded to include air traffic management systems. In addition to the CAAC and FAA, other government agencies, manufacturers, and airlines from both countries participated in civil cooperation projects.

The rapid expansion of air traffic in China after 1980 strained flight safety and other civil aviation institutions. Chinese airlines suffered a series of accidents, leaving them with a dismal safety record by 1995. In response to these problems, the U.S. and Chinese civil agencies cooperated on training Chinese technical personnel. Under these programs, pilots, aircraft technicians and maintenance personnel, regulators, and airline managers participated in courses on aircraft and flight safety held in China and the United States. Boeing, Honeywell, GE Aviation, Osh Kosh, Textron, and other major U.S. aircraft firms active in China supported this effort through the bilateral Aviation Cooperation Program.

The CAAC and FAA expanded their cooperation to include the certification of aircraft for flightworthiness. In the mid-1990s, the agencies established their first “shadow” certification program for an aircraft designed and produced in China, the Y-12-4 twin turboprop. This project aimed to harmonise certification processes under Part 23 of the U.S. Federal Aviation Regulations. Under the program, the FAA did not “oversee the aircraft's development, test and

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manufacturing process as it would in the U.S.”\textsuperscript{224} Instead, it shadowed “those same efforts by the host country by an evaluation of its reporting system.”\textsuperscript{225}

Beginning in 2003, the FAA and CAAC entered into several successful rounds of negotiations about the AJR21-700 application for FAA-type certification and shadowing. This aircraft became the first Chinese-made and -designed jet expected to achieve this status.\textsuperscript{226} The FAA also established a CAAC Technology Support Office in Beijing and Shanghai to assist with this process.\textsuperscript{227} The shadow program was significant because earning FAA certification was “a precondition for the ARJ21-700 to enter the world market, an important goal in the aircraft airworthiness examination.”\textsuperscript{228}

As the soaring volume of air travel stressed China’s air traffic management capacity, bilateral cooperation continued and broadened to include this area. The FAA led an effort to train Chinese personnel in the basic technology and operation of the advanced U.S. Next Generation Airspace Management System (NextGen), an initiative focused on fostering interoperability between the U.S. and Chinese systems. The FAA committed to “expanding its cooperative efforts with China to collaborate on future NextGen air traffic initiatives” in a statement of its plans for the 2009-2013 period.\textsuperscript{229}

In February 2008, the FAA Air Traffic Organization and the Air Traffic Management Bureau of the [CAAC] signed an agreement to cooperate on harmonizing our respective air traffic system modernization programs. The agreement created the NextGen Air Traffic Management Steering Group and serves as a formal building block for the foundation that allows the two countries to work together to harmonize their broader NextGen strategies.\textsuperscript{230}

\textsuperscript{224} Ibid.
\textsuperscript{225} Ibid.
\textsuperscript{226} “FAA to Accept Type Certification on ARJ21-700,” \textit{China Civil Aviation Report}, 2012.
\textsuperscript{227} Ibid.
\textsuperscript{228} Ibid.
\textsuperscript{229} \textit{2009-2013 FAA Flight Plan}, 27.
\textsuperscript{230} Ibid.
Moreover, in its “Performance Targets” for the subsequent period, the FAA announced it would cooperate with China’s aviation authorities and industry toward their adoption of 27 safety enhancements by 2011.\(^{231}\) This cooperation would support “China’s efforts to reduce commercial fatal accidents,” indicated the report.\(^{232}\)

The Chinese and U.S. governments also supported bilateral industry efforts at research and development in civil aviation areas they prioritised.\(^{233}\) For example, China’s National Energy Administration, the U.S. Department of Energy, and the U.S. Trade and Development Agency supported an aircraft industry-led effort to develop “a new biofuels industry in China.”\(^{234}\) Within the framework of the U.S.-China Energy Cooperation Program established in 2009,\(^{235}\) Boeing collaborated with Air China and the China National Aviation Fuel company (part of PetroChina) to research and develop advanced fuels promising to reduce the environmental impact of aviation.\(^{236}\) U.S. aircraft companies Honeywell and UTC joined this effort.\(^{237}\) Boeing and its Chinese partners announced they were “now jointly addressing the challenges of sustainability and working to establish a pathway for China to create a sustainable aviation biofuel industry” on the occasion of the program’s first bio-fuelled flight from Beijing Capital International Airport in 2011.\(^{238}\)

Major U.S. companies also played a role in bilateral cooperation on civil aviation through various technical assistance programs, often set up as a means to cultivate relationships with Chinese officials. Efforts supporting civil aviation cooperation between the two countries

\(^{231}\) Ibid., 28.
\(^{232}\) Ibid.
\(^{233}\) Backgrounder: Boeing in China, 2.
\(^{236}\) Air China, Boeing and Industry Partners Conduct First Chinese Sustainable Biofuel Flight.
\(^{237}\) “PetroChina to Team with Boeing to Develop Aviation Biofuels.”
\(^{238}\) Air China, Boeing and Industry Partners Conduct First Chinese Sustainable Biofuel Flight.
included Boeing’s technical training and assistance programs. According to the company’s materials,

Boeing has long worked with China in areas such as safety, aviation quality practices, business and executive training, and technical support. Since 1993, in cooperation with Chinese airlines, CAAC and industry, Boeing has provided enhanced professional training to almost 40,000 Chinese aviation professionals in pilot techniques, flight operations, maintenance engineering, regulatory, air traffic management, executive management, airline management and marketing, manufacturing, quality assurance, finance and industrial engineering. Boeing considers this training an investment in the future of Chinese commercial aviation and provides it at no charge to China.  

As these initiatives suggested, U.S. firms’ support to civil cooperation grew with their investments in China.

Throughout these two decades, civil cooperation grew in tandem with bilateral industrial integration in the sector. U.S. and Chinese policy did not block technical cooperation in civil aviation, but fostered it. Policymakers in both countries agreed that they shared an interest in achieving common safety standards, procedures, and rules. They also agreed that their air traffic management systems should be interoperable. U.S. policymakers believed that training programs imparting technical know-how and expertise to organisations in China were a safe, effective, and mutually beneficial means to these ends.

Conclusion

During the two decades after 1989, China and the United States engaged in expanding bilateral trade, industrial integration, and technical cooperation in the air sector. The two countries’ aircraft-manufacturing industries traded in aircraft products and related services. Firms from both countries integrated their research, development, and production activities. In civil air,

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239 *Backgrounder: Boeing in China*, 2.
Chinese and U.S. agencies engaged in and expanded technical cooperation. Over the course of the two decades, bilateral trade, industrial integration, and civil cooperation continuously expanded in scale and to new areas. Both governments maintained and even strengthened national policies that created this bilateral order throughout this period. Even when evidence of illegal dual-use technology transfers and advances in China’s defense aircraft industry surfaced, the U.S. government’s commitment to these policies did not falter. In parallel, Chinese leaders adopted policies and programs, including two domestic airliner programs, that attracted foreign partners and further deepened industrial integration between the two countries.
The prospects for bilateral relations in air

Introduction

The trade, industrial integration, and technical cooperation that took place between China and the United States in the air sector was hardly a given at the start of this period. That China and the United States should become civil and commercial partners in the air sector could not have been read off their initial conditions in 1989 by an outside observer. The civil-commercial air sector presented a mix of factors shaping the prospects for relations between the two countries. Some of these factors were conducive to trade, industrial integration, and international cooperation, but other factors made interstate competition and mutual suspicion of their defense programs more likely. No preponderance of factors pushed the relationship toward either integration or competition. As relations grew more tense between the two countries throughout the 2000s, the continued integration of their aircraft industries grew less likely. In spite of these changes, industrial integration not only continued, but accelerated.

The first part of this chapter examines the factors that made trade, industrial integration, and cooperation between the two countries likely during this period. The second part examines the factors that made these outcomes unlikely.

1. Factors making trade and cooperation probable

Several factors made the air sector a promising site of trade, industrial integration, and civil cooperation between China and the United States. These factors included: Chinese demand for aircraft products and related services; U.S. supply of aircraft products and related services; the economics of commercial aircraft programs; and the European aircraft industry’s role in China.
1.1. China’s demand for aircraft products

A major factor making China and the United States likely trade partners in the sector was China’s substantial demand for imports of aircraft systems, sub-systems, and related services. In order to satisfy this internal demand, China would need to import aircraft. Meanwhile, by the turn of the millennium, international firms recognised that the developed aviation markets of North America and Europe were entering a cyclical dip. Opportunities for the future lay in large emerging markets, where air travel was still growing. U.S. firms focused on Asia, where China was the most important market.

Both the relative and absolute predicted size of China’s market for aircraft items and its expected growth rate drew foreign manufacturers. In the 1990s, industry observers believed that the importance of this market would be virtually unmatched in the following years. “China is potentially the biggest single aviation market in the world,” wrote aircraft finance analyst Butler Richards in 1999. By value, the country was to become the world’s second largest buyer of aircraft after the United States by 2020. Boeing in 2009 forecasted that “over 20 years China will need 5,000 new airplanes, worth more than $600 billion.” This projected demand would make “China Boeing’s largest commercial airplane customer.” Airbus analysts calculated that Chinese airlines would take possession of 1,530 passenger aircraft between 2003 and 2022. In particular, China would dominate global demand for very large aircraft. “Big enough for everyone” is how a manager with a U.S. firm based in China later described the market.

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241 Ibid.
242 Ibid.
245 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
Industry experts also expected China to become the world’s fastest growing market for aircraft items. In 1997, Airbus Industrie experts expected China’s annual growth in air travel to reach 10 per cent by 2016, exceeding the global average by a substantial margin.\textsuperscript{246} In 2006, Boeing analysts predicted that revenue passenger kilometres would grow nearly 9 per cent every year for the next two decades, faster than anywhere else.\textsuperscript{247} Industry experts anticipated that China would lead the world by far in growth of aircraft numbers in service, with annual average fleet growth exceeding 7 per cent.\textsuperscript{248} Whether measured by growth in revenue passenger kilometres, freight tonne kilometres, number and size of aircraft flown, number of airports, or other sectoral indicators, China was expected to become “one of the great dynamos for future growth” worldwide.\textsuperscript{249}

Industry analysts agreed on the general contours of these forecasts in spite of several factors that could have tempered optimism about Chinese market prospects. First, a measure of uncertainty inhered in the predictions of global demand for aircraft. Industry experts understood that demand for air travel was volatile and that other factors, such as the growth of markets for used aircraft and life-extension programs, complicated their forecasting.\textsuperscript{250} Second, China’s indigenous aircraft programs promised to meet some portion of domestic demand, leaving the size of the market for imports all the more uncertain. In particular, the C919 program competed directly with Boeing’s best-ever-selling plane, the 737. Foreign industry experts were confident that the ARJ21 and C919 programs would at minimum approach their stated goals of supplying, respectively, 10 and 30 per cent of the domestic market in their segment. Finally, China

\textsuperscript{246}Global Market Forecast 1997-2016: Confirming Very Large Demand, 9.
\textsuperscript{247}Boeing Current Market Outlook 2006 (Seattle, WA: Boeing Commercial Airplanes, 2005), 8.
\textsuperscript{248}Global Market Forecast 1997-2016: Confirming Very Large Demand, 12; Global Market Forecast 2000-2019, 23.
\textsuperscript{249}Global Market Forecast 2003-2022, 16.
presented foreign firms with significant political risks, even relative to other large emerging markets. U.S. firms investing in joint ventures could not ignore these after the 1989 Tiananmen crackdown and ensuing sanctions. In spite of these factors, China’s market was irresistible to U.S. manufacturers.

1.2. U.S. supply of aircraft products

A second factor making bilateral trade in the sector likely was the competitiveness of U.S. manufacturers of the products that Chinese buyers sought. As China’s domestic aircraft industry was not yet able to produce either finished airliners or major sub-systems, it needed to import these products from the United States, Europe, Canada, Brazil, and Japan. In many respects, however, Chinese airlines and Comac had few alternatives to U.S. supply.

U.S. firms were global leaders in finished passenger jets and in major aircraft sub-systems. In all but small regional jets, Boeing competed only with Airbus to supply the world market. This global duopoly all but guaranteed Boeing at least some sales in China, since Chinese airlines sought to avoid depending on Airbus alone. Chinese industry experts explained that policymakers sought to keep a roughly even split of domestic market share between the two giants.251

In the production of major sub-systems, few alternatives to U.S. companies were available to Chinese buyers. Some U.S. companies were nearly unchallenged leaders. Commercial engine makers GE and Pratt & Whitney competed mainly with Europe’s Snecma and Rolls Royce and, for the largest programs targeting the Chinese market, these companies formed transatlantic alliances. U.S. avionics suppliers Honeywell and Rockwell Collins faced no

251 Interview with manager at one of China’s three major airlines, Interviewee 00-00-00, Xi’an, China, 2010; Interview with Lu Feng, Professor in the School of Government and Director of the Lee Ko-Guan Institute for Business and Government at Peking University, Beijing, China, 2009.
serious foreign competition in some product areas. U.S. firms’ strengths in these technologies made them suppliers of choice to the ARJ21 and C919 programs and attractive partners for joint ventures.

1.3. The economics of aircraft development and production

A third factor that made China-U.S. trade, industrial integration, and civil cooperation probable outcomes in the air sector consisted in the economic features of aircraft development and production. The economics of aircraft programs created pressures and incentives for transnational integration between firms. For example, a large body of research examined how these factors had compelled the integration of several European manufacturers into Airbus and its even larger parent company, the conglomerate European Aerospace and Defense Systems (EADS). While similar factors undoubtedly shaped China-U.S. industrial integration, conditions in the bilateral context different from those in other transnational settings, mitigating the impact of some of these factors.

The two main economic factors that fostered transnational integration in the sector were economies of scale and high risks. Aircraft manufacturers faced paradigmatic economies of scale in development and production. For any given program, average unit costs feel sharply as production volume grew. According to management economists Christian Koenig and Raymond-Alain Thietart, “the break-even point for an aircraft program [was], broadly speaking,

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between 300 and 600 units.” Other observers placed this figure at 600 for most models.\footnote{254} Moreover, as production experience increased further beyond this break-even point, additional learning effects kicked in and drove costs further down.\footnote{256} No single country had a market large enough for a national firm to capture these economies.\footnote{257} Aircraft manufacturers in Europe and the United States consolidated or pooled to achieve the largest possible market penetration during the 1990s.\footnote{258} Economies of scale induced global trade and transnational industrial integration.

These effects were particularly pronounced in aircraft manufacture. In general, aircraft systems and sub-systems were produced at low volumes.\footnote{259} For example, with the exception of the Boeing 737, total production volume on major aircraft programs did not exceed several hundred units. The lower the volume of production, the greater the impact of marginal increases in volume on average unit costs. Companies were heavily incentivised to aggressively pursue every global market opportunity, large or small. While volumes remained low during those two decades, new programs became even more costly to launch. Technology development costs spiralled.\footnote{260} Pre-production research, development, and testing periods lengthened.\footnote{261} The launch of new platforms was expensive, slow, and risky for producers to undertake. The same was true of sub-systems, such as engines.

\footnote{254}{These numbers depended upon whether the aircraft was “new or an offspring of another program and on the ability to gain experience early.” Koenig and Thietart, “Managers, Engineers and Government: The Emergence of the Mutual Organization in the European Aerospace Industry,” 53.}
\footnote{255}{Sandholtz and Love, “Dogfight over Asia,” 138.}
\footnote{256}{Ibid., 139.}
\footnote{257}{Koenig and Thietart, “Managers, Engineers and Government: The Emergence of the Mutual Organization in the European Aerospace Industry,” 53.}
\footnote{258}{Ibid., 53–54.}
\footnote{260}{Sandholtz and Love, “Dogfight over Asia,” 138.}
\footnote{261}{Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.}
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A second major factor inducing transnational integration among aircraft manufacturers was the high levels of risk they faced. The technical, commercial, and economic risks in the manufacture of aircraft products were greater than in many other high-technology sectors. Demand for aircraft from airlines was difficult to reliably anticipate. Long development times on new systems increased commercial risks by making market predictions “very hazardous.” High development costs ratcheted up financing needs and, with them, economic risks on major programs to levels that no single firm could typically bear alone. By the 1990s, “[a]ll manufacturers ha[d] developed risk-sharing schemes with partners,” wrote Koenig and Thietart. Prime contractor-subcontractor arrangements and other collaborations allowed firms to spread risks and costs. The firms best suited to partner in these ways were often based in different countries.

Economies of scale and high risks fostered the transnational integration of commercial aircraft programs. This integration took vertical and horizontal forms. Companies engaged in a loose form of vertical integration by creating stable, firm-like chains of suppliers from different countries. Integrating closely with their sub-contractors, major firms built global manufacturing networks. Rolls Royce, for example, relied on a transcontinental web of suppliers to build its

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264 Ibid.; Costa, Harned, and Lundquist, “Rethinking the Aviation Industry.”
266 Ibid.
267 Ibid., 54.
268 For example, all the successful strategic alliances in the following study are international: Pierre Dussauge and Bernard Garrette, “Determinants of Success in International Strategic Alliances: Evidence from the Global Aerospace Industry,” Journal of International Business Studies 26, no. 3 (Third Quarter 1995): 505.
By 2008, Boeing in practice built only airframes in house, but specialised in managing a complex worldwide operation of sub-contractors. System integrator and sub-system suppliers worked closely together throughout the entire lifecycle of each program.

Manufacturers also engaged in horizontal integration. Firms formed strategic alliances for specific programs, such as aircraft platforms and major sub-systems. These collaborations often joined rival makers of the same product. For example, erstwhile competitors GE Aviation and Snecma partnered on the Leap X1C engine to create a joint venture in China that won the C919 contract. Bombardier allied with Comac to collaborate on technical initiatives and to explore supplier synergies and jointly marketing their competing C-series and C919 planes.

In principle, these circumstances made industrial integration between China and the United States through joint ventures appear all but inevitable. China’s large market, offset requirements, and the sector’s economies of scale combined to create strong incentives for integration between the two countries’ firms. Moreover, the sheer size of the Chinese market

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270 By 2008, Boeing in practice built only airframes in house, but specialised in managing a complex worldwide operation of sub-contractors. System integrator and sub-system suppliers worked closely together throughout the entire lifecycle of each program.


meant that if U.S. firms were excluded from it, their total production volume would be lower and their average unit costs would remain much higher than otherwise.

Moreover, for some U.S. companies, joint ventures with Chinese firms presented attractive cost- and risk-sharing opportunities. For example, partners to joint ventures developing sub-systems on the C919 program expected the Chinese government to compel Chinese airlines to buy a minimum number of the aircraft. If these sales were in fact nearly assured as some observers believed, then they reduced the uncertainty these sub-system makers faced in predicting the market for their new products.

While these factors were conducive to bilateral integration through joint ventures, their impact was mitigated by other circumstances. At least four factors indicated that U.S. firms would not reap all the usual benefits of transnational integration in their partnerships with Chinese companies.

First, most of the cost- and risk-sharing opportunities that economists identified as arising from transnational integration applied to the entire development and production process of a system or sub-system. This process spanned the launch of the program through to the delivery of products to clients. In cases where joint ventures developed new products, Chinese firms could indeed approach genuine cost- and risk-bearing partners. In many cases, however, the work on which Chinese firms participated was not developmental. Instead, Chinese firms manufactured mostly mature technologies until at least the mid-2000s. In these situations, the Chinese partners did not shoulder any of the most significant early costs and risks of the program. Cost- and risk-sharing were not major factors compelling integration through joint ventures during most of this period.

274 Dussauge and Garrette, “Determinants of Success in International Strategic Alliances.”
Second, moving production to facilities in China imposed its own additional costs and risks on U.S. firms. Absent the offset requirement, the optimal solution for U.S. firms in many instances was to produce in their pre-existing facilities and deliver finished products to Chinese clients. When foreign companies assessed the costs of localising production in China comprehensively and considered the risks associated with this process, they often found it more advantageous to keep production at facilities outside China.\footnote{This issue is examined in Joseph C. Anselmo, Michael Mecham, and Bradley Perrett, “Made in China: Airbus’s Tianjin Assembly Plant Replicates European Quality, but at a Higher Cost,” *Aviation Week & Space Technology*, April 25, 2011.} The costs of localisation included building and equipping new facilities, expatriating personnel, training and retaining local personnel, and absorbing the high turnover of local personnel.\footnote{Interview with China-based senior manager at a European aircraft manufacturer with joint ventures and facilities in China, Interviewee 19-22-00, Tianjin, China, 2009.} Transportation costs were also high, since many large sub-systems had to be delivered to Chinese facilities from abroad in pre-assembled form.\footnote{Anselmo, Mecham, and Perrett, “Made in China: Airbus’s Tianjin Assembly Plant Replicates European Quality, but at a Higher Cost.”}

The costs of locating the production of a foreign-designed and -developed aircraft items in a Chinese joint venture were not necessarily offset by China’s lower labour costs, the factor most often cited as an inducement to locate manufacturing in China. Only a relatively small proportion of aircraft manufacture as a whole was labour intensive.\footnote{Interview with China-based senior manager at a European aircraft manufacturer with joint ventures and facilities in China, Interviewee 19-22-00, Tianjin, China, 2009.} Moreover, wages for skilled manufacturers in China were rising during this period. Retaining trained local personnel was costly and difficult for foreign firms and foreign-invested joint ventures.\footnote{Interview with China-based senior manager at a European aircraft manufacturer with joint ventures and facilities in China, Interviewee 19-22-00, Tianjin, China, 2009.} In short, the economics of production often dis-incentivised U.S. firms from establishing joint ventures in China.
Fourth, the economic conditions that drove transnational integration between U.S. and European aircraft firms did not always exist between U.S. and Chinese firms. Western companies that integrated their activities often brought complementary specialisations and core competencies to their partnerships. Chinese aircraft firms, however, lagged behind U.S. firms in technology and productivity. Moreover, this gap made partnerships with them more risky for U.S. firms, which often feared they were training a future competitor. In these respects, U.S. firms’ collaborations in China promised them fewer benefits and greater risks than their collaborations with European firms.

These four factors mitigated incentives for China-U.S. industrial integration stemming from the economics of development and production in the sector. Without offset requirements, the business rationale for U.S. firms to locate production in China was weak. The economics of aircraft development and production – economies of scale, low production volumes, and the size of the Chinese market – help explain why U.S. firms aggressively competed for a share of the Chinese market. In other words, these factors explain bilateral trade. However, the economics of aircraft programs alone do not explain why U.S. firms located their activities in joint ventures with Chinese firms on such a scale. In other words, program economics do not explain the extent of bilateral industrial integration during this period. Nor do they explain why integration broadened and deepened throughout the two decades as it did.

Instead of program economics, it was policies adopted in Beijing and Washington that compelled accelerating bilateral industrial integration through joint ventures in the air sector. In China, these policies consisted in the government’s offset requirements, the larger strategy of

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280 These relationships are discussed in Koenig and Thietart, “Managers, Engineers and Government: The Emergence of the Mutual Organization in the European Aerospace Industry”; Esposito, “Strategic Alliances and Internationalisation in the Aircraft Manufacturing Industry”; Berrittella et al., “Modelling Strategic Alliances in the Wide-body Long-range Aircraft Market”; Frear and Metcalf, “Strategic Alliances and Technology Networks.”

281 Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies.”
integrating national firms with the global aircraft industry, and the inclusion of foreign sub-
system suppliers in the national airliner programs. In the United States, these policy choices
consisted in maintaining a permissive export control regime.

1.4. The role of European firms active in China

A fourth factor shaping the prospects of China-U.S. relations was the role of European
firms active in China. The Chinese market for aircraft items was so large that neither U.S. nor
European firms could afford to ignore it. U.S. and European firms competed for shares of
China’s market in in systems, sub-systems, and components. An important dimension of their
competition was the negotiation of offsets with government officials and Chinese industry actors.
While these dynamics shaped China-U.S. trade and industrial integration, the tight integration of
the U.S. and European aircraft industries mitigated these effects. U.S. and European firms were
partners as often as they were competitors in the Chinese market.

U.S. and European aircraft manufacturers vied for global market share. China was an
important battleground for this competition. Economies of scale in the production of systems
and sub-systems compelled foreign firms to compete for this market despite the high costs of
access. Some observers argued that, if U.S. firms withdrew from China, they would cede the
market to their European competitors, losing not only sales revenue but also production volume
and with it unit-cost reductions. U.S. industry representatives argued that their firms’
performance in the China market shaped their prospects on world markets.

The Europe-U.S. rivalry with the highest dollar-value stakes was between Boeing and
Airbus. Representatives from each of these companies said that they could not afford to lose the

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282 Dolven, “Dogfight over China”; Sandholtz and Love, “Dogfight over Asia”; Newhouse, “Chapter Eight: A
Challenge from Asia.”
China market to their rival. In addition, makers of smaller sub-systems and components based in Europe competed with U.S. firms for sales in China. European manufacturers operating or establishing joint ventures in China included Safran, Snecma, Turbomeca, Eurocopter, Liebherr Aerospace Lindenberg, Liebherr Aerospace Toulouse, Fisher Advanced Composite Components, Labinal, and Messier-Dowty.283

European-invested joint ventures were among China’s most visible. The most high-profile of these was Airbus’s Tianjin Final Assembly Company that put together A320s for sale in China. Airbus also established a joint venture with Avic in Beijing that would focus on the development of composite aero-structures for the A350 program. Addressing Chinese officials, Airbus representatives could point to these examples of large-scale and technically demanding work that their company brought to China as evidence of its commitment to developing the local aircraft industry. Chinese officials celebrated these ventures as models of international commercial cooperation.284

Studies and media reports often presented the transatlantic competition for dominance in the China market as acute, but these analyses often focused on the Airbus-Boeing duopoly and ignored dynamics at the level of sub-system and component suppliers.285 At these lower tiers, the U.S. and European aircraft industries were tightly integrated. On many large projects in China, they were not rivals, but partners. For example, GE and France’s Snecma established a 50/50 joint venture that supplied the engine to the C919 through facilities and partnerships in China.

283 Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies.”
284 Interview with China-based senior manager at a European aircraft manufacturer with joint ventures and facilities in China, Interviewee 19-22-00, Tianjin, China, 2009.
When Airbus received a major order for planes from a Chinese airline, U.S. sub-system suppliers partnering on the program benefitted in proportion to their role. In practice, U.S. policymakers recognised that many of the largest U.S. firms in the sector rose and fell with their European counterparts, a circumstance that complicated the picture of a “dogfight over China” between these two industries.\textsuperscript{286} Thus, while competition from European firms in China may have compelled some U.S. firms to establish and expand joint ventures in China, European competition was not as decisive or unidirectional a shaper of China-U.S. trade and industrial partnerships as some observers suggest.

These four factors combined to make the air sector a probable site of trade and cooperation between China and the United States. The two countries featured complementarities of supply and demand in the sector. The economics of technology development and production created some incentives for the two national industries to integrate their operations. Competition from European firms selling products to China created pressures for U.S. firms to more aggressively pursue opportunities there by establishing joint ventures.

2. Factors making bilateral trade and cooperation improbable

While the factors cited above provided inducements for China-U.S. trade, industrial integration, and civil cooperation, there were other factors in the bilateral relationship that made these outcomes unlikely. The most important factors making this outcome improbable were: the strategic status of the sector itself; technology transfer risks inherent in bilateral integration and cooperation; the applicability of commercial technologies to defense programs; concurrent

\textsuperscript{286} Interview with government official responsible for aircraft-manufacturing industry at U.S. International Trade Administration, Interviewee 16-01-00, Washington, DC, 2011.
advances in China’s defense technology programs; and export control violations, including by U.S. and Chinese aircraft firms engaged in business together.

2.1. The strategic status of the civil-commercial air sector

A factor making bilateral trade, integration, and civil cooperation between China and the United States unlikely in the air sector was the strategic status of civil and commercial aeronautic technologies. Aeronautic technologies played a strategic role in the economies of both countries. Moreover, aeronautic technologies were embedded in the critical infrastructures of both countries, making both societies reliant upon them. These factors made the air sector an improbable site of integration and cooperation between countries in tense security relationships, which China and the United States became over those two decades.

Both governments regarded the civil-commercial air sector as a strategic linchpin of the national economy for several reasons. First, aircraft manufacture was a sector with high barriers to entry, meaning that successful entrants could enjoy economic rents. These brought national welfare benefits in the form of high-wage jobs and taxable revenue. For some governments, these benefits justified strategic intervention in international markets to support domestic firms. Second, aircraft manufacture generated positive economic externalities in the form of innovations. A sector sustaining hubs of scientific and technical expertise, the industry directly and indirectly generated new technologies with commercial applications in other sectors. Third, aircraft manufacture and aviation brought beneficial spill-overs by supporting secondary industries and enabling other economic activity. For instance, local communities thrived off airport economies. Flexible and efficient air transportation facilitated business. Aircraft manufacture and aviation occupied these strategic nodes in both the Chinese and U.S. economies.
In addition, the civil and commercial air sector was a part of vital national infrastructures in both countries. The air transportation system enhanced personal mobility and cargo travel, making possible a way of life that citizens took for granted. Aircraft and aviation systems also performed critical public safety functions, such as securing coasts and fighting forest fires. Air traffic management systems safeguarded the national airspace, monitoring entrants and preventing accidents. Aeronautics research, development, test, and evaluation facilities were “critical national assets.” In these many ways, technologies in the sector played a pivotal role in the economies and basic infrastructures of both China and the United States.

The strategic status of aircraft manufacture and civil aviation made the sector an unlikely site of industrial integration and civil cooperation between countries whose governments were suspicious of each other. Such governments were unlikely to adopt policies allowing their national industries and agencies in this sector to share technology and integrate their operations.

2.2. Technology transfer risks in bilateral industrial integration

A second factor making bilateral trade and industrial integration improbable lay in the technology transfer risks these outcomes presented. Transfers of technology and know-how from U.S. to Chinese firms were inherent in their partnerships. These transfers posed a commercial risk to U.S. firms, which feared they might be breeding future competitors through their partnerships in China. While U.S. experts disagreed on the value and newness of any given specific technology or capacity shared between the two countries, they agreed that the cumulative and systemic effect of these partnerships was to improve and strengthen China’s aircraft

287 National Aeronautics Research and Development Policy, 8.
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Building local aircraft-manufacturing capacity was the explicit objective of the Chinese government’s offset requirements.

Foreign partnerships were a major source of new aircraft technologies for Chinese firms. Technology items spanning a vast range were shared through these collaborations. Transferred technologies ranged from intangible items, such as program management practices, to tangible pieces of hardware, such as the precision-machining tools imported to a joint venture’s manufacturing facilities. Transferred technologies also varied in their degree of specificity: some consisted of basic technical knowledge of general applicability, while others were associated with the manufacture of particular articles. Transferred items ranged from those involved in production to those required for research and development. Inbound technologies were significant in part because China’s aircraft industry was developing from a low initial level of capacity.

Joint ventures required the transfer to China of foreign technology, expertise, and know-how by their very nature. In order for products made in China to enter a major international firm’s global supply chain, they first needed to meet the certification standards set by the FAA and its European equivalent, the European Aviation Safety Agency. For an aircraft to obtain certification from these agencies, its various sub-systems and components also needed to obtain certification. To achieve certification for items made by a joint venture in China, a foreign

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288 Interview with government official attached to the U.S. Navy based in Hong Kong and with a background in naval aviation, Interviewee 04-13-00, Hong Kong, China, 2009; Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010; Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009; Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.

company needed to assist its Chinese partner in developing not only products, but also facilities, personnel, and production methods that met the high standards of quality, safety, and reliability required by these international authorities. Compliance with these standards was demonstrated in concrete technical and management practices, which foreign firms imparted to Chinese contributors. This aspect of certification was an important factor behind the bilateral partnerships: Comac’s business plan to eventually sell ARJ21s and C919s to international airlines hinged on the promises of the foreign partners to the joint ventures supplying the aircraft’s sub-systems that they would smoothly achieve international certification.  

U.S. industry experts based in China acknowledged the pressures to transfer technology. Describing the challenges of operating in China, one senior industry participant listed “export controls” and “IPR (intellectual property rights)” as the “toughest” because “you’re always going to be pushed” to share more by the Chinese side. Managing these difficulties required deciding and recognising “where to draw the lines, what is the competition willing to do, the lines change on you, given how the technology evolves.” As this participant saw it at the time, there is “still a lot outside of the core” of know-how that is not shared with the Chinese partner, which “doesn't enable the Chinese to compete with [U.S. company name] in world markets.” But, he cautioned, “fast-forward five years? Who knows.”

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290 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009; Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
291 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
292 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
293 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
294 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
To describe the pressures to transfer technology, another U.S industry participant drew a square box with arrows moving outward from each of its sides. The box, he said, represented his company’s guarded know-how and proprietary knowledge shared with the joint venture. The arrows represented how the Chinese partner would try to expand the box in every possible direction at every opportunity.  

U.S. industry participants in China accepted that a measure of technology transfer was unavoidable. U.S. firms hoping to succeed in China needed to “redefine their expectations” to understand that their Chinese partners “have to get something of value” out of their collaborations with U.S. firms, explained one such expert. Referring to offsets as the price of market access, Boeing International President Shep Hill described China as a place where you “have to pay to play.”  

The “build-to-print” model, which allowed firms to meet offset requirements while limiting technology transfers by outsourcing only the production of older systems to China, grew less and less viable during this period. Chinese partners sought greater workloads and roles in producing more technically demanding and sophisticated products, including participation in the development of new products. These experiences would contribute the most to China’s sectoral development, allowing Chinese firms to acquire the most technology and know-how.  

U.S. industry experts understood that these technology transfers could be costly in the long run. They were familiar with the process of technology transfer through outsourcing and co-production from other contexts. For example, a panel of the NRC examining the U.S. aircraft

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295 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
296 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
297 Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies,” 47.
industry described how sharing technology with European industry partners had bred competitors that later ate away at the U.S. share of the global market for rotorcraft.

These coproduction agreements began with repair and maintenance and U.S. export of "knockdown" kits for assembly in the licensee nation. This was followed by a gradual increase in content manufactured in the licensee nation. The agreements served as important conduits for the transfer of manufacturing technology, as well as more limited transfer of design skills and data.

The magnitude of the transfer of technology through these coproduction agreements is very difficult to document. However, such licensed production undoubtedly helped create the manufacturing base for the European rotorcraft industry, and supported indirectly the growth of European components design and production capability.298

Industry specialists also cited other examples of how integration between the U.S. and European aircraft industries transferred technology to Europe with the effect of creating European competitors. They were also aware of earlier cases of technology transfer in the opposite direction, as in the case of the British Whittle engine, which GE copied in the 1930s: “The American turbojet program was built directly from the Whittle engine,” wrote one U.S. specialist.299 Moreover, U.S. experts pointed to Japan’s sub-system manufacture as an example of an industry that emerged after companies learned from their foreign partners.300

The launch of China’s ARJ21 and C919 programs brought more opportunities for in-bound technology transfers. With these programs, Chinese companies went from being suppliers to U.S. client firms to becoming clients of U.S. suppliers. Comac came to enjoy a client position


relative to GE Aviation, Honeywell, Rockwell Collins, and Parker Hannifan. The ARJ21 alone had 19 major international suppliers, providing 60% of the aircraft’s sub-systems and components. This change was significant because the client-supplier relationship required substantial information-sharing by the supplier. A system integrator, such as Comac, and its suppliers of sub-systems needed to collaborate closely throughout a program. Moreover, a system integrator had the leverage to extract tightly guarded technical information from suppliers, who competed fiercely amongst each other for lucrative contracts on the program.

In spite of this situation, technology transfers from U.S. to Chinese firms remained a controversial and sensitive subject. As the NRC report cited above noted, technology transfers were inherently difficult to document, measure, and characterise. Equally credible experts sometimes reached different conclusions about the significance of particular technology transfers. However, most industry, government, and academic experts agreed that the cumulative effect of many transfers over several years would be substantial. Despite agreement on this point, U.S. policy did not block or otherwise hinder the expansion of bilateral industrial integration and technical cooperation during these two periods.

2.3. **Effect of bilateral commercial partnerships on China’s defense aviation**

A third factor hindering the prospects for trade, integration, and cooperation between China and the United States in the air sector was the risk that these outcomes could assist in the development of China’s defense aircraft industry. Given the close relationship between civil-commercial and defense-military technologies in the sector, the technologies transferred in bilateral partnerships could be legally or illegally applied to defense programs. During this time,

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301 Webinar, US commercial service, Department of Commerce. TO FIND CITATION INFO
302 Interview with international industry analyst specializing in the Chinese commercial aircraft industry, Interviewee 02-16, Beijing, China, 2009.
the U.S. government aimed to maintain a technological advantage in defense aircraft systems over China. These preoccupations only grew as security relations between the two countries deteriorated after 1999. A sectoral policy consistent with this objective would have curtailed bilateral industrial integration because of its potential to accelerate the development of China’s defense aircraft industry.

China’s commercial aircraft partnerships with foreign firms were likely to assist in the development of its defense aircraft industry in a diffuse and indirect, but significant, way. In principle, U.S. and European export controls prevented the transfer of defense aircraft technology to China. However, as air industry experts Roger Cliff et al. of RAND note, joint ventures and other forms of localised production created opportunities for China’s defense aircraft firms to obviate these export controls.303 Moreover, commercial aircraft partnerships resulted in the legal sharing of controlled and uncontrolled technology items, some of which contributed to defense aircraft development. The nature of a technology transfer and its impact in each case depended on the specific item and how it was shared with a Chinese partner.

Experts were divided on the impact of these transfers of commercial technology. Many believed that, individually, most transfers would have only a minor impact on China’s defense aircraft industry. The effect of any single given transfer was likely to be at most incremental, hypothetical, and diffuse. The transfer of an item might bring only a marginal improvement to a local industrial capacity that had some defense-industry relevance.

Moreover, the assessment of a particular transfer’s impact on the defense industry was likely to be a hypothetical construct, rather than a demonstrable fact. In many cases, a technology transferred through a partnership with a foreign commercial firm could in time have

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303 Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies.”
been developed indigenously or obtained through another channel.\textsuperscript{304} For example, a commercial transfer might have at most slightly accelerated the acquisition of a defense-relevant capability.\textsuperscript{305}

Finally, any given technology transfer was likely to have only a diffuse impact on the defense industry. The transferred technology may not have had a specific defense application, but contributed in a general sense to the development of capacity in the integrated commercial-defense industry. In short, most experts believed that individual commercial technology transfers probably had only minor effects on China’s defense industry.

In spite of these ambiguities, specialists tended to agree that, in the aggregate, many such individually negligible transfers could or would become significant. Over three decades, foreign firms imparted countless commercial and/or dual-use technology items to their Chinese partners through their collaborations. The cumulative effect of these transfers was likely to become apparent only a systemic, macroscopic level. In other words, it was unlikely that any particular then-current or future defense aircraft innovation could be traced to a specific commercial technology transfer. Instead, Chinese firms’ exposure to and absorption of foreign commercial technologies contributed to building a stronger base of comprehensive national scientific, technical, and industrial capacity in the aviation sector. This strengthened base was applicable to both commercial and defense aircraft programs.

U.S., European, and Taiwanese experts recognised that some of the civil and commercial technologies on which U.S. and Chinese firms collaborated were transferable to defense programs. These included engines; structures; avionics systems; advanced materials, including

\textsuperscript{304} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.

\textsuperscript{305} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
steel technologies, aluminium alloys, and carbon fibre composites; and air traffic management systems.\(^{306}\) There was a close relationship between civil-commercial and military-defense aircraft products and between production techniques for both types of items. Even when specific commercial aircraft products did not have direct military applications, the capabilities required to engage in the research, development, and production of commercial aircraft could be applied to defense systems.

That the Chinese state intended to foster the absorption of commercial technologies by the national defense industries was not in doubt. Statements by China’s most senior leaders reiterated this goal.\(^{307}\) These policy ideas were familiar to China specialists and defense experts in the United States. According to Tai Ming Cheung, the Chinese government undertook a “major effort” establish an “integrated relationship between the civil and defense sectors” of the economy during this period.\(^{308}\)

This effort to forge an integrated civil-military dual-use economy was encapsulated in a set of guiding principles put forward by Jiang Zemin and the Chinese leadership at the end of the 1990s: \textit{Junmin Jiehe} (Combining Civil and Military Needs - 军民结合), \textit{Yujun Yumin} (Locating Military Potential in Civilian Capabilities - 军于民), \textit{Dali Xietong} (Vigorously Promoting Coordination and Cooperation - 大力协同) and \textit{Zizhu Chuangxin} (Conducting Independent Innovation - 自主创新).\(^{309}\)

These principles guided strategies and programs for China’s technological modernisation.

The most important of these concepts was \textit{Yujun Yumin}, which refers to the forging of an integrated civil-military dual-use system. At the third plenum

\(^{306}\) Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009; Taiwanese scholar, Taipei; Interview with senior executive at a European aircraft components manufacturer with operations in China, Interviewee 05-03-00, Shanghai, China, 2009.

\(^{307}\) Ruan Ruxiang [阮汝祥], \textit{Theory and Practice of Civil-Military Integration with Chinese Characteristics} \(\text{[中国特色军民融合理论与实践]}\).


\(^{309}\) Ibid.
of the 16th Party Congress in 2003, a decision was taken to construct a new civilian technological and industrial base with embedded military capabilities. This called for the building of an innovative “Junmin Jiehe, Yujun Yumin”-based system that focuses on the “mutual promotion and coordinated development of the defense and civilian technological sectors.” This elevated the Yujun Yumin guiding principle into the strategic outline for the future dual-use economy.

The high-level leadership support for the Yujun Yumin strategy provided the necessary momentum for an active, sustained and wide-ranging program of reforms and initiatives to take place over the past decade to establish a dual-use economic, technological and innovation apparatus.  

Moreover, individuals familiar with China’s industry believed that, once a technology item reached a commercial Chinese company, it would easily migrate to defense programs. There was “easy transfer from commercial to military within Avic organisations,” observed a Canadian diplomat responsible for the sector.

When asked, specialists in the aircraft industry and U.S. government acknowledged that China’s commercial aircraft partnerships brought “indirect benefits” to its defense aircraft industry. “Yes and no” is how one U.S. industry expert answered the question of whether U.S.-invested joint ventures were assisting the modernisation of China’s defense aircraft industry. There is “always that concern” for U.S. companies. That the “line [was] unclear” between commercial and defense technologies made it “hard for U.S. companies,” this participant explained.

310 Ibid.
311 Interview with senior Canadian diplomat responsible for Canadian aircraft industry interests in China and familiar with the Chinese aircraft manufacturing industry, Interviewee 16-16-00, Beijing, China, 2009; also interview with China-based senior manager at a European aircraft manufacturer with joint ventures and facilities in China, Interviewee 19-22-00, Tianjin, China, 2009.
312 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
313 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
314 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
U.S. industry specialists were aware that strengthening China’s defense aviation industry was a major motive behind the country’s commercial aircraft programs. Among other factors, U.S., European, and Chinese experts judged that, at a fundamental level, the motives behind the programs were not commercial. For example, they observed that the C919 program was uneconomic: it was expected to generate losses and its costs would significantly exceed the cost of importing proven foreign aircraft. Moreover, system integration was among the most risky, most saturated, least profitable, and least innovative segments of the commercial aircraft industry, making Avic’s entry into this particular area irrational from a strictly economic perspective. Neither commercial objectives nor economic development goals justified these programmatic choices.

Instead, foreign experts believed that a goal of Chinese programs was raising the level of technology and capacity in defense aviation. Asked what were the main reasons the Chinese government pursued these uneconomic programs, one U.S. industry specialist answered that they “overlap[ped] with their military aspirations.” Another industry expert said that the Chinese government pursued these programs in order to “get the technology and develop the industry [on] the military side.”

The potential impact of commercial partnerships with foreign firms on defense aviation took several forms. They involved the following six areas: 1) manufacturing processes; 2) innovation through commercial-to-defense spin-on; 3) the economic and organizational benefits of dual development; 4) background technical knowledge; 5) manufacturing equipment

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315 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
317 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
318 Interview with senior executive at a European aircraft components manufacturer with operations in China, Interviewee 05-03-00, Shanghai, China, 2009.
diversion; and 6) hardware diversion. The rest of this section examines each of these aspects in turn.

### 2.3.1. Manufacturing Processes

Commercial aircraft partnerships with foreign firms were likely to transfer complex manufacturing-process technology that could serve defense aircraft programs. Part tangible and part intangible, processes were combinations of personnel, knowledge, equipment, procedures, and organizational forms constituting essential inputs into development and production. Examples of processes common to commercial and defense products included program management and supply chain management.  

Although the processes involved in commercial and defense production differed in their specifics, they relied on common elements. The capacities required to perform commercial processes could be applied to equivalent defense processes. Mastering complex and demanding processes was necessary, but not sufficient, for China to develop an advanced defense aircraft industry. That commercial and defense aircraft manufacturing processes shared major commonalities had been widely understood in the United States and China for many decades. For example, aeronautic experts described the intertwining of production processes in the two segments in a 1985 NRC report to the U.S. Foreign Secretary.

Despite the differing requirements for civil and military aircraft, the technology base, much of the supplier base, and the skills and processes used are essentially common. They become mutually supportive in attaining diverse civil and military objectives. The technological synergies are very constructive. Military developments stress performance, while commercial aircraft developments emphasize lowered production costs, vehicle

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319 Interview with Dr. Roger Cliff, defense industry analyst specializing in aerospace and China who led research projects in these areas for the RAND Corporation, Arlington, VA, 2010.
operating efficiency, and high availability with low maintenance—attributes that are valuable to the military establishment.320

Among other factors, the need to obtain certification for elements produced by China-based joint ventures compelled foreign participants to impart processual know-how to their Chinese partners. This factor was significant because many Avic companies’ weaknesses were related to processes.321 To learn manufacturing processes, Chinese firms needed more than abstract knowledge of procedures and access to equipment. Direct experience and active technical assistance were indispensable ingredients. While some technology items could be reverse engineered, bought, or stolen, critical processual know-how had to be taught hands on.322 The most effective way to learn manufacturing processes was to participate in co-production and co-development.323

Several commercial aircraft processes transferred through integration with U.S. firms could have benefitted Chinese defense programs. The most important was program management, which included both organisational and engineering dimensions. For large programs, the management challenge facing a platform manufacturer was integrating sub-systems concurrently engineered and/or manufactured by different suppliers on budget, on schedule, and up to verifiable standards. Achieving stable and efficient production with unfaltering reliability required capably performing sophisticated technical and organisational processes. As Chinese companies participated in the integration of sub-systems and systems with U.S. firms, they were

321 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
323 Ibid.
exposed to and learned many of these processes. The management of the C919 program itself and the joint ventures established to supply its sub-systems created these opportunities.

There were also narrower processes transferred in the context of joint ventures. These included the implementation of quality control programs. Quality control processes comprised testing and documentation practices necessary for achieving FAA certification. These practices were also integral to innovation in aircraft technology. Moreover, earlier studies of China’s defense industries indicated that it was precisely in the area of quality control processes that they faced the greatest challenges. Quality control lapses caused some of the defense industries’ most spectacular failures.\footnote{For example, failures of Long March rockets in the 1992-1996 period owed to problems in the ground testing of components before flight, including of improperly soldered wires in the follow-up frame to the rocket’s inertial measurement unit. Lewis R. Franklin, “A Critique of the Cox Report Allegations of PRC Acquisition of Sensitive U.S. Missile and Space Technology,” in The Cox Committee Report: An Assessment, ed. Michael M. May (Stanford, CA: Center for International Security and Cooperation, Stanford University, 1999), 81–99; Select Committee, United States House of Representatives, “Satellite Launches in the PRC: Hughes,” in U.S. National Security and Military/Commercial Concerns with the People’s Republic of China, vol. II (Washington, DC, 1999), 1–93; Select Committee, United States House of Representatives, “Satellite Launches in the PRC: Loral,” in U.S. National Security and Military/Commercial Concerns with the People’s Republic of China, vol. II (Washington, DC, 1999), 95–215.}

\textbf{2.3.2. Innovation and commercial-to-defense spin-ons}

Technologies transferred through U.S.-invested commercial joint ventures could assist the modernisation of China’s defense industries by improving innovation in defense aircraft. The skills and capacities that Chinese firms acquired by participating in commercial programs were applicable not only to the manufacture of existing defense systems, but also to the development of new systems and the upgrading of existing systems. This learning could occur through co-production arrangements. As RAND experts Roger Cliff et al. noted, “the potential to contribute
to the development of China’s military capabilities [was] even greater” when foreign companies jointly developed new systems with Chinese enterprises.325

China’s commercial aircraft industry development had the potential to assist defense innovation for at least two reasons. First, in critical technical areas, Chinese defense aircraft companies were less sophisticated than the world’s leading commercial manufacturers with whom they partnered. Second, even at the cutting edge, innovation in defense aircraft often involved technology spin-ons from commercial programs. Some of the most advanced Chinese defense programs benefitted directly from commercial inputs. Tai Ming Cheung testified before the U.S.-China Economic and Security Review Commission about the assistance that commercial technologies and practices brought to the development of new Chinese fighter jets. For example, Chengdu Aircraft Corporation reduced the development time for the FC-1/JF-17 fighter by as much as 50 percent in some areas through improvements in design and project management, including the use of computer-assisted design and manufacturing processes.326

According to a once common view of innovation in aeronautics, advanced technologies move through a cycle of defense-to-commercial application. Specialists, however, recognise that his view has been outdated since at least the 1980s.327 By that time, a growing proportion of advances in defense aircraft resulted from commercial technology development and refinement.328 The demands of commercial production and operation often yielded improvements that only later became applicable to defense aircraft.

Evidence of such spin-ons in the most advanced aviation industries was abundant. A panel of U.S. aeronautic experts wrote in a 1985 NRC report that “the results of civil research or

325 Cliff, Ohlandt, and Yang, Ready for Takeoff: China’s Advancing Aerospace Industry, 121.
328 Ibid.
component design” are often subsequently used for military purposes, with effects such as “improved fuel efficiency, maintainability and reliability of jet engines, super-aluminum alloys, flight management systems, and composite structures.” The NRC’s 2006 *Decadal Survey of Civil Aeronautics*, characterised innovation in the same way: “advances in civil aviation are being transferred to military applications, and dominance of the skies will be greatly affected by the results of civil aeronautics research.” This trend was apparent in the most innovative areas of aircraft manufacture, such as engine and avionics manufacture. Both of these were areas of weakness in China’s defense aircraft manufacture, regarded as bottlenecks on the sector’s development.

Exposure to commercial engine technology from abroad could help Chinese firms overcome difficulties in defense engine manufacture. In the U.S. context, defense engine technology had advanced with commercial engine programs. In some respects, engine technologies on both sides evolved to meet similar needs. A committee of experts studying U.S. aircraft manufacture noted in 1985 that “military engines for bombers, transports, patrol aircraft, and helicopters share common performance requirements with commercial aircraft.” Both types of users sought low fuel consumption, a high thrust-weight ratio, a long operational life, and high reliability. The “need for high pressure ratio-high temperature engines is also

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333 Ibid.
common to both” commercial and defense users.\textsuperscript{334} Innovation in the two areas was mutually supportive.

U.S. commercial engine programs had brought distinct innovations to military engine technology. “Commercial engines gain service experience 10 to 15 times faster than military engines, even military transport engines,” wrote the NRC panel. In order to stay competitive, commercial engine makers “are under continuing pressure to improve fuel efficiency, reliability, and service life – all resulting in significant cost savings to the user.”\textsuperscript{335} These improvements “recycle back into military engines.”\textsuperscript{336} Examples of these processes included improvements to the CF6 turbofan, an engine derived from the TF39. Advances developed during commercial service of the CF6 were incorporated into later versions of the TF39. Thus, the committee found, “commercial experience provides the DoD with better engines for transport and mission support aircraft than would have been produced by military experience alone.”\textsuperscript{337}

Aeronautic experts studying large non-fighter engines for the U.S. Secretary of the Air Force characterised innovation in the same way. For the force, as for commercial airlines, “the importance of fuel conservation cannot be overstated,” wrote the committee.\textsuperscript{338} Given this common priority, commercial programs could foster improvements in defense aircraft. Among the commercial engines or their derivatives installed on Air Force weapon systems were the CFM56, F108, CF6-50, CF6-80, and PW2040.\textsuperscript{339} Improvements to these models, once incorporated into the military fleet, could improve its fuel efficiency. “The military may also benefit from much of the nonrecurring engineering work that will have already been done” on

\textsuperscript{334} Ibid.
\textsuperscript{335} Ibid.
\textsuperscript{336} Ibid.
\textsuperscript{337} Ibid.
\textsuperscript{339} Ibid.
these programs found the experts.\(^{340}\) In short, U.S. Air Force engines were more efficient and less expensive because of commercial aircraft programs.

Avic’s defense engine makers were in a position to similarly benefit from the group’s commercial engine programs. These included not only domestic programs but also co-production arrangements with leading U.S. manufacturers, through which Avic companies acquired expertise and know-how. For example, describing an effort by Avic Commercial Aircraft Engine Company to recruit foreign aeronautic specialists, industry observer Bradley Perrett wrote that the effort “has clear military implications, since commercial aircraft share many technology features with those of combat aircraft.”\(^{341}\) “Many military aircraft use commercial powerplants with only slight modifications,” he added.\(^{342}\)

Another area in which commercial innovations could bring spin-ons to defense programs was avionics.\(^{343}\) Elements of commercial fly-by-wire systems could be adapted to military use. Moreover, migration from commercial to defense systems occurred because of the different innovation cycles of aircraft platforms and computer electronics.\(^{344}\) Throughout the 1990s and 2000s, launches of new aircraft platforms grew less frequent, averaging several years apart.\(^{345}\) Advances in electronics were far more rapid, their product cycles measured in mere months. Best-available computer hardware could be incorporated into commercial aircraft before it was

\(^{340}\) Ibid.
\(^{342}\) Ibid.
\(^{343}\) Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
introduced to defense systems.\textsuperscript{346} Moreover, open-architecture avionics, in use on some U.S. military aircraft, allowed operators to take advantage of advances in computing power throughout the operational life of a vehicle. Though a joint venture with GE, China’s main avionics maker, Avic Systems, began to develop a new open-architecture avionics platform for the C919.\textsuperscript{347} As Chinese firms acquired the capacity to develop commercial avionics systems, they could apply it to developing more advanced defense avionics systems.

As integration with more capable U.S. firms brought advances to China’s commercial technology, it had the potential not only to improve Chinese manufacture of existing defense systems but also to foster the development of new systems and upgrades. Raising the level of industrial and technical capacity through commercial programs was likely to facilitate and enable innovation in China’s defense programs.

2.3.3. \textit{Economic and organisational benefits of dual development}

U.S.-invested joint ventures assisted the development of China’s defense aircraft industry through the economic and organisational benefits they brought. Building up the commercial and defense segments of the industry in parallel brought efficiencies, synergies, and complementarities at the levels of individual firms and of the industry as a whole. Major companies within AVIC were poised to capture these benefits because they produced both commercial and defense items.

In the industries of established aircraft-manufacturing countries, firms benefitted from the integration of their commercial and defense businesses on an organisational level. Commercial

\textsuperscript{346} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.

\textsuperscript{347} Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
and defense aircraft manufacture supported each other. An important complementarity stemmed from the cyclical nature of demand for commercial and defense products. Commercial business offset the effects of dips in demand for defense products and vice-versa. Commercial aircraft “account for 80 percent of the total aircraft production weight during times of peace,” explained industry analyst Vicki Golich.348 Because the two segments “share virtually the same production base,” synergies with commercial manufacture “reduce the cost of providing an essential military base” in aircraft-manufacturing countries.349

The workforce complementarities between the commercial and defense segments of the industry were substantial. In the United States, the aircraft industrial base comprised not only system integrators, but also some 15,000 specialised firms that supplied sophisticated components, materials, and production equipment.350 For many smaller second-tier or third-tier suppliers, “the military and civil production outputs are sufficiently common that the same facilities and labor pools produce both.”351 A similar situation existed in Europe, where a common base of sub-system and component suppliers produced both defense and commercial products.

The specialised personnel who developed and produced new military aircraft were kept “in a state of increased readiness by the requirements of the civil market,” noted aeronautical experts from the NRC and the National Academy of Engineering.352 The manufacture of commercial aircraft “challenges the assemblage of technical skills of design and production

349 Ibid.
351 Ibid., 100.
352 Ibid., 2.
teams.”\textsuperscript{353} At the same time, commercial manufacture “shares payment of their overhead with military programs,”\textsuperscript{354} ensuring that the industrial base is available “in an emergency surge capacity.”\textsuperscript{355} For Avic companies, commercial ventures promised similar benefits to their defense programs. In particular, commercial programs could facilitate capital improvement on the defense side. For example, the revenues generated by their commercial partnerships could “be used to upgrade the facilities and machine tools of both civilian and military production lines,” observed the analysts at RAND.\textsuperscript{356}

China’s aircraft companies were in a position to realise economies, complementarities, and other synergies by simultaneously developing integrated commercial and defense aircraft industrial capacity, as policymakers intended. Belonging to a single defense industrial group, Avic companies entering into joint ventures were poised to capture these organisational benefits. Moreover, as these bureaucratic state-owned enterprises reformed into more cost-sensitive and profit-driven entities, they were incentivised to further exploit efficiencies in the integration of their military and commercial activities.\textsuperscript{357}

\textbf{2.3.4. Background Technical Knowledge}

Industrial partnerships with U.S. manufacturers could foster transfers of background technical knowledge with defense applications to Chinese firms.\textsuperscript{358} Although specific commercial and defense aircraft products differed, at a basic level aeronautic knowledge was

\begin{footnotesize}
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\item\textsuperscript{353} Ibid., 148.
\item\textsuperscript{354} Ibid.
\item\textsuperscript{355} Ibid., 2.
\item\textsuperscript{356} Cliff, Ohlandt, and Yang, \textit{Ready for Takeoff: China’s Advancing Aerospace Industry}, 121.
\item\textsuperscript{357} Cheung, \textit{Remaking Cinderella: The Nature and Development of China’s Aviation Industry (Testimony Before the U.S.-China Economic and Security Review Commission)}; Cheung, \textit{Fortifying China}.
\item\textsuperscript{358} U.S. Civil Aviation Manufacturing Industry Panel, Committee on Technology and International Economic and Trade Issues of the Office of the Foreign Secretary, Commission on Engineering and Technical Systems, National Research Council, \textit{The Competitive Status of the U.S. Civil Aviation Manufacturing Industry}, 148.
\end{itemize}
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applicable to both commercial and defense manufacture. In this context, “technical knowledge” refers to knowledge that is more applied than basic scientific knowledge, but general enough to be applicable to several types of products. As Chinese aviation firms acquired technical knowledge through their commercial programs, they could evolve or adapt it toward defense applications. Examples of such transferred items included technical knowledge related to engines, airframes, and composite materials.

Background technical knowledge related to engine technology could serve both commercial and defense programs. On the one hand, engines on commercial and defense aircraft were designed, built, and tested to different specifications, including vastly different tolerances and performance requirements. On the other hand, commercial and defense engines shared a common core of basic technology. For that reason, within some of the world’s top engine manufacturing firms, engineers and scientists travelled between commercial and defense projects throughout their careers. Moreover, from at least the 1990s onward, most commercial engine technologies were so sophisticated that, in a few areas, their research, development, and production in fact engendered spin-on benefits to defense engine development, such as testing technologies. Acquiring technical knowledge of engines could support both commercial and defense aircraft manufacture.

Background technical knowledge related to airframe design, development, and production could also be applied in both commercial and defense programs. Comac and other Chinese firms acquired technical knowledge related to airframe design and integration through interacting with

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the foreign suppliers to the ARJ21 and C919. This knowledge could be applied to the
development of military airframes in the future.\footnote{Cliff, Ohlandt, and Yang, \textit{Ready for Takeoff: China’s Advancing Aerospace Industry}, 121.}

Background technical knowledge applicable to both commercial and defense production
was also found in the area of advanced materials, including new metal alloys and composite
materials.\footnote{Cheung, \textit{Remaking Cinderella: The Nature and Development of China’s Aviation Industry (Testimony Before the U.S.-China Economic and Security Review Commission)}; Cliff, Ohlandt, and Yang, \textit{Ready for Takeoff: China’s Advancing Aerospace Industry}, 120.} Composite material structures were necessary for the manufacture of advanced
fighter jets. The specific composite-material products used in commercial and defense aircraft
could differ. However, as Chinese manufacturers acquired the technical knowledge to produce
commercial composite-material products, they could become more capable of producing similar
defense products.\footnote{Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems
invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.}

As Chinese firms collaborated with U.S. firms to co-produce or jointly research and
develop new products, their personnel gained exposure to technical knowledge applicable to both
their commercial and defense programs. Commercial knowledge-sharing had the potential to
accelerate or otherwise contribute to the development of China’s defense aviation.

\subsection*{2.3.5. \textit{Manufacturing equipment}}

U.S.-invested joint ventures could assist China’s defense aircraft programs by creating
opportunities for the diversion of commercial manufacturing equipment to defense production.
U.S. companies exported specialised tools to equip their joint ventures’ facilities in China.
Diversion of these items could consist in the repurposing to defense programs of equipment
hardware; computer software used in development and production; or the skills required to use
specific equipment. Specific foreign commercial equipment items had the potential to assist
China’s defense aircraft programs. For example, precision-machining tools used in commercial manufacture could be applied to defense production. Once these items travelled to China, their illicit repurposing became possible. A diversion of five-axis precision-machining tools occurred in the context of McDonnell Douglas’s production of the MD-90 in China. Imported for the commercial program, these items were later found in use at another Chinese factory making defense items.\(^{364}\) Other commercial equipment that could be diverted to defense programs included computer software, such as computer-assisted design and computer-assisted manufacturing software.\(^{365}\) The introduction of such technologies into defense aircraft development and production processes improved Chinese firms’ imitation and incremental innovation upon foreign designs.\(^{366}\) Diversions of such software could also accelerate indigenous development programs.\(^{367}\)

According to the U.S. Department of State, aircraft sub-system and component makers within U.S.-headquartered United Technologies Corporation (UTC) operating in China illegally shared such items. In 2002 and 2003, UTC subsidiary Pratt & Whitney Canada provided “U.S. origin, ITAR-controlled engine software” used to develop China’s first military attack helicopter.\(^{368}\) The firms’ commercial operations in China provided the setting within which the transfers occurred.

\(^{364}\) Select Committee, United States House of Representatives, “Manufacturing Processes.”
\(^{365}\) Cliff, Ohlandt, and Yang, Ready for Takeoff: China’s Advancing Aerospace Industry, 120.
\(^{366}\) Ibid.
\(^{367}\) Tai Ming Cheung has found that incorporating commercial/dual-use computer-assisted manufacturing technologies significantly accelerated Chengdu Aircraft Corporation’s FC-1/JF-17 fighter program, in Cheung, Remaking Cinderella: The Nature and Development of China’s Aviation Industry (Testimony Before the U.S.-China Economic and Security Review Commission), 7.
2.3.6. **Hardware**

Commercial partnerships with foreign firms allowed Chinese manufacturers to develop and produce specific items of hardware with applications to defense programs. Particular items of commercial hardware could be repurposed for military users with only minor modifications. These technologies included entire systems, such as utility helicopters and transport planes. They also included sub-systems, such as commercial avionics items that could be adapted to military systems. Finally, commercial hardware with defense applications included many smaller components. These dual applications were apparent to Chinese policymakers, who advocated using commercial off-the-shelf technology to modernise defense manufacture. Sectoral policies and directives guided Avic to maximise the resort to commercial solutions available on world markets when indigenous defense technologies were not available.

Bilateral industrial integration created opportunities for this form of diversion.\(^{369}\) Certain commercial aircraft products were nearly identical to defense items. Some military requirements “do not place important demands for specialized performance on suppliers,” noted aeronautic experts from the NRC and National Academy of Engineering.\(^{370}\) Among these were complete aircraft, such as general personnel and supply transports, navigation and command control trainers, and in-flight refuelers.\(^{371}\) Examples included the C140A (Jetstar), U-SF (Seminole), T-39A (Sabreliner), E-3 (707), E-4 (747), C-9A (DC-9), KC-10 (DC-10), Lear jet 35A (designated

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\(^{371}\) Ibid.
C-21A) and Beech Super King Air (designated B 200C).\textsuperscript{372} These were “civil aircraft that have evolved into dual-use aircraft with major cost avoidance to the nation,” found the expert panel.\textsuperscript{373}

In China, the same was true. The ARJ21 and C919 airframes could serve as troop transports or military cargo aircraft.\textsuperscript{374} In addition, these airframes had “the potential to form the basis for a variety of special-mission aircraft,” observed the analysts at RAND.\textsuperscript{375} U.S. experts and policymakers were also familiar with the reported illegal conversion in China of an imported Boeing 737 to a military airborne warning and control aircraft, photographed at a military base.\textsuperscript{376}

Specific commercial sub-systems, components, and development technologies also had direct applications to defense programs. These included flight-control systems, high-bypass turbofan engines, composite materials, micro-electronics, precision-machining tools, and computer-aided design and manufacturing technologies.\textsuperscript{377} China’s defense industry developed a range of military combat systems that “incorporate commercially available sub-systems and components,” according to Cheung.\textsuperscript{378} Given these similarities in commercial and defense hardware, the idea of a “purely” indigenous Chinese military aircraft grew more and more remote. Instead, the fighters and military transports flying off China’s runways several years later were composite artefacts integrating defense and commercial, indigenous and foreign elements.

Civil aviation systems also had direct defense and security applications, albeit in a narrow range. Among these was the NextGen air traffic system on which the FAA cooperated with the CAAC. In its decadal survey, the NRC’s aeronautics steering committee observed that

\begin{footnotesize}
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\item \textsuperscript{372} Ibid.
\item \textsuperscript{373} Ibid.
\item \textsuperscript{374} Cliff, Ohlandt, and Yang, \textit{Ready for Takeoff: China’s Advancing Aerospace Industry}, 121.
\item \textsuperscript{375} Ibid.
\item \textsuperscript{376} Gertz, “U.S. Eyes New Controls on China Exports.”
\item \textsuperscript{377} Cliff, Ohlandt, and Yang, \textit{Ready for Takeoff: China’s Advancing Aerospace Industry}, 120.
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In some cases, advances in civil aviation are being transferred to military applications, and dominance of the skies will be greatly affected by the results of civil aeronautics research. A more capable air transportation system could also enhance homeland security. For example, a next-generation air transportation system that uses a network-based approach to communications and the exchange of information would allow surveillance data collected from various air traffic sensors to provide the same comprehensive operational picture to all systems users and monitors, including the DHS (Department of Homeland Security) and the North American Aerospace Defense Command.379

As this statement indicated, even dedicated civil aeronautic capabilities had concrete defense applications.

Leading U.S. authorities recognised the close relationship between civil-commercial and defense-military aeronautic technologies in their technical and programmatic analyses of the sector. Specialists examining China’s aircraft industry observed that advances in commercial aircraft manufacture could assist the country’s defense aircraft programs through several channels. Finally, research on the sector in the United States, Europe, and Japan established that technology transfers inhered in industry partnerships. Experts communicated these findings to policymakers throughout the two decades under study. These circumstances made the sector an unlikely site of China-U.S. trade, industrial integration, and civil cooperation.

2.4. China’s defense aviation made major advances

A fourth factor making China-U.S. trade, industrial integration, and civil cooperation improbable was the fact that, as bilateral joint ventures multiplied and grew, China’s defense industry made important technological advances. U.S.-invested commercial programs advanced in step with China’s indigenous defense programs. These developments presented U.S.

policymakers with mounting evidence that bilateral partnerships could be accelerating the development and modernisation of China’s defense aircraft industry.

During those two decades, the aircraft industry completed several defense technology development programs begun in the 1980s and 1990s, demonstrating major new systems. By 2012, the Chinese military had test flown new indigenous fighter aircraft, including a reported stealth variant, developed over the previous years. That year, the PLA Navy performed China’s first aircraft carrier landing at sea with an indigenous fighter, the culmination of an development effort that U.S. defense experts had tracked for a decade. U.S. experts at the time also expected the Chinese military to soon test a new indigenous fighter engine.  

Aeronautic specialists in both China and the United States recognised that Avic companies had made significant progress in a range of defense products, from airborne radars to fighters. Once the most laggard and technologically backward of China’s defense industries, aircraft manufacture made strides toward the end of this period. Guided by the long-term goal of making China a self-sufficient developer and producer of defense aircraft systems, policymakers implemented a program to modernise technology in the PLA’s air forces and sweeping reforms of the manufacturers equipping them. After a slow start, these policies yielded important advances in indigenous defense aircraft manufacture, shrinking the technology gap between the PLA and the advanced air forces of the world.

In 1989, China’s defense aircraft industry was weak. The PLA Air Force only began to introduce modern systems at the start of the following decade, when it imported Su-27 fighters and ground-based air defense systems from Russia. “At that time, China’s aviation and

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380 Interview with Dr. Roger Cliff, defense industry analyst specializing in aerospace and China who lead research projects in these areas for the RAND Corporation, Arlington, VA, 2010.
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aerospace industries were not yet able to produce modern systems of this class,” wrote U.S. air power analyst Wayne A. Ulman.382 In the mid-1990s, Avic began to produce Su-27s under license and started on development of a domestic fighter, the J10.383

But by the early 2000s, Avic firms “demonstrated an increasing ability to develop and produce advanced weapon systems.”384 The J10 entered serial production and operation. Avic companies also developed upgraded versions of the J10 and the J11, a Chinese-produced version of the Su-27. In 2011, these firms developed and test-flew an indigenously designed and built fourth-generation stealth fighter known as the J20 and a second domestic fifth-generation (or 4.5-generation) stealth fighter called the J31 in late 2012.385 In addition to fighters, Avic companies developed and produced airborne early warning and intelligence-collection platforms.

The industry not only built manufacturing capacity, but also innovated in strategic technologies. For example, developing its own aircraft with stealthy characteristics allowed the industry to improve its counter-stealth technologies. The military and industry worked toward “technologies, systems, and procedures to detect, track, and engage stealth aircraft and cruise missiles.”386 U.S. analysts expected “the development of tactics, training, and procedures for use against low-observable threat systems,” increasing the PLA Air Force’s ability to deter or engage U.S. forces in a Taiwan Strait contingency.387

During this time, the Chinese military continued to buy weapons systems, sub-systems, technology, and expertise from Russia and other countries, but it reduced its reliance on imports of complete, finished systems to focus instead on purchasing foreign sub-systems for use on

382 Ibid.
383 Ibid.
384 Ibid.
386 Ulman, “China’s Military Aviation Forces,” 47.
387 Ibid.
indigenously designed platforms. By the late 2000s, the Chinese air industry’s progress was evident in the country’s shrinking imports and growing exports of defense aircraft. After numbering in the hundreds in the 1990s, imports of Russian military aircraft dropped to single-digit orders. Buoyed by generous defense budgets, PLA Air Force and PLA Navy continued to buy new aircraft in large numbers, but bought more of them from domestic producers. Meanwhile, Avic had also begun to export fighter aircraft, including those produced under foreign license.\footnote{Jane Perlez, “China Gives Pakistan 50 Fighter Jets,” \textit{The New York Times}, May 19, 2011, sec. World / Asia Pacific.} Because of stable demand from the PLA and growing exports, defense aviation was the first and only segment of China’s aircraft industry to earn profits by 2012.\footnote{\textit{Transforming China: Initiating on China Aerospace & Defense: Focus on Spending, Returns and Growth}, Global Investment Research (The Goldman Sachs Group, Inc., January 17, 2012), 4.}

Exports and defense aircraft development in general were stymied by enduring weaknesses in engine technology. Unable to develop a capable engine of their own, Chinese manufacturers outfitted their aircraft with Russian-made engines – a stop-gap measure to remain in place until suitable Chinese replacements were available. Defense aircraft engines under development by Avic companies during this period included WS10 and WS15 (Shenyang Aero-Engine Company) WS13 Taishan (Guizhou Aircraft Industry Corporation).

Advances in Chinese defense aircraft technology occurred in the context of larger changes to the military’s missions and strategy. Under the Jiang and Hu administrations, Chinese leaders redefined the PLA’s strategic environment and guidelines to broaden its missions. Seeing a new role for air power in the Taiwan Strait after 1999, China’s strategists expanded the PLA Air Force’s role in air defense, which had until then relied almost exclusively on missiles controlled by a separate service. Fighters, bombers, and drones, they decided, would make a greater contribution to the country’s military power.
During this time, leaders also decided that the PLA’s maritime forces should evolve in the direction of a “blue-water navy” capable of conducting operations beyond China’s second-island chain. With this new aspiration, the military’s naval aviation needs grew. The PLA Navy acquired a Ukrainian aircraft carrier that it began rebuilding and eventually deployed for training. China’s defense industrial conglomerates also worked toward developing an indigenous carrier.

In step with these developments, China’s aircraft industry developed carrier-supported aircraft, including fighters and trainers. In 2012, a fighter capable of long-range combat, the J15, conducted China’s first carrier-based take-off and landing. Analysts expected carriers and naval aircraft to become core elements of a “counter-intervention” or “area-denial” strategy for the waters off China’s coast and in the vicinity of the Taiwan Strait. Leaders intended for air systems to satisfy more of the country’s defense needs in the long term.

In the United States, aeronautic and defense experts closely monitored these advances. Throughout these two decades, they communicated these developments to policymakers. Experts testified about China’s defense modernisation to the Congress and related institutions. They briefed policy specialists in executive departments and agencies. Beginning in 2000, the Department of Defense issued a widely circulated annual report on China’s military power examining advances in Chinese defense technology.

In spite of the information reaching them, U.S. policymakers maintained permissive controls on aircraft technology transfers to China. They allowed trade and integration to proceed unhindered by additional export restrictions or other measures to curb the development of China’s aircraft industrial base. Consensus on a regulatory distinction between commercial and

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defense exports persisted, deflecting attention from the national security implications of bilateral industry partnerships. Exports of dual-use aircraft items to China did not rise to the attention of the legislative or executive branch. Policymakers did not examine whether bilateral partnerships carried implications for China’s defense modernisation and U.S. security.

2.5. Illegal transfers to China of defense-relevant aircraft technologies

A fifth factor that made continued and expanding China-U.S. trade, industrial integration, and civil cooperation improbable during this period was a series of export control violations and related incidents involving U.S. aircraft technologies. Some of the offenses were committed by or implicated U.S.-owned firms with operations in China.

These developments dimmed the prospects for continued bilateral trade and industrial integration in two ways. First, the incidents provided evidence of demand within China for controlled aircraft technologies, including defense items on the U.S. ML. Second, cases of illicit technology transfer cast doubt on the efficacy and viability of the U.S. export control regime. To some experts, evidence was mounting that export controls were insufficient to protect sensitive U.S. technologies when commercial interests motivated U.S. companies to share them with Chinese entities and conceal end-user violations.391

U.S. federal investigations documented cases of illegal aircraft technology transfers to China by U.S. firms, including unlicensed or prohibited exports and diversions. An example of such an illegal transfer was investigated and documented by the Cox committee, the very same body that investigated and recommended a prohibition on bilateral trade in space items. In the

aircraft technology case, the U.S. manufacturer McDonnell Douglas exported controlled precision-machining equipment to a Chinese commercial facility and later allowed its diversion to a Chinese factory making military aircraft components and cruise missiles.\textsuperscript{392}

In 2012, the Department of Justice reached a major settlement with UTC, a U.S. corporation that owned leading aircraft firms, for export control violations and related offenses. The “charges involved more than 800 exports in violation of the Arms Export Control Act from the mid-1990s to 2011.”\textsuperscript{393} An unspecified number of these offenses occurred in connection with the firms’ sales and joint-venture operations in China. Among the most significant violations were those committed by UTC-held jet engine maker Pratt & Whitney Canada. U.S. officials said that the company illegally exported “U.S.-origin military software used in the development of China’s first modern military attack helicopter, the Z-10” and engines that were installed on the Z-10 during its development phase.\textsuperscript{394}

During this same period, the U.S. Department of Justice charged or prosecuted several individuals for actual or attempted illegal exports of controlled aircraft technologies to China. These items included complete and partial inertial navigation systems for fighter jets (1998), fibre-optic military gyroscopes with military aircraft applications (1999), U.S. military source code designed for the precision training of fighter pilots (2007), carbon-fibre material with applications in defense aircraft (2008), military technical data on unmanned aerial vehicles (2008), C-130 military aircraft training equipment (2008), trade secrets relating to the U.S. Air


Force’s C-17 transport aircraft and the B-1 Bomber (2008), and fighter pilot cueing systems (to Taiwan, 2008).\textsuperscript{395} Other individuals were found by law enforcement agencies to have illegally attempted to sell to China during this period “military microprocessors that could be used in airborne battle management systems;” a complete afterburning turbofan engine, built by GE to power the U.S. F-16 fighter; and complete UH-60 Blackhawk helicopter engines.\textsuperscript{396} The number and nature of the violations indicated that Chinese demand for controlled aircraft technologies existed throughout this period. The incidents also suggested that U.S. export control compliance and verification institutions were weak.

Finally, assessments of the U.S. export control regime by government agencies identified weaknesses in this system, raising doubts about its efficacy as a means to manage the technology transfer risks posed by U.S. aircraft industrial integration with China. The GAO conducted several studies that exposed problems which weakened aspects of the regime applicable to exports of dual-use and defense aircraft items.\textsuperscript{397} These included overburdened licensing,


monitoring, and verification units and weak enforcement mechanisms in specific areas. These studies also found that conflicts of interest facing actors both implementing and bound by export controls risked undermining the regime. The GAO concluded that these problems compromised the functioning and reliability of the system.

Over these two decades, evidence suggesting that export controls were not reliable means to prevent sensitive technology transfers to China mounted. Concerns about the robustness of the export control regime dovetailed with growing worries about Chinese efforts to illicitly acquire sensitive technologies across many areas, including guarded industrial and national security information. In spite of these developments, U.S. leaders maintained policies and programs that sustained bilateral trade, industrial integration, and cooperation in the air sector.

These different factors combined to make the air sector an unlikely site of China-U.S. trade, integration, and cooperation. The strategic status of the air sector, the risks of technology transfers inherent in trade and integration, the applicability of commercial aeronautic technologies to defense programs, advances in China’s defense aircraft programs, and major export control violations all posed obstacles to bilateral trade and cooperation. In view of these circumstances, the U.S. government was unlikely to maintain policies allowing trade, industrial integration, and cooperation throughout this period, and yet it did.

**Conclusion**

The civil-commercial air sector presented a mix of conditions shaping the prospects for China-U.S. trade and cooperation during the 1989-2009 period. Some conditions made trade, integration, and cooperation likely between the two countries while others made them unlikely.

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Several factors induced bilateral trade and civil cooperation. China’s demand for aircraft products was soaring, while leading U.S. manufacturers of aircraft items sought new export markets. The economics of aircraft programs and manufacture compelled firms to engage in the transnational integration of their activities, suggesting the likelihood of China-U.S. industry partnerships. Finally, European firms both competed and collaborated with U.S. firms to capture a share of the Chinese market, making the withdrawal of U.S. firms from China unlikely.

Several factors also made bilateral trade and civil cooperation improbable sectoral outcomes. The status of the sector as a strategic element of national economies and infrastructures made it an unlikely site of commerce and cooperation between countries in a tense security relationship. Technology transfer risks inherent in industrial partnerships and the applicability of commercial aircraft items to China’s defense programs also hindered the prospects for bilateral relations. Concurrent advances in China’s defense aircraft technology suggested that U.S.-invested commercial partnerships strengthened an industrial base oriented toward China’s defense modernisation. Finally, illegal attempted or actual technology transfers to China during this period provided mounting evidence that the export control regime was insufficient to manage the transfer risks inherent in industrial integration. These developments gave U.S. policymakers reason to re-evaluate the permissive export controls and other policies that allowed bilateral integration to continue and expand during this period. Aircraft items became likely objects of tight U.S. restrictions on their export to China, rules that would curtail trade and industrial partnerships.

The air sector presented a mix of incentives and disincentives for bilateral integration and cooperation similar to the space sector’s. However, in contrast to space, in air both governments adopted and maintained policies that allowed and supported trade, integration, and cooperation. Policymakers judged that the benefits of bilateral trade and cooperation outweighed their costs
and risks. Trade and economic priorities guided U.S. policy toward China in the air sector, but subordinated to technology transfer concerns in the space sector.
The aeronautic specialist culture

Introduction

By the 1980s, commercial aircraft manufacture on a significant scale had spread from Europe and North America to other continents, including parts of East Asia and Latin America. Individuals engaged in commercial aircraft manufacture and civil aviation in these different countries shared a technical and professional culture unique to their sector. This culture consisted in a set of basic assumptions about humans and technology. Specialists expressed these philosophical commitments in their representational practices. These consisted in the habits of speech and writing they used to represent the sociotechnical systems of air flight.

Aeronautic specialists routinely represented configurations of aeronautic technologies and humans in action. Their depictions located particular aeronautic artefacts in their practical settings, comprising human operators, organisations, facilities, policies, and other institutions. As experts described relationships between these parts, they performed representational practices shared throughout their community. These practices reflected and expressed a set of basic philosophical assumptions about the human-technology relationship. Circulated throughout the specialist community in representational practices, this set of philosophical commitments constituted a common sectoral culture.

This culture shared among specialists was neither intrinsic to their technical practice nor given by the properties of aeronautic devices themselves. Rather, their culture was a historical artefact, the product of several currents of thought and practice that converged within the specialist community. Aeronautic experts internalised and appropriated these currents of thought and practice and then reproduced them in their own habits of speech and writing. They relied on these habits when they represented their sector in the course of their work.
These habits of representation circulated between national aeronautic communities, spreading throughout the global air sector. Aeronautic experts in different countries came to share a single common transnational specialist culture, expressed in common representational practices. This gradual diffusion occurred through several channels during the period after World War II. Once this specialist culture had spread throughout the global air sector, other mechanisms maintained and reinforced it. Trade and the movement of people also facilitated the bilateral movement of cultural practices and ideas between the United States and China.

As a result, aeronautic experts in both China and the United States tended to represent the sociotechnical systems in their sector in similar ways. As they articulated human to technical systems in these depictions, experts conveyed their common understanding of relations between humans and machines and between society and technology. In specialists’ representations, humans enjoyed agency over their devices. Individual humans were purposeful and capable actors, the instigators of technical change. Societal conditions shaped technical systems. These conceptual relationships formed the background knowledge structuring experts’ representations of sociotechnical systems.

As aeronautic experts in China and the United States advised policymakers and decisionmakers in their countries, they imparted their representational practices and the background knowledges these carried. Specialists represented and interpreted the sector for these individuals in government, in the process defining and constituting it as an object of policy. Experts’ representations of sociotechnical configurations in the sector conveyed their underlying philosophical assumptions about humans, technology, and international politics. These background knowledges called forth implicit policy prescriptions. Policymakers and decisionmakers in China and the United States adopted policy rationales based on these representations, underlying assumptions, and tacit prescriptions. Embedded in both countries’
policies in these ways, the aeronautic specialist culture was constitutive of the bilateral order in this sector.

This chapter examines the content and origins of the specialist culture shared among Chinese and U.S. aeronautic experts. The first part of this chapter examines the anthropology, sociology of technology, and theory of international politics espoused as background knowledge by this transnational community. The second part traces the content of this sectoral culture to some of its major sources. The third part illustrates how aeronautic experts of the 1990s and 2000s expressed their specialist culture by reproducing specific constructions of their sector.

1. Human-technology relations in aeronautic discourses

Aeronautic experts’ discourses conveyed their common assumptions about human-machine and society-technology relations. These formed the background knowledge underlying their representational practices. Experts did not relate their philosophical commitments explicitly, but expressed them implicitly in the ways they represented individuals, society, and technology in their sector. They conveyed their specialist culture in their representations of the sociotechnical systems of flight through air. Their discourses revealed the substance of their community’s culture, rendering it observable to outsiders.

Specialists’ shared background assumptions about humans and technology formed three informal theories about humans, societies, and technology. The first of these tacit theories was an anthropology, the second was a sociology of technology, and the third was a theory of international politics.
1.1. The aeronautic specialist’s anthropology

Aeronautic specialists’ representations of their sector conveyed a distinct anthropology made up of basic assumptions about how individuals relate to society and to their tools. Their tacit anthropology comprised two elements: a view of human beings as individual agents and an a view of technologies as instruments.

1.1.1. Society and the individual

Expert representations of aeronautic sociotechnical systems tended to convey an implicit understanding of society as a collection of individual agents. This mode of representation produced purposeful and capable individuals as sources of change in sociotechnical systems. In specialist accounts, the technical configurations of flight did not change as a result of diffuse and impersonal structural processes. Rather, the choices and actions of individuals transformed these systems over time.

In this vision, the prime movers of change were individuals’ desires and needs, rather than their structurally determined circumstances. Moreover, individuals were not derivatives of their contexts, but idiosyncratic personalities. In histories of aeronautics, experts tended to emphasise the characteristics of individuals. Their representations focused on the impact of outsized and unconventional individuals – rebels and eccentrics – on their sector’s history. A collection of capable, purpose-driven, and unique people had created and shaped the systems of flight.

1.1.2. Humans and their tools

As sectoral experts represented the sociotechnical systems of flight, they also articulated humans to their technologies. These depictions reflected a shared theory of the human-machine
relationship. This theory comprised an instrumentalist view of technology in general and a processual understanding of particular technological artefacts.

When aeronautic experts represented human and technical systems in action, they represented technologies as passive instruments of their human masters. Machines, in this view, possessed no inherent capacity or efficacy. Technologies did not cause outcomes or generate effects upon the world around them. They became consequential only in the hands of human users and operators, who applied them to their ends. Pilots flew their planes. They were not flown by them. Humans were not constituted by their technologies. Instead, technologies only mattered insofar as humans used them in pursuit of their goals. Devices were means, interchangeable and substitutable. They were incidental, not fundamental. By analogy, these ideas amounted to two propositions: guns do not kill people; people with motives kill people.\textsuperscript{399}

Aeronautic experts’ depictions of technology in general and of certain technologies in particular produced them as derivative of human processes. Specialists characterised devices as resulting from individual choices, labour, and use. The technical was the “human-built.” From inception to the end of its operational life, an artefact was the sum of human inputs. Humans’ design choices created machines. Physical and intellectual labour built them. A passenger jet embodied the priorities of its designers; the regulations and standards of its social context; its producers’ methods and interests; its owner’s maintenance practices; and its users’ history of in-flight operational choices. Humans constituted and reconstituted their objects through the uses to which they applied them. Rather than endowed with inherent properties or features, artefacts derived from and reduced to the intentions of their human makers and users. These processes –

creation, fabrication, definition, and constitution in use – were integral to how specialists represented the devices of flight.

Aeronautic specialists’ representations of technology reflected their humanistic commitments, including their view of humans as intentional and capable. They portrayed human agents as shapers of technology. Sometimes, aeronautic specialists adopting this mode of representation committed the “designer fallacy.” In other words, they assumed that human designers deliberately foresaw and intended every later feature and consequence of the devices they made. In some views, specialist portrayals of human actors in aeronautics at times granted them too much foresight, clarity of intent, and capacity.

1.2. The aeronautic specialist’s sociology of technology

Aeronautic specialists’ representational practices conveyed assumptions about the interaction of societal and technological conditions, forming a distinct sociology of technology. Part of their background knowledge, this sociology was built upon the same vision of the human actor as their anthropology. Their tacit sociology comprised two elements: a view of the sources of technical change and a view of the society-technology relationship.

1.2.1. Sources of technical change

When aeronautic experts described the evolution of particular sociotechnical systems, such as jet engines and air traffic control systems, they expressed an implicit understanding of

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401 Ibid.
402 E.g. Walter G. Vincenti, “The Technical Shaping of Technology: Real-World Constraints and Technical Logic in Edison’s Electrical Lighting System,” Social Studies of Science 25, no. 3 (1995): 553–574. Although this article is about electric lighting, Vincenti is primarily an aeronautical historian. His major works on aeronautics are listed in the bibliography.
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technical change and what caused it. Specialists explained technical change as a process led by human agents, whom they portrayed as deciding the pace and direction of technology’s evolution. Technical advances were not exogenous to their social context, but occurred at the instigation of human agents and in response to societal conditions. Beyond mere circumstantial shapers of technical change, these factors were substantive determinants of the process: they determined not only the likelihood and rhythm of technological evolution, but also its form and content.

1.2.2. The society-technology relationship

In addition to representing individuals as shaping particular sociotechnical systems, aeronautic experts sometimes represented technological transformation in more general, abstract terms. Representing their sector at this higher level of abstraction, experts reiterated a similar sociology. They defined society as unilaterally shaping technology. Technical systems evolved in response to societal forces, conditions, and demands. For example, changes in the global availability of fuel, investment in research and development, and regulatory institutions shaped the properties of aeronautic hardware.403 Technology was endogenous to society. For aeronautic experts, technology itself could neither be held responsible for humanity’s ills, nor credited for its improvement. Rather, it was the inventors and pioneers of flight who were celebrated as changing the world with their bold innovations and daring actions.

1.3. **The aeronautic specialist’s theory of international politics**

As aeronautic specialists represented sociotechnical systems of air flight, they also conveyed a tacit theory of international politics. Aeronautic experts tended to see the international environment as relatively benign, populated by a diverse set of entities, connected to other terrestrial systems, and trans-boundary in nature. The sociotechnical systems of flight transcended national borders. Aeronautic experts’ theory of international politics comprised two elements: a view of the air domain and a view of the international system.

1.3.1. **The air domain as a site of international politics**

As aeronautic experts represented the sociotechnical systems of flight, they also constituted the air domain and the air sector, populated with actors and institutions they envisioned, as sites of international politics. They tended to associate both the physical environment and the sector with terrestrial resources and infrastructure systems. They also defined airspace and the air system as transnational environments.

When experts represented the air domain as a physical environment, they described it as a finite three-dimensional space: a layer enveloping the surface of Earth and about 100 km thick. The airspace consisted of the planet’s atmospheric layers, ending at the notional boundary of outer space, where the effects of drag on moving objects approached zero. Most commercial aircraft operated in the stratosphere and below, so in practice many aeronautic experts thought of the air as an even more bounded environment.

Represented as a setting for human action, the air domain was a configuration of sociotechnical systems linking ground and sky. Equipment manufacturers, airlines, air forces, traffic control towers, protocols, and practices came together in configurations that created air travel. Aeronautic specialists conceived of devices and systems – radars, radios, and runways –
as interfaces between the physical domains of air and land. These sociotechnical arrangements constituted for pilots, passengers, and controllers the common experience of a point-to-point journey between destinations on the ground, rather than a foray off the surface of their planet. The air sector was of the Earth.

Experts represented airspace as a configuration of corridors connecting destinations. In the process, they produced the air domain and the air sector as a global network. Integral to these visions of the air domain was unfettered movement across national borders. Desirable and seemingly natural, global connectedness was the main advantage presented by the transportation infrastructure in which experts located the air domain and aeronautic technologies.

1.3.2. Nature of the international system

When aeronautic experts represented the sociotechnical systems of flight, they also conveyed their conception of the international system. They tended to represent the environment beyond their borders as composed of diverse actors entangled in webs of mutual dependence. Furthermore, although aeronautic specialists represented international commercial competition as ubiquitous, they characterised the international environment as fundamentally benign.

In aeronautic experts’ representations, a variety of entities acted in the international system. Diverse actors populated the global environment they perceived, including national and local government agencies, international and national standard-setting organisations, regulatory bodies, firms large and small, airlines, airports, and passengers. Any transaction implicated a plethora of public and private organisations and actors. The sector was a public-private hybrid composed of vastly different entities embedded into each other.

Aeronautic experts represented the international system as featuring important interdependence and interconnectedness between countries. Interdependence resulted from trade
in aviation goods and services and was fostered by international institutions. National
governments agreed to common rules and procedures for ensuring safe and efficient flight. As
states built up international regimes governing the civil, commercial, and military use of airspace,
they deepened their reliance on each other and on multilateral institutions. Aeronautic experts
took for granted that intergovernmental cooperation was successful and productive.

In these representations, nation-states were fragmented, internally differentiated, and
composite. Their constituent parts were intertwined with actors beyond their borders. Just as air
traffic crossed national boundaries, so too did the reach of these entities. Organs of the nation-
state operated in, with, and through foreign territories. These transnational arrangements were
integral to how state agencies pursued their goals.

Despite these interdependencies, aeronautic specialists did not see a purely cooperative
international environment. Instead, they observed cooperation co-existing with fierce and
unrelenting international commercial competition in their sector. Airlines and aircraft
manufacturers vied for global market share. Equipment manufacturers competed in defense
markets, contending to supply militaries around the world. For the aeronautic specialist, then, the
international system was both competitive and cooperative. North-Atlantic allies partnered on
collective air defense, but their national aircraft manufacturers fought each other for commercial
and military contracts everywhere. Although experts described this commercial competition as
ubiquitous, they did not represent it as existentially threatening or spiralling out of control.
Some even characterised international competition as fostering innovation and efficiency. The
international system was fundamentally benign and presented more opportunities than threats.

Aeronautic experts’ distinct social theories coalesced to form a coherent specialist culture.
Sectoral experts in different countries shared and expressed this specialist culture in their
representational practices. It comprised an anthropology, which assumed that society was
reducible to a collection of individuals and that technological artefacts were passive instruments moulded to human intentions. This specialist culture also comprised a tacit sociology of technology, in which societal factors shaped technical systems. Individually or collectively, humans decided the course of technological change. Finally, these social theories included a shared theory of international politics. In this theory, the international system reflected the air domain itself, a trans-boundary space. Diverse public and private entities were entangled in complex, interdependent relations on regional and global scales, engaging in both cooperation and competition. The international environment was benign.

2. Sources of the aeronautic specialist culture

Aeronautic experts’ representational practices reflected this community’s encounter with intellectual currents and fields of activity related to, but just outside of, their own. Some of these currents originated within aviation and aircraft manufacture, but predated participants in the air sector of the 1990s by many decades. Others originated outside the sector, but were absorbed and internalised by aeronautic experts over time.

These sources provided the individualist, humanist, and technologically instrumentalist conceptions of human-technology relations guiding how aeronautic experts represented the sociotechnical systems in their sector. As specialists reproduced these philosophical commitments in their representational practices, they reinforced, perpetuated, and spread them. The intellectual currents and fields of practice that supplied these philosophical assumptions originated in parts of Western Europe and the United States, but later diffused throughout the transnational aeronautic community, including to Chinese specialists.

There were four important sources of the transnational aeronautic community’s specialist culture. The first source was an origin story of air flight itself, which centered on early aviation
pioneers. The second was the cult of the pilot, a tradition of elevating the pilot figure in habits of speech and organisational practices. The third source lay in the liberal-internationalist convictions of British air power advocates before and during World War II. The fourth source consisted in microeconomic models and analyses of the aircraft-manufacturing industry. While the aeronautic specialist culture was necessarily a sum of countless influences, expert discourses of the 1990s and 2000s suggest that these four sources were among the most important.

2.1. Histories of early aviation pioneers

As aeronautic specialists of the 1990s and 2000s described their sector, they conveyed the philosophical conceptions of society and technology that underlay histories of aviation pioneers. These narratives recounted the dawn of flight, forming a set of origin myths circulated throughout the transnational community of aeronautic specialists. The sources and subjects that inspired the writers of these histories spanned the period from 1875 to 1948, from the days of early aeronautic experimenters to the end of the Second World War. Most came from the United States, England, and France. Embedded within these histories were tacit theories of the individual, society, and technology. An individualist, agential anthropology and a humanist sociology of technology structured how these specialists told the early history of flight. As these narratives circulated throughout the aeronautic community, so did their representational practices and the philosophical assumptions contained within them.

Experts shared these stories with successive generations of their community and the general public. They also transmitted them across national borders. Specialists all over the world grew familiar with these stories because materials to which they were exposed reproduced
and referenced them. Aeronautical engineering textbooks, industry publications, policy documents, and other official communications, from speeches to inscriptions, introduced early aircraft pilots and engineers. Commemorative practices honouring these historical figures were performed at international events, such as airshows, conferences, and competitions.

Many histories took the form of biographies that “canonized the early aircraft pioneers,” wrote Dominick Pisano, Curator of Aeronautics at the U.S. National Air and Space Museum. The authors of these accounts located agency in individual human actors. Their proponents subscribed to a Great Man history of flight, explaining historical processes as results of individuals’ actions. Among these processes were changes in the sociotechnical systems of flight. Examples of included transformations in transport aircraft technology or the introduction of new means to apply air power in war. In these accounts, changes to sociotechnical systems were not determined by structural factors, but contingent on individual action. Pioneers, adventurers, experimenters, entrepreneurs, and explorers made aeronautic history.

The model of human actor underlying these histories was individualistic and intentional. Biographical texts lionised their subjects, carefully rendering traits and experiences that made them exceptional characters. Historical outcomes often hinged on protagonists’ idiosyncratic personalities. In the stories these specialists told, structural forces – power relations, institutions, ideologies, modes of production – receded, providing a mere backdrop for figures who took center stage and drove the plot. Special individuals prevailed against or transformed their

408 Ibid.
conditions, seizing opportunities and overcoming obstacles. The traits that aeronautic specialists celebrated in their heroes were grit, doggedness, and ingenuity. Gumption and greed propelled the development of flight; wars and markets provided the settings. Visionaries defied their naysaying contemporaries. In these accounts, conviction trumped context and character overcame constraints.

Aeronautic historians introduced this model of the human actor through the “new personalities” they developed in their narratives about the dawn of aviation. Foremost among these characters was the aviation “pioneer,” but they also celebrated aviators, aeronauts, pathfinders, swashbucklers, flyboys, entrepreneurs, dreamers, visionaries, conquistadors, “Barons of the Sky,” and “Knights of the Air.” Their subjects pursued “a

416 Benson, Aviator of Fortune.
dream of wings”\textsuperscript{422} and the “conquest of the skies.”\textsuperscript{423} They raced for flight and fought for aviation supremacy.\textsuperscript{424}

Epitomising this tendency were written and oral histories of Orville and Wilbur Wright, remembered as the inventors of the modern flying machine.\textsuperscript{425} The tale of the Wright brothers was familiar to every aeronautic expert. The Wrights embodied the traits of the ideal-type aeronautic protagonist. The ultimate entrepreneurs, the Wrights were self-taught, self-made, and, in the beginning, self-funded.\textsuperscript{426} They were unique individuals whose impact on the history of aviation stemmed from their peculiar personalities and convictions. Their commitment to the dream of flight remained unshakeable in the face of initial scepticism and ridicule. The perseverant and inspired Wrights overcame these challenges, changing history in the process.\textsuperscript{427}

\textsuperscript{421} Lester J Maitland and Charles Pelot Summerall, \textit{Knights of the Air} (Garden City, N.Y.: Doubleday, Doran & Co., 1929).
\textsuperscript{422} Crouch, \textit{A Dream of Wings}.
U.S. government texts and policy statements reproduced this characterisation of the Wrights as the lone, pioneering originators of flight. According to the U.S. Federal Aviation Administration’s institutional history,

The modern age of powered flight began in 1903, when Orville Wright made the first sustained, powered flight on December 17 in a plane he and his brother Wilbur built. This twelve-second flight led to the development of the first practical airplane in 1905, and launched worldwide efforts to build better flying machines. As a result, the early twentieth century witnessed myriad aviation developments as new planes and technologies entered service.\footnote{428 "A Brief History of the FAA,” Federal Aviation Administration, February 1, 2010, http://www.faa.gov/about/history/brief_history/.
\footnote{429 National Aeronautics Research and Development Policy, 6.
\footnote{430 Meilinger, Airmen and Air Theory: A Review of the Sources.
and through their efforts, individuals shaped their situations and the structures around them. An introduction to such an account illustrates this tendency.

Filled with colorful characters from early aviation history, including Charles Nungesser, Igor Sikorsky, René Fonck, Richard Byrd, and Paul Tarascon, history and the imagination take flight in this gripping account of high-flying adventure, in which a group of courageous men tested the both limits of technology and the power of nature in pursuit of one of mankind's boldest dreams.

Histories of the early days of flight also conveyed a vision of the human-machine relationship. In this implicit understanding, technologies were instruments, created by human agents. The advance of aeronautics was neither linear nor dictated by some logic internal to technology itself. Instead, it was inventors and innovators who progressed the technical systems of flight. A text by historian and retired U.S. Air Force colonel C.V. Glines illustrated aeronautic history told in this mode.

Man dreamed of vertical flight long before Leonardo da Vinci made his famous 1483 sketch of a lifting airscrew [...]. It wasn’t until the first two decades of the 20th century, however, that interest in rotary-wing development intensified and experimenters in a dozen nations persisted in trying to make those dreams a reality. [...] The names of early rotorcraft pioneers, rarely remembered today, include Gaetano Crocco of Italy, who patented a cyclic pitch mechanism in 1906. The French brothers Louis and Jacques Breguet built a gyroplane that hovered for one minute in 1907.

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A subset of aviation histories was dedicated to figures that had overcome structural adversity. These accounts celebrated individuals who had succeeded despite discrimination, inequity, or other obstacles through the force of their character, their will, and their hard work. Examples of histories and biographies of this type include histories of the first African-American pilots and aeronautic engineers and of early female aviators and innovators. Broadnax, Blue Skies, Black Wings; Fred Erisman, From Birdwomen to Skygirls: American Girls’ Aviation Stories (Fort Worth, Tex.: TCU Press, 2009); Janann Sherman, Walking on Air: the Aerial Adventures of Phoebe Omlie (Jackson: University Press of Mississippi, 2011); Claudia M Oakes, U.S. Women in Aviation through World War I. (Washington: Smithsonian Institution Press, 1978); Bieke Gils, “Pioneers of Flight: An Analysis of Gender Issues in United States Civilian (sport) and Commercial Aviation 1920–1940” (MHK, University of Windsor (Canada), 2009); Linda McCann, “Feminine Wings: The Women’s International Association of Aeronautics” (M.A., California State University, Fullerton, 2012).

Bak, The Big Jump.

That same year, Paul Cornu, a French bicycle maker, is credited with making a helicopter with counter-rotating rotors rise in full flight with him aboard for about 20 seconds. Two years later, Igor Sikorsky built a pair of helicopters in Russia with dual coaxial rotors, but the engines were underpowered, and both machines vibrated dangerously.\footnote{C.V. Glines, “Autogiro Genius: Juan de La Cierva Made Several Pivotal Breakthroughs That Helped Solve the Stability and Control Problems of Early Rotorcraft,” \textit{Aviation History}, 2012, 54.}

As these histories circulated throughout the transnational aeronautic community, so did their underlying theories of the individual, society, and technology. They conveyed an individualist anthropology and a humanist sociology of technology. These philosophies later structured how specialists represented the sociotechnical systems in their sector. Reproducing these ideas at the turn of the millennium, specialists portrayed individuals as agential and capable. They also explained technical processes in their sector, such as improvements to aircraft systems, as resulting from human choices and subject to human direction and control.

2.2. The cult of the pilot and the human operator

Aeronautic specialists’ implicit social theories of technology also reflected the so-called “cult of the pilot” and related concepts of the human operator of flight machinery. Described and analysed in historiographical and cultural studies of aviation, the cult of the pilot referred to the celebration of the role and traits of the human controllers of aircraft. It found expression in representational practices, in the design of technical systems, and in the structure of organisations. The bulk of these manifestations of the cult of the pilot-operator dated from the period between 1903 and the late 1960s and originated in the United Kingdom and the United States. The pilot-operator concept remained central to aeronautic knowledge and practice throughout the first century of flight, even as aircraft evolved and the demands they placed upon pilots changed.
The pilot figure was engrained in American popular culture of the period after World War II. As a cultural trend, the cult of pilots elevated them to icons and heroes. Military histories, museums, novels, and films lionised the pilot-hero. Their authors partook of the representational practices used by the historians of early aviation pioneers, discussed above. Chroniclers of pilot-hero exploits constructed personalities, such as “the aristocratic aviator, the fighter pilot, the ace, the barnstormer, the stunt pilot.” Subjects of these accounts included Charles Lindbergh, Amelia Earhart, Chuck Yeager, and the fighter pilots of World War I and II.

The pilot-hero archetype existed in and circulated to different settings – civil and military, professional and private – in different countries. For example, historian Martin Francis described wartime Britain, where the public was spellbound by the martial endeavours and dashing style of the young men of the RAF, especially those with silvery fabric wings sewn above the breast pocket of their glamorous slate-blue uniform. Decades later, aeronautical experts’ recollections of private pilots illustrated the pervasiveness of these ideas in the United States.

This personality core [for pilots] describes a man who expresses a higher manifest need for achievement, exhibition, dominance, change, and heterosexuality than the national norms for adult males. This aviation profile fits well with the popular description of pilots in song, movies and verse, as [a] courageous, romantic, “he man.”

Research on news coverage of a 2001 incident in which a U.S. intelligence aircraft and a Chinese fighter collided at sea indicated that the pilot-hero image was reproduced in Chinese press

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436 Mindell, *Digital Apollo*, 20.
437 E.g. Bak, *The Big Jump*.
accounts of the event. It suggested that this mode of characterisation resonated with publics in China.

In the United States, the pilot-hero figure lingered in the imagination of specialists long after its real-life exemplars disappeared. An expert observed this trend in the 1970s.

We remember vividly our awesome wonder at those lean, keen-eyed, rarefied members of the Superman Club. Their casual, careless, slouching manners toward all mere earthbound people and objects. Their helmets and goggles, silk scarves, big wrist watches, leather jackets.... Now, of course, aviation has become commonplace. Superman has been replaced by the shoe manufacturer across the street who is bald, has a paunch, and uses his own four-place plane to run his three factories scattered around the landscape.

Portrayals of the pilot-operator as heroic became an important element of aviation culture. They laid the foundations of the humanistic and individualistic theories shared throughout the transnational aeronautic community, including aviation professionals and enthusiasts and technical specialists.

While the pilot-figure was familiar to both specialists and non-specialists, among technical aeronautic experts, a distinctive cult of the pilot emerged. In the specialist context, it consisted in practices that expressed the conceptual and operational centrality of the pilot. Expert practices produced the human operator of the aircraft as possessing agency, command, and a core position in the sociotechnical systems of flight. These practices reinforced the instrumentalist theory of technological devices, reiterated a humanistic sociology of technology, and expressed a model of the human actor as a differentiated individual.

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Just as space specialists debated the appropriate roles for humans and robots at distant destinations, aeronautic experts deliberated their own dimension of the human-machine relationship. Historians describe two competing schools of thought about the pilot and aircraft in early aeronautics. The first portrayed pilots as “airmen,” emphasising their skill and control over the vehicles they commanded. Advocates of this view argued that engineers should design aircraft to be highly manoeuvrable and responsive to their pilots, features that came at the expense of their ease to fly and stability.\textsuperscript{442} The second school characterised pilots as “chauffeurs,” sedately and passively operating stable, self-guided, easy-to-fly vehicles.\textsuperscript{443} These experts believed in automating aircraft, advocating design choices that reduced pilots’ discretion and bounded their control of the machine.

During the first decades of flight, the concepts of airmen and pilot controlprevailed.\textsuperscript{444} While these ideas co-evolved with flight machinery, aeronautic experts perpetuated their underlying anthropology, which produced human operators as agents and technologies as powerful but compliant tools. As aeronautic engineer and historian David Mindell summarised of early aviation, “the Wright brothers invented not simply an airplane that could fly, but also the \textit{very idea} of an airplane as a dynamic machine under the control of a human pilot.”\textsuperscript{445} When specialists represented human-machine configurations in flight, they reproduced these ideas. Aeronautic experts imagined pilots as daring flyers at the helm of technological marvels.

Inherent in the early aviators and engineers’ “idea of a controllable aircraft was a new type of person: a skilled pilot,” found Mindell.\textsuperscript{446} Wilbur Wright himself wrote in 1900 that, in

\begin{itemize}
\item \textsuperscript{442} Mindell, \textit{Digital Apollo}, 22.
\item \textsuperscript{443} Ibid.
\item \textsuperscript{444} Ibid., 23–29.
\item \textsuperscript{445} Ibid., 21.
\item \textsuperscript{446} Ibid., 22.
\end{itemize}
flying, “what is chiefly needed is skills rather than machinery.” In this view, “The Wright brothers, by emphasizing the importance of skill, created not simply a controllable flying machine, but also its human counterpart – the pilot.” To early aviators, the human participant in the sociotechnical system dominated the machine. As Mindell explained, “the pilot’s continuous, active involvement – his skill – is required to maintain stable flight. Flight itself is then a product of the pilot. If the pilot creates flight, then his status rises accordingly.”

These early portrayals of the pilot also instilled an individualism in the aeronautic community. Specialists during these formative decades emphasised the notion of “personal skill” as an essential attribute of pilots. Their characterisations rendered differentiated individuals. Not all pilots were equally skilled. Skill is “highly personal” and “[s]kills set people apart,” wrote Mindell. Representations of flight emphasising pilot skill reinforced an individualistic anthropology and agent-centred sociology among aeronautic specialists.

This vision of individual capacity was written into histories of flight. Biographers and other historians specialising in aeronautical development expressed this model in their portrayals of pilots. For example, Colin Pengelly depicted such an early military aviator.

Albert Ball's individuality and his insistence on fighting alone set him apart from other fighter pilots during World War One. His invincible courage and utter determination made him a legend not only in Britain but also amongst his enemies, to whom the sight of his lone Nieuport Scout brought fear.

Individual-level factors, such as the skill and character of the pilot, rather than the strength of his corps’s training or the sophistication of his machine, decided success or failure in these stories. Particular, individuated persons determined outcomes and shaped history. From the Wrights

447 Ibid.
448 Ibid.
449 Ibid., 23.
450 Ibid., 22–23.
451 Colin Pengelly, Albert Ball V.C.: The Fighter Pilot Hero of World War One (Pen & Sword Aviation, 2010), back cover.
through the emergence of the first professional pilots in the 1930s and through the rest of the century, these ideas remained influential among aeronautic specialists. Sectoral participants entrenched and perpetuated this conception of the pilot-as-individual through their social habits and rituals.  

For many decades, aircraft engineers also experienced pilots as unique personalities, seeing them as eccentric, daring, and even crazy. Pilots in the early age of flight resisted engineers’ designs, preferring to rely as much as possible on their own embodied flying skills rather than the technician’s rules, measurements, and cockpit instruments.

As flight grew more routine and safer after World War II, aeronautic specialists redefined the ideal pilot. Their representations began to emphasise the concept of control. Specialists characterised the human in the cockpit by his control of his machine, perception, and posture.

The pilot evolved into the “aeronautical decision maker,” an agile problem-solver commanding

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452 For example, professional societies and personal scorecards measured differences in pilot performance, creating and celebrating personalities in this occupational class. Fighter pilots enjoyed special distinction as flyers because fighter aircraft were less automated than commercial jets, whose design sacrificed some manoeuvrability for stability. The difficulty of operation of a pilot’s craft defined his level of accomplishment since, in the community’s theory of human-machine interaction, mastery of one’s machine correlated with achievement. Mindell, Digital Apollo, 29–32; Tom Wolfe, The Right Stuff, Revised Edition (New York, NY: Picador, 2008).  

453 Mindell, Digital Apollo, 26.  

their aircraft under unpredictable conditions.\textsuperscript{455} Global specialists’ perceptions of the aeronautic pilot converged around this understanding.\textsuperscript{456}

Aeronautic experts reproduced these models of the human actor as they created and applied technical knowledge in a range of areas. Throughout the 1950s and 1960s, engineers and scientists evolved the concept of the pilot-as-operator to form the ontological foundation for the disciplines of human factors engineering and ergonomics.\textsuperscript{457} In their discourses, the pilot figure became abstracted and anonymous, losing its individuality and heroic aspect. But, even as experts modified aspects of the pilot concept, they continued to represent the same human-machine relationship underlying it. The pilot’s role relative to his aircraft remained of operator, controller, and master.

As aviation matured, aeronautical science became increasingly adept at measuring and modeling the airflow around an aircraft and designing structures and devices to accommodate it. But the core of the aircraft was still the pilot, a human being, a subject that engineering has never fully mastered. Hence the pilot’s importance: performing tasks that are difficult to measure or model.\textsuperscript{458}

Aeronautic specialists continued to represent pilots in these terms into the 1980s, 1990s, and 2000s.\textsuperscript{459} Their portrayals reaffirmed the agential and individual qualities of the human


\textsuperscript{458} Mindell, \textit{Digital Apollo}, 20.

operator, even as flight became more automated and machines took over responsibilities
previously assumed by pilots.\textsuperscript{460} As a professional FAA handbook titled \textit{Aeronautical Decision
Making for Commercial Pilots} explained, “new cockpit technology has tended to place even
more importance on the pilot as an information processor, decision maker, and manager.”\textsuperscript{461}

The cult of the pilot also existed in the form of organisational practices. Expressed in this
way, the humanistic understanding of flight machinery left its mark on aeronautic policy in the
United States. For example, experts described the culture of the U.S. Air Force as centred on the
pilot. Pilots were the most revered individuals in the service.\textsuperscript{462} In the dominant Air Force vision, pilots
were skilled masters of their vehicles, endowed with “the right stuff.”\textsuperscript{463} Aircraft were appendages to
their human commanders. The ideal fighter pilot did not fly an aircraft, but “wore” it like a jacket, or rode his machine “like an expert horseman.”\textsuperscript{464}

This collective emphasis on the pilot role structured the broader organisation of the
service. The leadership and command structure of the Air Force reflected the privileged status of
the fighter pilot as system operator. The sociotechnical systems of air operations were designed
to give play to the judgment and discretion of pilots in action. For defense intellectuals in this
community, the application of air power boiled down to pilot actions and choices, centring on
sorties and strike decisions.\textsuperscript{465} In the United States and the United Kingdom, “airmen’s
organizational interests” helped maintain conceptions of air warfare strategy.\textsuperscript{466}

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\item[461] Jensen and Adrion, \textit{Aeronautical Decision Making for Commercial Pilots}, 1.
\item[462] Meilinger, \textit{Airmen and Air Theory: A Review of the Sources}.
\item[463] Wolfe, \textit{The Right Stuff}.
\item[465] Meilinger, \textit{Airmen and Air Theory: A Review of the Sources}.
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Air Force investments reflected an institutional preference for technical systems that perpetuated a large corps of traditional pilots. The cult of the pilot fed the reluctance of the force’s leaders to develop unmanned aerial vehicles in the 1990s and 2000s, despite mounting evidence that these systems would become integral to the organisation’s mission. The organisational centrality of the pilot may have also been among the factors explaining why fighter programs remained budgetary priorities for the Air Force despite their cost overruns, their uncertain value to the force, and pressing needs for other systems. Air Force decisionmakers resisted changes to technical systems that ran counter to the organisation’s engrained anthropology.

Aeronautic specialists and enthusiasts circulated a concept of the pilot that reinforced a theory of the human-technology relationship tacitly shared within their community. Whether they envisioned the pilot-hero or the pilot-as-operator, their practices reinforced an understanding of humans as agents dominating their machines. In the sociotechnical systems these individuals inhabited and observed, humans possessed capacity and efficacy, while technologies were responsive extensions of their operators. Humans controlled evolving technical systems.

2.3. The liberal internationalism of World War II British aviation advocates

Another source of the background knowledges shared among aeronautic specialists of the 1990s and 2000s was the cultural legacy of earlier British aviation advocates. This community of political elites, industrialists, and military personnel coalesced in interwar England, its influence growing during the Second World War and persisting in its aftermath. These aviation advocates dedicated themselves to growing Britain’s air power, a programmatic agenda that grew out of their liberal-internationalist political ideals. Vindicated by the allied victory, proponents of this vision and their successors later disseminated their ideas among aeronautic specialists in other
countries. The liberal-internationalism of British aviation enthusiasts introduced distinct social theories to the transnational aeronautic specialist community.

In his 1991 book *England and the Aeroplane*, historian of technology David Edgerton examined the philosophical and political commitments of the country’s early advocates of aviation.\(^{467}\) Although British aviation advocates were not uniformly liberal, Edgerton argued that “a liberal-internationalist, and thus anti-nationalist and anti-fascist ideology, was central to British enthusiasm for the aeroplane, and for bombing, from the interwar years” onward.\(^{468}\)

Air enthusiasts of this stripe shared an agential anthropology, reflecting a democratic vision that emphasised and celebrated the freedom, rights, and capacities of the individual. Also central to their commitments was a construction of aeronautic hardware itself: “the liberal view of the aeroplane.”\(^{469}\) Advocates discursively produced sociotechnical systems in which the technologies of flight – civil transports, bombers, and fighters – served and defended a liberal social order. Edgerton found that liberal internationalists saw great dangers in the rise of nationalism and militarism. They sought to counter these enemies of liberalism not only by collective security, but also with modern machines, particularly aeroplanes, which they associated with a possible world organisation charged with defending a liberal world order.\(^{470}\)

Aviation advocates’ international politics presupposed an underlying harmony of interests between nation-states. In their view, countries and their citizens would collectively and individually benefit from peaceable economic relations, were they not hindered by their autarkic and fascist enemies. British air-sector participants cherished “dreams of free trade and peace.”\(^{471}\)

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469 Ibid.
470 Ibid.
471 Ibid.
This community’s liberal-internationalist views also included an implicit sociology of institutions. British aviation proponents believed in the influence of institutions on society, within their country and for the world. A commitment to democratic institutions and a hostility to totalitarian regimes guided their domestic politics and their air power agenda. For example, even as they advocated for building more aircraft, they parted ways with those on the continent who called for the large-scale state-led mobilisation of societal resources for aeronautic technology programs. The British advocates’ preferences for decentralised and market-based institutions shaped their program.

Looking beyond their borders, the aviation enthusiasts saw the promise of institutions for the world. They called for the establishment of robust international organisations, even envisioning forms of world government. These ideas included creating an “International Air Police,” a proposal that became “commonplace” in this community. “In the hands of a world authority,” aeroplanes “would bring the world to its liberal senses,” explained Edgerton. Support for this proposal was substantial not only in Britain, but also in the United States and France during the interwar period, World War II, and its aftermath.

In interwar Britain, the liberal-internationalist aviation community expressed ambiguous ideas about the inherent potential of technology, seeing for it a role in reshaping international

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475 Ibid.
relations. Their enthusiasm for the aeroplane included the belief that, in the right hands, it could literally transform the world.  

In this influential view aeroplanes were technologies of (long-distance) communication which crossed political and geographical barriers. In doing so they realised liberal internationalist dreams of free trade and peace. Although the term ‘global village’ was not used, the idea that the aeroplane was bringing about a smaller world – shrinking time and space – was a standard cliché.

The airplane presaged a transnational age for this community. The vision of a borderless future inspired early aviation advocates.

Following the end of the war, the movement’s recollections of wartime aviation and the role of the aeroplane in the Allied victory diffused beyond England to aeronautic communities in the United States and continental Europe, where enthusiasm for aviation was already strong.

Representations in popular culture, in British political life, in trade publications, and in the memorialisation of Royal Air Force heroes perpetuated and disseminated liberal-internationalist values and commitments. Britain’s interwar aeroplane advocates reinforced the model of human actor expressed by sectoral specialists describing early aviation pioneers and pilot-heroes. They also introduced a sociology of institutions and a post-national and trans-boundary concept of airspace and air systems to aeronautic expert circles. As these ideas spread throughout the expert community, they reinforced and complemented the other assumptions making up the sector’s specialist culture.

British interwar aviation advocates introduced and reinforced a theory of international politics within the aeronautic specialist community. This theory assumed a benign international
environment, in which an underlying compatibility of interests between nation-states awaited realisation. This theory also rested on a transnational and post-national vision of the international system, in which firms and individual citizens participated in cross-border trade and global organisations assured their security. Finally, this theory of international politics assumed that institutions were powerful shapers of international and domestic conditions.

2.4. Economic models and *homo economicus*

A fourth source of the aeronautic specialist culture was the post-World War II academic discipline of microeconomics. Economists in the Anglo-American tradition studied and modeled the aircraft-manufacturing industry during this period and, in particular, after 1970, when Airbus was created and a global duopoly in large aircraft manufacture solidified. As economic concepts and models of the sector entered the aeronautic community, they smuggled in their underlying theories of the individual, society, and technology. Throughout the 1990s and 2000s, aeronautic experts reproduced items of economic knowledge in their representations of the sociotechnical systems of flight. In the process, they also expressed and entrenched the discipline’s philosophical assumptions and foundations.

Members of the specialist communities of major aircraft-producing countries gained exposure to and familiarity with how economists represented their sector. Aeronautic specialists became fluent in the basic language of game theory and strategic trade theory. This vocabulary was embedded in the knowledges and practices of their field. Policy documents, legal and regulatory texts, specialist reports and analyses, statements by industry associations, and trade publications reproduced representational practices that drew on economic models and concepts. These media carried economic ideas into the common knowledge of aeronautic specialists in different countries.
Aeronautic experts were exposed to at least two bodies of economic theory that they applied to their sector. The first of these was game theory, a variety of microeconomics used to model firm behaviour in strategic markets. The second was strategic trade theory, another variant of microeconomics that supplied a policy rationale for government support to major aircraft manufacturers. These bodies of academic knowledge shared a common foundation of philosophical assumptions about actors and markets. In the theoretical models of academic economics, society was reducible to an aggregation of rational, utility-maximising individuals. Technical change was a function of policies and the markets they created. They assumed an individualist anthropology and a humanistic sociology of technology. As economic concepts circulated throughout the transnational aeronautic specialist community, they imported and spread these background assumptions.

Game theory concepts diffused across the transnational aeronautic specialist community in several forms. Aeronautic experts drew on microeconomic models of duopoly markets to represent the competition between Airbus and Boeing. Academic economists developed and refined theories of duopolistic competition, such as the Cournot and Bertrand models. Several generations of economists used the competition between the two aviation giants as the paradigmatic real-world illustration of their concepts.480

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Not all aeronautic experts closely studied these models, but ideas derived from them became basic background knowledge within this community. For example, participants in the sector tended to share the expectation, derived from game-theoretic models, that duopolies tend toward a fifty-fifty market split between their two players. They also believed that firms in duopolistic industries tended toward low and decreasing profit margins. In addition to theories of duopoly, aeronautic experts drew on game-theoretic ideas about oligopolies to represent how makers of small jets behaved.


Most economists conceived of society as a collection of individual persons, a theoretical commitment that reflected the discipline’s tradition of methodological individualism. Large-scale societal outcomes – institutions, innovation, trade, and elections – reduced to the discrete actions of many individuals, each pursuing their preferences. The social was the sum of the individual. Aeronautic specialists reproduced this thinking in their representational practices.

Economics also supplied philosophical assumptions about technology, which aeronautic experts also adopted and reproduced. Economists treated technology in different ways. In some
cases, they treated technology as an input into their models. In other cases, they aimed to explain technical change, such as the large-scale adoption of a new technology. Economists often conceived of technical change as the outcome of many individuals’ responses to the incentives and disincentives provided by their institutions and environments. This tendency was illustrated in a body of research and theory about national innovation systems. These analyses traced changes in technology to the choices of calculating human agents. For example, economists saw the growth of robotic manufacture as a result of actors’ responses to exogenous changes in the cost of labour and capital.

As this understanding of technology entered the aeronautic community, it structured how its members represented their sociotechnical systems. In their depictions, the technical features of aircraft were not objectively given by the constraints of physics or engineering, but often a function of actors’ economic choices. As an expert study of supersonic transportation explained, “[i]mplicit in aircraft design specifications are costs—development, production, operations, and maintenance costs— that are considered affordable.”483 Aeronautic specialists described a relationship between “vehicle characteristics and economic goals.”484 Suppliers’ rational adaptations to market competition on price and operating costs shaped the devices they produced.485 In these depictions, business choices were built into aircraft hardware, from the margins in its design to the materials it contained. In other words, aeronautic experts adopted economic discourses to describe the social shaping of technology.

Aeronautic experts similarly represented modes of production in their industry as reflecting economic and regulatory rather than technical constraints on firms. From a technical

484 Ibid.
485 Marsh, “Duelling with Composites.”
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perspective, they saw supply chains linking facilities in multiple countries as sub-optimal. However, they explained that this geographically dispersed model dominated in the sector because of offset policies. Distributing work across countries was the most rational strategy for firms facing markets shaped by these requirements.\(^{486}\) The production of aircraft was not technologically determined, but shaped by economic and political factors. The sociotechnical systems of aircraft production reflected policy choices by calculating government actors, rather than the intrinsic properties of aeronautic technology.

Another source of aeronautic specialists’ representational practices lay in theories of strategic trade applicable to their sector. Economists saw aircraft manufacture as prone to strategic trade policies. In academic economics, scholars modeled particular industries featuring high barriers to entry and the potential to generate rents. Prospective entrants to these sectors initially required government support to overcome these hurdles, but, once established, they enjoyed secure positions and reaped high profits, their future competitors deterred from attempting entry. Firms ensconced in strategic sectors benefitted their national economies by creating positive spill-overs into other sectors, secure high-wage jobs, and taxable revenue. For the strategic trade advocate, the promise of such benefits justified state support to national firms in these sectors.

Strategic trade economists used aircraft manufacture to empirically illustrate their theories. High barriers to entry, the promise of high revenues for those firms that overcame these barriers, and opportunities for governments to shape firms’ strategies through policy combined to make aircraft system integration an ideal-typical strategic sector. For example, the Brander-Spencer

\(^{486}\) Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
model of strategic trade policy explained the decisions of European governments to support and develop Airbus as a competitor to Boeing.487

Ideas of this type spread to sectoral specialists and policymakers in all the major aircraft-manufacturing countries. These ideas grew familiar to aeronautic experts in North and South America, Europe, Japan, and China. The creation of Airbus owed to the agreement on strategic trade theory ideas between the European aerospace industry and policymakers. Infant-industry arguments drew on a similar logic and accorded with strategic trade theory. These were familiar to sectoral specialists in Japan and Brazil. Chinese policy also aimed to foster “apex industries:” high-value-added export industries that posed barriers to entry.488 Chinese aeronautic experts emphasised the value of such industries to their country’s economic advance. Drawing on these economic arguments, they defined passenger jet programs as promising China’s escape from the trough of low value-added, low-tech manufacturing exports.489

Aeronautic experts recognised that strategic trade models provided compelling rationales for policies supporting aircraft manufacturers in different countries. From direct transfers through subsidies for new product development to aggressive export financing, a range of activist policies rooted in strategic trade ideas created and sustained national commercial aircraft industries. Sectoral participants understood that, without these policies, the major manufacturers would have existed in entirely different forms or not at all.490

Economic theories insinuated themselves into the discursive practices of aeronautic specialists through these various channels. In the process, these models introduced and

489 Ibid., 92–96.
490 E.g. a discussion of how government intervention created and supported the British aircraft industry is found in Robin Higham, “Government, Companies, and National Defense: British Aeronautical Experience, 1918-1945 as the Basis for a Broad Hypothesis,” *Business History Review (pre-1986)* 39, no. 000003 (Autumn 1965): 346–347.
embedded their underlying assumptions about individuals, society, and technology into this community. Aeronautic experts absorbed the philosophy of human agency built into these intellectual constructs without needing to closely study economic models. Aeronautic specialists reproduced models of actors, institutions, and technical change from economics in their discourses. Their representations of the sociotechnical systems in their sector located agency in individual human actors and characterised machines and technical processes as derivatives of human choices.

Economic concepts were so deeply embedded in the policies and practices of the sector that they in a sense constituted the sector itself, including the aircraft industry and its actors. Aeronautic specialists in industry and government adopted the analytical tools of academic economics, reproducing them in their representational practices. Expert depictions of the sector drew on economic terms and concepts, influencing policy in aircraft-manufacturing states. At the same time, real-world aircraft manufacture inspired economic theories. Academic economics and the aircraft industry co-evolved.

These developments in aircraft manufacture and academic economics were consistent with how economic sociologists understood the real-world impact of economic theories. For example, Callon observed that theoretical representations of economic actors – *homo economicus* – effectively summoned them into existence, constituting them and participating in their production. A study of financial models by Donald Mackenzie revealed a similar process. In his analysis, theories did not merely represent the economy, but also participated in it. Economic models shaped the behaviours they purported to explain. To paraphrase Mackenzie, rather than

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“cameras” observing the sector from without, economic models were “engines” that shaped aircraft manufacture from within.\textsuperscript{493}

Modern academic economics supplied aeronautic specialists with a vocabulary and conceptual toolkit for representing their sector. In the process, it also conveyed to them a tacit anthropology and sociology of technology. As aeronautic specialists reproduced economic insights in their representations of sociotechnical systems in their sector, they also expressed these basic social theories. Performing these representational practices, specialists produced humans as masters of their machines and large-scale technical processes as reflecting institutions and human choices.

Economic representations of the aircraft industry expressed the same philosophical presuppositions as earlier contributions to the cultural landscape of the air sector. The histories of early aviation pioneers, depictions of pilot-operators, the liberal-internationalist commitments of British airplane enthusiasts, and economic theories were complementary sources of basic philosophical assumptions shared by aeronautic specialists, then and later. These currents coalesced to a form an internally consistent set of social theories shared by the field’s experts in the 1990s and 2000s. As their representational practices diffused across borders and circulated between national aeronautic communities, they formed a transnational specialist culture.

Aeronautic specialists experienced and expressed this sectoral culture through their performance of common discursive practices. These practices consisted in producing representations of sociotechnical systems structured by their community’s tacit anthropology, sociology of technology, and theory of international politics. Through their representations, aeronautic experts conveyed an agential and individual view of the human actor and an instrumental view of technologies. They also expressed a humanistic sociology, in which

\textsuperscript{493} Ibid.
technical change resulted from human action and technology responded to social needs and conditions. Moreover, aeronautic experts represented the international environment as benign. They depicted it the international system as featuring a diversity of actors locked into complex relationships of interdependence. They described international institutions as effective and promising.

3. Recurring representations of aeronautical systems

Aeronautic experts revealed their background social theories in constructions of specific aspects of their sector throughout the 1990s and 2000s. Diverse specialists reproduced these constructions across different settings, illustrating that these were widely shared and enduring habits of expression. The first of these recurring constructions was of technical change as innovation. The second was of air systems as belonging to terrestrial transportation infrastructure. The third was of aircraft as intrinsically civil and commercial technologies.

3.1. Invention, innovation, and the human shaping of aeronautic technology

Aeronautic experts explained technical change as the result of invention and innovation by human actors. These representations conveyed an agential anthropology and a humanistic sociology of technology. For aeronautic specialists, technology did not progress autonomously or according to an inherent logic, but was modified by purposeful humans. Experts described changes to the sociotechnical systems of flight as driven by their human constituents.

The pragmatic effect of representations in this mode was to constitute aircraft technology as targets of policy. When experts depicted technical processes effects of human action and social conditions, they also produced them as unthreatening, manageable, and subject to human manipulation and intervention. When experts defined their technologies as passive, they also produced the potential and risks associated with them as finite and subject to human control. Through these practices, specialists constituted technical changes in their sector as processes that could be regulated, contained, and adjusted to serve societal interests.

Specialists expressed their concept of technical change at different scales and levels of abstraction. In some cases, they represented technical change in specific devices as their invention or improvement by individuals. The main ingredient of this innovation was human ingenuity. This creativity was the wellspring of technological progress. Schemers and dreamers brought advances to technical systems. Inventors, engineers, and craftsmen decided the specific content and form of new systems. For example, aeronautic historian and retired U.S. Air Force colonel C.V. Glines attributed the introduction of flapping rotor blades, “the single most important discovery in helicopter development,” to the “genius” designer of the Autogiro, Juan de la Cierva.495

In other cases, aeronautic specialists represented technical change at the scale of larger sociotechnical systems or in more abstract terms. Examples of these included aircraft designs in

495 Glines, “Autogiro Genius.”
general and models of production. For instance, a committee of NRC experts analysed the prospects for the general class of aircraft known as high-speed civil transports, i.e. supersonic passenger planes, in their 1992 report titled *Aeronautic Technologies for the Twenty-First Century*. These representations lay midway between particular technical systems and abstract notions of “technology” writ large. In these accounts, specialists again explained changes in sociotechnical configurations as driven by human action and conditioned by social constraints. They described them as shaped by societal factors other than the breach of limits on technical feasibility itself.\(^{496}\) Individuals, firms, or other organisations brought advances to technology. Institutions and interests shaped technical systems.\(^{497}\)

Finally, experts represented changes to aeronautic technology in general, understood as a theoretical concept removed from specific cases.\(^{498}\) In these abstract representations, specialists again articulated a theory of technological change that again located its sources in human choice and action. For example, Devendra Sahal proposed a general model to explain how engineers confront trade-offs in aircraft design.\(^{499}\) George W. Mechling Jr. described the pace of long-term technological development as a function of learning effects in designers and producers.\(^{500}\) Others observed aircraft in general as improving – “the costs of air travel have decreased significantly over the last 60 years while at the same time both range and speed of the aircraft have increased”

\(^{498}\) Hill, “Developments in Aeronautical Science,” 750.
– in response to customer demands, not an inherent technological momentum. They explained and predicted this trend in technology development continuing:

Most of the improvements are due to the use of better technology. The future needs will be more focused on customer value and benefit; the era (if there ever really was one) of better technology incorporation just because it is new or improved will certainly not be the driving force for future use in commercial transports.

Like the representations of more concrete and specific sociotechnical configurations, these accounts and models attributed the technical features of hardware to human and social factors.

For example, experts described the introduction of composite materials into commercial aircraft manufacture in this way. This evolution of new aerospace materials reflected the “influence of design, manufacturing and in-service performance,” found Allan G. Miller and Donald T. Lovell of the Boeing Commercial Airplane Group and James C. Seferis of the Polymeric Composites Laboratory at the University of Washington. A main factor behind the adoption of new materials, specialists explained, was competition between airframe manufacturers on the operating costs of their aircraft. To reduce these costs, they each sought to design and build aircraft that consumed less fuel in flight. Using lighter materials on their airframes was one means they used to achieve this end. Once large-scale composite structures were introduced to one airliner program, subsequent aircraft designs incorporated them.

Miller et al. similarly explained how the materials found on modern aircraft were not a function of the properties of the materials themselves. Rather, they argued, material selection reflected programmatic demands, namely ensuring that a new material can be “scaled up to

502 Ibid.
production use.” They describe the process of “new material selection and use” within the schedule-driven production context,

The process has many different facets and, consequently, one must never lose sight of overall program needs (e.g. weight or cost targets) in order to understand clearly why some materials are selected. New composite material systems must meet increasing quality requirements for consistency and control in order to give better parts and opportunities for improved business systems (reduced inventory, reduced testing costs and reduced flow times) in order to justify their use in the airplane environment.

The content of aircraft reflected not the technological cutting edge in polymeric composites, but whether and how a given material’s “properties and characteristics could be translated into items of value to a manufacturer's customer.”

The habit of representing technical change as resulting from human inputs was traceable to histories of early aviation. In some accounts of early innovations, these human inputs consisted of vision, creativity, perseverance, and spirit. In other accounts, human inputs consisted in physical effort and labour. In yet other cases, human inputs consisted in the sacrifice and risk acceptance of those willing to experiment with new systems. Thus, according to Michael Sterling Pavelec, “without substantial support, but with dogged determination” the Englishman Frank Whittle successfully raced the Germans to develop a turbojet engine in the 1930s. Another observer wrote that “mankind's ability to fly was earned through the blood, sweat, tears and deaths of pioneers and visionaries.” The organisers of the Farnborough Airshow similarly honoured the “heroes of aviation” by remembering their contributions to the

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505 Ibid.
506 Ibid.
507 Pavelec, “The Development of Turbojet Aircraft in Germany, Britain, and the United States,” ii.
508 King, “Swashbucklers of the Sky.”
demanding process of innovation in early aircraft technology.\textsuperscript{509} As the event’s press release explained,

\begin{quote}
Early aviators, who were carrying out trials from as early as the mid-1800s, suffered many setbacks and a number lost their lives as they worked on a way to solve the great mystery of heavier-than-air controlled flight. But eventually their perseverance paid off and by the turn of the 20th century various teams and individuals were ready to build and test functional aircraft models.\textsuperscript{510}
\end{quote}

When historians explained changes in the sociotechnical systems of flight over time, they attributed them to the deliberate choices and purposeful actions of humans participants to these assemblages. Specialists represented major advances in aeronautic knowledge and technology as inventions and innovations by particular individuals. In the early days of aviation, these figures included pilots, mechanical engineers, self-styled inventors, and builders, professional and amateur.\textsuperscript{511} Technology itself did not progress. Rather, individuals acted upon technology to improve it.

Later depictions of technical change, even in vastly different aviation contexts, perpetuated this humanistic sociology. Individuals shaped the sociotechnical systems of flight to meet their needs and interests. The FAA’s institutional history, for instance, explained the emergence of air traffic control technology in this way.

\begin{quote}
As air travel increased, some airport operators, hoping to improve safety, began providing an early form of air traffic control (ATC) based on visual signals. Early controllers stood on the field and waved flags to communicate
\end{quote}

\textsuperscript{509} Farnborough International Ltd.
\textsuperscript{510} Ibid.
with pilots. Archie League, the system's first flagmen, began work in the late 1920s at the airfield in St. Louis, Missouri.\textsuperscript{512}

Humans invented technology in response to social needs that preceded the emergence of the technology. The development of aircraft technology was contingent upon human choice and action, rather than progressing along an autonomously determined course. These representations reaffirmed human control over and the shaping of evolving sociotechnical systems. Whether individuals or organisations, such as firms and governments, human actors made possible and managed technological processes. Through their representational practices, aeronautic specialists defined technical changes in their sector as processes that could be regulated, contained, and transformed to serve societal interests.

3.2. Aeronautic systems as elements of ground-based transportation infrastructure

During the 1990s and 2000s, aeronautic experts in both China and the United States represented the physical air domain and air transportation systems in similar terms. Specialists’ common representational practices sustained a shared understanding of airspace, aeronautic systems, and sectoral actors as integrated into land- and sea-based transportation systems. The air sector served functions on the ground. Aeronautic experts discursively connected airspace and aeronautic technologies to social needs, as they represented the sociotechnical systems of air transportation. Through their representations, experts constituted this physical environment as a particular type of setting for human action and the technologies within it as serving terrestrial functions. As specialists depicted the airspace and air transportation systems as global, they produced the sector as requiring policies that supported trans-boundary operations and transnational integration.

\textsuperscript{512} “A Brief History of the FAA.”
Aeronautic experts defined what the airspace was through their representational practices. Contending visions of airspace, originating in related disciplines, circulated throughout the community, moving between different aeronautic professional circles. In fluid mechanics, the airspace was a dynamic complex of flows helping or hindering the movement of an aerofoil.\footnote{Committee on Breakthrough Technology for Commercial Supersonic Aircraft, National Research Council, \textit{Commercial Supersonic Technology}, 18.} In meteorology, the airspace was composed of contending winds and waters, fleeting and unstable natural states challenging routine human operations. In atmospheric physics, the airspace contained the fundamental and enduring structures sustaining the Earth’s climate.\footnote{Panel on Atmospheric Effects of Aviation, National Research Council, \textit{A Review of NASA’s “Atmospheric Effects of Stratospheric Aircraft” Project} (Washington, D.C.: The National Academies Press, 1999), 1, 5, 25.} In transportation economics, the airspace was an exploitable medium or resource, interchangeable with land and sea as costs and benefits dictated. These diverse representations co-existed, moving within and between aeronautic expert circles.

seamlessly connected these different sub-systems. Roads and sea lanes on the Earth’s surface extended into the sky and re-descended.

Experts described airspace as another medium for the travel of vehicles: currents buffeting aircraft and corridors coursing with traffic to be managed. In this view, the stratosphere, where jet aircraft cruised, was not apart from the physical Earth, but of it.\textsuperscript{517} When defining airspace as a setting for human activity, specialists built it into terrestrial systems. This mode recurred in expert discourses addressing substantive issues and representing different aspects of the sector. For example, specialists on the National Interagency Aviation Council studying the use of aircraft to address wildfires explained that

\begin{quote}
Aviation resources very seldom work independently of ground based resources. When aviation and ground resources are jointly engaged, the effect must be complimentary and serve as a force multiplier.\textsuperscript{518}
\end{quote}

As aeronautic experts reproduced these representational practices, they also expressed an implicit understanding of the society-technology relationship. The atmosphere and its technical systems supported a way of life on the ground.\textsuperscript{519} Configurations of natural, technical, and social systems in the air had evolved to meet human needs down below. In these depictions, specialists reiterated the social shaping of technology.

Transport by air of passengers and cargo underpinned the global economy and had emerged to serve its demands. The responsibility of policymakers, in this view, was to continue

\begin{footnotesize}
\begin{enumerate}
\item Committee on Breakthrough Technology for Commercial Supersonic Aircraft, National Research Council, \textit{Commercial Supersonic Technology}, 43.
\end{enumerate}
\end{footnotesize}
adapt this critical infrastructure to the growing needs of commerce and the changing lifestyles of consumers.\textsuperscript{520}

Civil aviation has become a vital component of today’s lifestyle and of modern economic life. Just as Thomas Friedman asserts that cheap and ubiquitous telecommunications have lowered impediments to international competition and innovation, the airline industry has shattered barriers of distance that once limited many global economic transactions. More and more households and businesses have become reliant on the advantages and cost effectiveness of air transportation. Like the Internet and new labor-saving technologies, the growth and maturation of the aviation industry, and civil air transport in particular, is truly a modern marvel.\textsuperscript{521}

In characterising the air domain as sustaining a way of life on the ground, aeronautic experts produced it as shaped by, rather than shaping, societal circumstances. Society advanced; technology followed. The habits of representing the air domain reinforced and perpetuated the specialist community’s anthropocentrism.

Through these representations, experts also produced the sector as a site for state action and an object of policy. As they articulated aeronautic systems to societal needs and functions, they implicitly prescribed policies consistent with this understanding. The sociotechnical systems of flight served social functions, rather than evolving in their own runaway direction. They were subject to human intervention and manipulation. Moreover, in representing air transportation systems as global, specialists produced the sector as requiring policies supportive of trans-boundary operations and the transnational integration of industrial activity.

3.3. Aviation and aircraft as intrinsically civil and commercial

A third recurring representation of the sector depicted aviation and aircraft as intrinsically or primarily civil and commercial. In this characterisation, military-defense applications of

\textsuperscript{521} (FAA economic impacts 2009 report, p. 12)
aeronautic systems superseded and transcended their origins in military and defense programs. The cumulative effect of constructing aeronautic technologies as civil and commercial was to constitute the sector as a site requiring particular forms of state action. Through these representational practices, specialists called forth sectoral policies and programs that supported transnational commerce, including the trade in finished aircraft and industrial integration. At the same time, experts constituted the sector as a site of civil activity by government agencies, casting the state in the role of civil-aviation participant and supporter.

During the period following the Second World War, aeronautic experts in the United States, parts of Europe, and Japan often represented aircraft technologies and aviation activities as civil and commercial first and as military second. Historian of aeronautic technology David Edgerton documented these practices in a book-length study of British and American participants in the sector.522 These habits of representation persisted even though aircraft technology lent itself to alternative representations.523 Even when experts acknowledged the relationship between aircraft and security, they tended to maintain a separation between civil-commercial and military-defense aeronautic activity.

Despite its construction as civil and commercial, modern aviation had been a primarily military activity. Modern jets remained in many ways derivatives of military planes, yet these origins were obscured in specialist discourses. While aircraft manufacture was often co-located with defense production, experts discursively maintained a separation between the two activities. Policies, such as the National Aeronautics Research and Development Policy, addressed both

522 Edgerton, England and the Aeroplane.
civil-commercial and military-defense air, but foregrounded the civil and commercial content. The air domain itself was a strategic environment and combat theater of unmatched significance, yet experts tended to associate it with travel and transportation rather than war. They articulated the technical systems in their sector to civil-commercial functions. Expert representations obscured not only the military origins of and legacy in commercial aviation and aircraft, but also the enduring military-defense functions of aeronautic systems in general.

In spite of these prevalent representations, more focused technical and programmatic analyses indicated that air operations remained central to the U.S. way of war in the 1990s and 2000s. During World War II and after, the sky was the U.S. military’s most active battlefield. Air strikes constituted its main use of force. Airborne systems – fighters, bombers, helicopters, and drones – were the most potent instruments of war used in war by the U.S. military. Each service sustained an enormous infrastructure to support air operations, including aircraft carriers and distant military bases. Even satellites, regarded as integral to U.S. military strength, played their most important combat role when they supported the application of air power by precisely guiding airborne munitions to their targets.

Air operations were central to every major U.S. military engagement of the 1990s and 2000s. In each case, the strength of U.S. air power proved a decisive determinant of the conflict. Air bombing brought a swift U.S. victory over Iraqi forces in 1991’s Operation Desert Storm and a rapid overthrow of the same regime in 2003. Targeted strikes by U.S. fighters over Kosovo in 1999 brought an end to that stage of the war in the former Yugoslavia. Bombers, helicopters, and

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524 National Aeronautics Research and Development Policy.
fighters performed the brunt of operations against Taliban forces during the initial stages of the 2001 war in Afghanistan. Airborne drones later took over.\footnote{This paragraph, John Andreas Olsen, ed., \textit{A History of Air Warfare} (Dulles, VA: Potomac Books, 2010); Robert A. Pape, \textit{Bombing to Win: Air Power and Coercion in War} (Ithaca, NY: Cornell University Press, 1996).}

Similarly, when U.S. engagements abroad were unsuccessful, limits on U.S. air power were an important factor. U.S. forces abruptly withdrew from Somalia when rebel forces unexpectedly downed helicopters with machine-gun fire over Mogadishu in 1996. With air dominance lost, U.S. forces were ordered to abandon their mission.\footnote{John R. Bolton, “Wrong Turn in Somalia,” \textit{Foreign Affairs} 73 (1994): 56.} A major factor preventing the U.S. military from intervening in the civil war in Rwanda was its lack of heavy-lift aircraft capable of rapidly sending troops and supplies into the otherwise inaccessible interior of the African continent.\footnote{Alan J. Kuperman, “Rwanda in Retrospect,” \textit{Foreign Affairs} 79, no. 1 (2000): 94–95; Karen U. Kwiatkowski, \textit{Expeditionary Air Operations in Africa Challenges and Solutions}, December 2001.} Air capabilities were a determinant of whether and how the United States used force.

Despite the unique significance of aircraft to U.S. strategy and defenses, in many contexts sectoral experts represented these technologies as primarily civil and commercial. Foremost in specialist representations were the mobility, freedoms, and economic opportunities that aircraft brought to individuals, not the security and military power they provided to the nation. For example, when describing the major contributions of aviation and aircraft manufacture to the U.S. national interest, experts pointed to the trade and economic activity they supported and to the quality of life they afforded citizens. Specialists discursively located aviation in commercial and civilian spheres, such as business travel, tourism and other leisure, and mail and cargo delivery. Their representations highlighted the impact of airports on communities and local economies and of air travel on conceptions of self and relationships. Specialists stressed the adaptations of
aeronautic technology to social functions. They emphasised the role of aviation in lives of individuals, families, businesses, and communities, but not the defense of the nation.

As aeronautic specialists represented aircraft technologies as primarily civil and commercial, they reproduced their community’s tacit theory of international politics. As they represented their sector, experts articulated technical systems to the needs and interests of interdependent sub-state actors, such as civilians and firms tied into transnational networks. These depictions reinforced a view of the international system as a benign environment in which commerce and international cooperation were normal. These representations dissimulated the connection between aeronautic systems and state power, including military force. Specialist depictions also implicitly prescribed sectoral policies and programs that fostered transnational commerce, including trade and industrial integration. At the same time, experts defined the sector as a site of civil activity, creating a role for government agencies in supporting and ensuring the safety of civil aviation worldwide.

These three recurring constructions of the sector illustrated the embedding of the specialist culture in the expert community and its outward manifestation in representational practices. Aeronautic specialists both expressed and reinforced their common social theories when they represented technical change in their sector as innovation or invention. They did the same when they discursively produced the sociotechnical systems of flight as integrated with and serving ground-based transportation systems. Finally, specialists reproduced their community’s background social theories when they represented aircraft technologies as intrinsically civil and commercial.
Conclusion

Participants in commercial aircraft manufacture and civil aviation shared tacit background knowledge particular to their sector. Consisting of philosophical commitments, this background knowledge was not directly observable. Yet its content was discernible in aeronautic experts’ representational practices, which revealed their shared understanding of human-technology relationships. Aeronautic experts in different countries expressed common underlying concepts of humans and the human-built world. Expressed in representational practices, these understandings formed their specialist culture.

The sources of aeronautic specialists’ social theories lay in fields of activity outside of, but close to, their contemporary sector. Their specialist culture incorporated currents of thought about society and technology from these adjacent fields. These sources included histories of early aviation, the cult of the pilot-operator in organisational and technical practice, the liberal-internationalist commitments of interwar British aviation enthusiasts, and economic models of the sector. These sources supplied models of human-technology relations that aeronautic specialists assimilated and repurposed in their own representations. Aeronautic experts of 1990s and 2000s applied these tacit models to the individuals, social factors, and technologies that they encountered in the course of their own work. They reproduced these theories in their representations of sociotechnical assemblages.

Specialists in academia, industry, and government expressed their theories in representations of particular phenomena or entities in their sector. Examples included their representations of advances in flight technology as processes of invention and innovation by individuals. Experts’ philosophical commitments also informed their rendering of aeronautic systems as incorporated into ground-based transportation infrastructures. Finally, experts drew on their common background theories when they produced aircraft and aviation as intrinsically
civil and commercial. Over time, the effect of these recurring constructions of aeronautic sociotechnical systems was to constitute the sector to policymakers and decisionmakers as a site requiring particular forms of state action and suited to specific policies.
The constitution of bilateral order in air

Introduction

Two decades of trade, industrial integration, and cooperation between China and the United States in civil-commercial air resulted from policies and programs adopted by both governments acting on specific views of the sector. Policymakers’ understandings of the air sector were shaped by sectoral experts.

Aeronautic experts’ representations of sociotechnical systems to policymakers and decisionmakers constituted the air sector as a site requiring particular forms of state action and suited to specific policies. As experts described the sector drawing on their specialist culture, they defined what state interventions in it were possible and desirable. Their representations implicitly prescribed sectoral policies and programs that supported the transnational movement of goods and people, transnational commerce and industrial integration, and intergovernmental civil cooperation. Experts created agreement among policymakers in both countries that the sector required policies supporting bilateral trade, integration, and cooperation.

Moreover, when experts described humans as initiating and directing technical change, they established the feasibility of measures to control technological processes, such as the diffusion of technologies to new settings. Defined as subject to human intervention and manipulation, technological processes became manageable and benign to U.S. policymakers and decisionmakers. Specialists represented technology transfers as limited and controllable through rules and procedures, removing concerns about the national security impact of bilateral trade and industrial integration.

Policies and programs in both countries were needed to foster bilateral trade, industrial integration, and civil cooperation. In China, government actors implemented a sectoral
development strategy to attract U.S. aircraft firms’ development and production to China while integrating Chinese firms into global production networks. Leaders also sought to develop an FAA-style certification process that would facilitate the sale of Chinese passenger jets on world markets. In parallel, the U.S. government implemented policies and programs to promote U.S. aircraft exports, for which China became the largest market during this period. The most important of these measures were stable export controls that permitted exports of dual-use aircraft items to China. U.S. also policy aimed to harmonise certification and foster the interoperability of air traffic systems in different countries, including China.

Together, these policies and programs formed a stable bilateral order that allowed and fostered expanding trade, industrial integration, and civil cooperation during these two decades. By 2009, the Chinese and U.S. aircraft industries were more intertwined than ever before. The two countries’ civil agencies also cooperated and charted a course toward expanded technical collaboration. By the end of the two decades, the tendency toward bilateral integration in air appeared all but irreversible.

When Chinese and U.S. governments adopted these policies and programs, they acted on specific views of the sector. Policymakers’ understandings were shaped by experts, whose represented and interpreted the sector to them. Experts contributed to the bilateral outcome in air by creating agreement among policymakers on the nature and demands of the sector, implicitly prescribing policies that supported bilateral integration and cooperation.

This chapter examines how aeronautic experts’ background knowledges and representational practices were implicated in the building and maintenance of a bilateral order fostering trade, industrial integration, and technical cooperation in air. The first part of this chapter discusses the roles of specialists in sectoral policymaking in China and the United States. The second part examines the cultural production of bilateral order in experts’ representational
practices. The third part examines how experts discursively produced the sector as global and transnational, implicitly prescribing policies supporting trade, integration, and cooperation. The fourth part examines how U.S. specialists produced commercial and defense aircraft technologies as distinct, establishing that regulated bilateral trade in a certain class of items was safe and feasible. The fifth part examines how U.S. experts produced the risks of aircraft technology transfers between the two countries as manageable, reinforcing the feasibility of regulated bilateral trade and integration. The conclusion reviews how a tacit consensus on these features of the sector guided policymaking.

1. **The aeronautic specialist community and sectoral policy**

   Although the basic institutions of government were different in China and the United States, the policymaking processes in both countries allowed for substantial input from sectoral specialists. In both systems, policy specialists responsible for designing and proposing sectoral policies and decisionmakers with the authority to adopt or fund sectoral policies were in regular and systematic contact with subject-matter experts. Through these channels, specialists conveyed their community’s basic philosophical commitments to policymakers in both countries.

1.1. **Aeronautic specialists and policymaking in China**

   In China during the 1990s and 2000s, specialists of aircraft manufacture and aviation were found in a range of institutions. These individuals constituted a reservoir of technical expertise for policymakers and leaders to consult. Policymakers drew on their insights when they made, evaluated, and revised policy for the sector.\(^{530}\) Experts contributed to these policymaking

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\(^{530}\) Interview with scholar specializing in technology policy in the School of Management under the Graduate University of CAS, Interviewee 12-24-12, Beijing, 2010.
processes through several channels. They briefed, wrote reports, and presented at conferences for policymakers preparing five-year plans and strategies for the sector, such as the *Medium- and Long-Term Plan*.

Institutions straddling China’s commercial and defense technology worlds housed aeronautic specialists. Costind, the PLA GAD, and Avic had their own small but important policy research staffs that studied the air sector in China and abroad. Synthesising the analyses of Chinese and international experts, these researchers contributed their findings to the formulation of policy and of Avic’s reform and development strategy. MOST and the Ministry of Commerce also had divisions dedicated to aeronautic technology development programs and manufacture. Policy experts in these units analysed and devised policy recommendations.

A number of large and growing think-tanks included experts who advised policymakers. The most influential of these think-tanks were national-level institutions, but regional and local think-tanks also grew and developed during this period. Government-affiliated research organs of this type included the Institute of Policy and Management and the Graduate School of the CAS. Researchers and academicians in these institutions studied the global air sector, major international firms, and foreign countries’ national aviation and aeronautics policies. Their comparative analyses provided an empirical basis for policy thought about how to adapt foreign models to China’s particular circumstances. During this period, the role of think-tank experts in national, provincial, and local policymaking grew and became more formal and systematic.

Other experts participated in policymaking in formal and informal roles. They included researchers at technical universities, such as Beihang and the China Civil Aviation University (Minhang) in Tianjin. Researchers in the fields of management studies, defense industry economics, innovation studies, transportation economics, and airport economics based at other universities, such as Peking University in Beijing and the National University of Defense
Technology (NUDT) in Changsha, also contributed to policy debates in the sector, writing analyses, reports, and articles on sectoral issues.

Senior leaders within Avic provided a direct conduit between the aircraft specialist community and policymakers. Top-level managers at Avic served on major political decision-making bodies, including as regular and alternate members of the Politburo. This level of government decided and adopted long-term strategies for the sector, including Program 863 and the *Medium- and Long-Term Plan*, each of which explicitly addressed aeronautics. As participants in these processes, Avic’s corporate leaders could join in efforts to define policy goals and the broad outlines of strategy for the sector. Avic executives brought to these roles technical training in aerospace engineering and transportation economics.

In China’s increasingly technocratic policymaking environment of the 1990s and 2000s, these specialists’ authoritative accounts provided a basis for how policymakers learned about and made choices for the sector. Through their representations of sociotechnical systems in their sector, specialists communicated to policymakers their tacit philosophical assumptions about human beings and technology. Committees of experts produced studies, reports, articles, and presentations for policymakers at various levels. In these media, specialists not only represented their sector, but also produced it as a site of state action and an object of policy. Through this process, specialists drew boundaries around the range of policies regarded as feasible and possible in their sector. Guided by these representations, policymakers decided on specific policies and programs.
1.2. Aeronautic specialists and policymaking in the United States

In the United States during the 1990s and 2000s, aeronautic specialists also contributed to policymaking. Experts in government agencies, industry, and academia provided input into the formulation of policies and programs for the sector and into decisions about whether to adopt and fund them. Specialists participated in this process through several direct and indirect channels.

Expert contributors to the policymaking process were found in several governmental and quasi-governmental entities. Experts in FFRDCs conducted studies of technical, programmatic, and policy issues, which they shared with congressional committees and the administration. Researchers within the GAO and CRS consulted aeronautic experts and collected their input into research reports drafted for the Congress.\(^{531}\)

The executive branch contained specialists who contributed their expertise to policy formulation. Technical and policy experts within NASA and the Department of Defense conducted studies of different aspects of the sector and circulated them among policy and decision makers. Moreover, units responsible for policy and technology development in these agencies contracted with specialised consultancies that provided studies of issues in the air sector. A small research staff within the White House OSTP also consulted sectoral experts.

Experts in industry testified before congressional committees and met with policy drafters in the administration on issues that concerned them, at times submitting written statements.\(^{532}\) Industry experts also briefed congressional staffers, who helped set the agendas and shaped the views of committees and individual members. Specialists acting on behalf of industry associations presented the policy preferences of the aircraft industry or of segments of it to


decision makers in reports, speeches, presentations, testimony, and through lobbying. For instance, the AIA issued analyses and position papers on specific air policy issues.

Researchers in universities, think tanks, and other research bodies also contributed their expertise to Congress, the administration, and government agencies. For example, academic and industry experts provided input into policymaking as participants in NRC studies of the sector. Many of the NRC’s studies were conducted at the request of executive department and agency heads, such as the Secretary of Transportation and the Secretary of the Air Force, for the express purpose of assisting in the formulation of policies and programs. Often focused on a specific segment of the sector, these studies examined the state and performance of U.S. industry, identifying needs and recommending policy adjustments or other measures. Other research evaluated already implemented policies and programs. Policymakers and decisionmakers were familiar with NRC reports and referred to them as authoritative. For example, the 2006 *National Aeronautics Research and Development Policy* cited the findings of the NRC’s *Decadal Survey of Civil Aeronautics* as a rationale for initiatives it mandated. As experts from outside government provided insights into policy issues, they tapped into a long tradition of leading industrialists, scientists, and other distinguished aeronautic professionals advising decisionmakers in the sector and a history of government-industry partnership in aircraft-manufacture.

Other influential organisations of experts also communicated their specialised knowledge to policymakers and decisionmakers through widely circulated reports and statements. For example, the Institute of Electrical and Electronics Engineers and the American Institute of

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Aeronautics and Astronautics (AIAA) produced reports and position papers that drew on their members’ insights into the state and needs of the air sector.

These various professional and academic societies organised the U.S. aeronautic expert community by conferring formal distinctions upon leading figures. Members appointed to leadership positions on committees and boards within these institutions were recognised as accomplished in their specialist circles, having earned their peers’ support and recognition. From these positions of authority and shored up by their community, distinguished aeronautic specialists were able to contribute influential analyses and recommendations to policymakers.

These specialists’ authoritative accounts provided a basis for policymakers, who drew on them to learn about and analyse the sector when formulating or evaluating policy. Committees of experts generated studies, reports, articles, and presentations for decisionmakers at various levels to consult. These products conveyed their representations of sociotechnical systems in their sector.

In both China and the United States, aeronautic specialists played indispensable roles in the making of sectoral policy. Although they acted within different institutional structures and through different channels, specialists in both countries produced knowledge goods to which policymakers were regularly exposed. These were among the most important means through which decisionmakers learned about the sector.

2. The cultural production of bilateral order

Trade, industrial integration, and civil cooperation between China and the United States resulted from policies and programs adopted by both governments acting on specific understandings of the air sector. Policymakers in these governments did not experience or learn about the air sector directly, but through the representations of sectoral experts advising them.
Aeronautic specialists represented, interpreted, and rendered the sector intelligible to policymakers. Expert depictions of the sector were not neutral, but achieved through the performance of theory-laden representational practices. Structured by and expressing their community’s tacit theories, expert representations constituted the sector as a target of policy. Guided by these constitutive representations, policymakers formulated and decided on policies and programs for the sector.

As specialists represented and defined the air sector to policymakers, they produced it as a setting for action and as an object of policy. As experts discursively produced their sociotechnical systems, they constituted the sector as suited to policy measures compatible with these underlying assumptions about human-technology relations. Specialist representational practices’ introduced their assumptions into policymaking. Recurrent representations implicitly and explicitly called forth philosophically compatible policies. Specialist representations of the sector both described and prescribed. Through many such performances, experts established a tacit consensus on what the sector was like and what it required.

Continually maintained in practices, this background consensus foregrounded some policy options and foreclosed others. Specialist performances of their practices defined and maintained the range of measures and outcomes that sectoral participants considered desirable and feasible. Policymakers and decisionmakers adopted policies and programs within the parameters of this agreement and guided by expert representations. As specialists and then policymakers performed these representational practices, they forged and sustained agreement that policies should foster, not hinder, bilateral trade, industrial integration, and technical cooperation. Within the United States, the performance of these practices also maintained a background consensus on the benign nature of these activities, foreclosing scrutiny and investigation of their national security implications, even as evidence of these mounted. In
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China, these representational practices fixed understandings of the sector as requiring policies that encouraged foreign participation in national programs, rather than autonomous technology development efforts. In this sense, the continual performance of these representational practices in both countries and, with it, the reaffirmation of the background knowledges they carried, was the basis for the bilateral order in the air sector.

Experts representations of the sector to policymakers in China and the United States sector constituted it as having three specific features that demanded policies fostering bilateral trade, industrial integration, and technical cooperation. First, specialists in both countries produced the sector as intrinsically global and transnational, constructing policies to support trade and industrial integration as feasible and desirable forms of state action in the sector. Second, U.S. specialists produced commercial and defense aircraft technologies as distinct, maintaining agreement that policies allowing regulated bilateral trade and integration were feasible and desirable. Third, U.S. experts produced aircraft technology transfers inherent in international commerce as manageable, constructing policies allowing regulated bilateral trade and industrial integration as feasible and optimal.

3. Producing the air sector as global and transnational

The first item on which experts helped create and maintain agreement among sectoral policymakers in China and the United States was an understanding of the civil-commercial air sector as intrinsically global and transnational. In their analyses, specialists represented airspace and air transportation systems, markets, manufacturers, and aircraft hardware. They characterised these entities as transcending national borders, constituting the sector as a natural site of bilateral trade and integrated production. Experts also rendered the sector incompatible with restrictions on the trans-boundary movement of aircraft articles. The apprehension of these
sectoral features by policymakers in both Beijing and Washington was a necessary precondition to bilateral trade, industrial integration, and civil cooperation.

Chinese and U.S. aeronautic specialists created and sustained this common understanding of the sector by representing the sociotechnical systems of air flight as globalised and transcending national borders. In depicting these assemblages, they reproduced representational practices that conveyed the specialist community’s social theories of technology. Their discourses reflected their specialist culture. Expert depictions of their sector drew on currents of thought traceable to interwar England and the United States, described in the preceding chapter as the liberal-internationalism of early air power and aviation enthusiasts. Specialists conveyed the tacit theory of international politics diffused within their community, emphasising the trans-boundary, interconnected, and interdependent nature of the sector. In addition, experts’ representational practices conveyed a humanistic sociology of technology, representing artefacts in a processual mode that emphasised human inputs into its manufacture. This tendency rendered aircraft items as resulting from the work of trans-nationally distributed actors.

Between the 1980s and the end of the 2000s, aeronautic experts and the policymakers they advised reproduced these representational practices as they described four aspects of their sector: the physical domain, markets, suppliers, and products. First, specialists represented the physical domain of flight, airspace, as intrinsically trans-boundary and integrated into the global transportation system. Second, experts produced markets for aircraft products as world markets. Third, specialists represented aircraft manufacture as a global and transnational industry and activity, describing manufacturers as networks stretching across countries and continents. Fourth, experts produced items of aircraft hardware as transnational composites, articles incorporating tangible and intangible contributions from all over the world.
3.1. Airspace and air transportation systems as global and trans-boundary

The first way in which aeronautic specialists produced the sector as global and prone to transnational integration was through their representations of the physical domain and sociotechnical systems of flight. Aeronautic specialists in both countries represented aviation systems as global and transnational, locating them in the trans-boundary environment of physical airspace. Policymakers performed these representational practices in writing policy documents and programmatic statements, in which such characterisations of the domain undergirded measures conducive to bilateral integration and cooperation.

When experts analysed U.S. aeronautic technologies, they situated them in “domestic and global air transportation systems” 536 and the “global transportation infrastructure.” 537 They located U.S. air traffic management needs and the national airspace system within the “global civil aviation” 538 sector and in relation to “worldwide air transportation traffic.” 539 Specialists described the physical domain of their sector as a single undifferentiated space. For example, outlining the FAA’s implementation of the NextGen, policymakers repeatedly invoked the image of “one seamless global sky.” 540

In specialist representations, air transportation systems provided worldwide coverage. Integral to “the way we live and do business,” aviation “link[ed] people from coast to coast and connect[ed] America to the world.” 541 The aviation system afforded the military “the ability, at a

536 Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, Decadal Survey of Civil Aeronautics, ix.
537 Committee on Breakthrough Technology for Commercial Supersonic Aircraft, National Research Council, Commercial Supersonic Technology, 43.
539 “Position Statement: National Aviation Safety Program” (IEEE-USA (Institute of Electrical and Electronics Engineers - USA), 2010).
540 FAA’s NextGen Implementation Plan, 4.
541 “A Brief History of the FAA.”
moment’s notice, to seamlessly use the national airspace system for defense anywhere within and approaching U.S. borders.”  These technologies allowed us “to literally fly anyone to anywhere at any time,” wrote AIAA experts. Air systems gave their operators “the capability to move goods and people, point-to-point, anywhere in the nation and around the world.” The ideal in this vision was “Moving anyone and anything, anywhere, anytime, on time!”.

In policy documents and programmatic statements, policymakers also envisioned transnational partnerships between government agencies and firms. For example, the FAA joined the “global aviation community” and “global partners” in its work. These actors included other civil aviation agencies, airlines, manufacturers, and international organisations. Their common goal, policymakers wrote, was “to provide safe, seamless, efficient and environmentally responsible operations worldwide.” The agency strove to “achieve global aviation objectives and meet the needs of airspace users around the world.” “Giving the world new ways to fly,” was how policymakers defined the FAA’s mission.

In the Decadal Survey of Civil Aeronautics, leading U.S. experts explained that their analysis presupposed a trans-boundary context to national aeronautic activities. The committee posed the following question at the very start of its report: “How does the U.S. air transportation system interact with a global economy, international aviation authorities, and international

542 National Aeronautics Research and Development Policy, 7.
544 National Aeronautics Research and Development Policy, 7.
546 FAA’s NextGen Implementation Plan, 4, 9.
547 Ibid., 37.
548 FAA’s NextGen Implementation Plan.
550 FAA’s NextGen Implementation Plan.
corporations that are interactive, interdependent, and integrated? With this question, experts took for granted the inevitability of transnational trade, industrial integration, and interdependence.

In expert representations, the trans-boundary nature of air systems was not only a given, but also a good. There existed “a U.S. advantage in the eventual formation of a globally compatible air system.” For the Steering Committee, “seamless links between U.S. and global air transportation systems enable U.S. manufacturers to operate efficiently even with global supply chains, and it allows foreign manufacturers to include U.S. suppliers in their supply chains.” The air system must “provide for seamless and secure operation of aircraft across U.S. boundaries to other parts of the globe,” said the National Aeronautics Research and Development Policy of 2006. These representations produced an integrated and connected global environment as intrinsically benign and desirable.

The FAA’s 2008 “Flight Plan” elaborated on how the agency pursued the goal of securing aircraft operations worldwide through international programs: “To make this happen, the FAA actively builds partnerships and shares knowledge to create a safe, seamless, and efficient global aviation system. Our premise is simple: national boundary lines should not be impediments to safety.” The Flight Plan explained how the agency “supported the future needs of the global aviation system by addressing fundamental international aviation challenges.”

The document stated: “Through partnerships, innovation, and collaborative efforts, we work

553 Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, Decadal Survey of Civil Aeronautics, 4.
554 National Aeronautics Research and Development Policy, 13.
556 Ibid.
with the rest of the world to ensure the safety of air travel, increase the efficiency of the global aviation system, and contribute to the well-being of the environment.  

Once again, this policy agenda presupposed the globalised and transnational environment that specialists described.

U.S. national leadership was an constant concern for aeronautic experts, but they treated this position as a means to realising goals that transcended the interests of any particular nation-state. In many representations, these interests were those of individuals and firms that used the air transportation system. Like their liberal-internationalist predecessors, aeronautic specialists and policymakers were confident in the possibility of international cooperation and the potential of international institutions. The second paragraph of the 213-page *Decadal Survey* illustrates this mode of reasoning.

With leadership comes opportunity, particularly with regard to setting international standards for aircraft certification and operations. A position of continued leadership would allow the United States to ensure that viable global standards continue to be established for the application of emerging technologies and operational concepts. Without such standards the global aviation market and the global transportation system will be fractured into separate fiefdoms ruled by national and regional aviation authorities acting independently. This would impede the ability of passengers and cargo to move seamlessly—and safely—from country to country.

Experts and policymakers stressed that the United States should lead the technical and practical integration of national systems and further reduce barriers in civil aviation. For example, aeronautic experts reviewing NASA’s aeronautic technology programs recommended

\[557\] Ibid.
\[560\] National Aeronautics Research and Development Policy, 7; FAA’s NextGen Implementation Plan, 18, 37.
that the administration pursue “Global Compatibility” in aviation. In concrete terms, this meant that “the United States, in cooperation with international partners, should play a leading role in ensuring global interoperability” of air traffic management systems. To meet “global aviation objectives,” said the national aeronautics policy, “NextGen will have to be interoperable with corresponding systems throughout the international community.” Thus, the FAA’s NextGen implementation would focus on “global harmonization” The agency planned to work “with the global aviation community to ensure aircraft operating globally receive the operational benefits in various international air traffic environments.” Within this context, the FAA’s counterpart in China, became another global “aviation partner.”

3.2. Markets as global and transnational

A second way in which aeronautic experts in China and the United States produced the sector as transnational and globalised was by representing markets for aircraft items as worldwide. As specialists reproduced them, these representations constituted the air sector as a site for policies facilitating trade and promoting exports. In particular, specialists constructed ensuring the competitiveness of national firms on world markets as a policy goal in itself.

By the late 1980s, aeronautic experts agreed that the forces of supply and demand facing aircraft manufacturers were global. This collective realisation was captured in a 1987 expert review of the National Aeronautics R&D Goals statement issued two years earlier: “The picture

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562 National Aeronautics Research and Development Policy, 7.
563 FAA’s NextGen Implementation Plan, 37.
564 Ibid., 9.
565 Ibid., 5.
has changed dramatically over the past decade. We are challenged by a new global economy with technologically equal, well-organized competitors actively backed by foreign governments."

Throughout the following two decades, experts continued to represent markets for aircraft items in these terms. They analysed “the worldwide air transportation market,” “the globalized world aviation market,” and a “worldwide market” for different types of air transports. They described the “global aircraft market” and global markets for sub-systems and components. The “commuter aircraft market,” “subsonic transport market,” and “future supersonic transport market” were global. Specialists studied and projected the size of the global aircraft fleet. The relevant forces were “global demand for commercial air travel in the coming decades,” “Worldwide Demand for Aeronautics Products and Services” and the “global supply” of aircraft items.

In global markets, competition was global. For U.S. aeronautic experts, sectoral dynamics reflected industrial competitiveness. The “U.S. aeronautics industry has been one

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568 Committee on Aeronautical Technologies, National Research Council, Aeronautical Technologies for the Twenty-First Century, 27.
570 Committee on Aeronautical Technologies, National Research Council, Aeronautical Technologies for the Twenty-First Century, 27.
571 Ibid., 3.
572 Ibid., 26; National Aeronautics R&D Goals: Technology for America’s Future - Agenda for Achievement.
573 Committee on Aeronautical Technologies, National Research Council, Aeronautical Technologies for the Twenty-First Century, ix.
575 Ibid.
of the undisputed success stories in global competitiveness,"\textsuperscript{581} observed a specialist group examining long-term trends in aeronautics, echoing an understanding commonplace in this community. For experts and policymakers in areas as wide-ranging as civil transports, rotorcraft, and air traffic management technology, the “international competitive position” of U.S. industry was a priority that should guide policies and programs.\textsuperscript{582}

At the same time, U.S. experts alerted policymakers that their country’s leading position was under threat.\textsuperscript{583} Aeronautic experts observed that “U.S. manufacturers’ share of the global market for civil [commercial] aeronautics” was shrinking before foreign competition.\textsuperscript{584} “Very clearly, the intensity of global competition in high technology poses a serious challenge to U.S. aeronautical preeminence,” wrote policymakers in 1985.\textsuperscript{585} Sectoral participants’ preoccupation persisted and grew into and throughout the 2000s. “The U.S. is losing global market share and leadership,” warned an official describing NASA’s aeronautics strategy in 2006.\textsuperscript{586}

In response, specialists repeated, U.S. policy should help industry “prosper in the global marketplace”\textsuperscript{587} and “help the United States compete in the global economy.”\textsuperscript{588} Experts and

\textsuperscript{579} National Aeronautics Research and Development Policy, 6, 11; Susan Gorton, Fundamental Aeronautics Subsonic - Rotary Wing Reference Document (Washington, DC: National Aeronautics and Space Administration, May 26, 2006), 3.
\textsuperscript{580} Steering Committee for a Workshop to Develop Long-Term Global Aeronautics Scenarios, Commission on Engineering and Technical Systems, National Research Council, Maintaining U.S. Leadership in Aeronautics, 9.
\textsuperscript{581} Ibid.; Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, Decadal Survey of Civil Aeronautics, ix.
\textsuperscript{583} Commission on Engineering and Technical Systems, Recent Trends in U.S. Aeronautics Research and Technology, 1; A Consensus for Change: Avoiding Aviation Gridlock and Reducing the Accident Rate, 1.
\textsuperscript{584} Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, Decadal Survey of Civil Aeronautics, 4.
\textsuperscript{585} National Aeronautics R&D Goals: Technology for America’s Future, 5.
\textsuperscript{586} “The NASA Aeronautics Blueprint - Toward a Bold New Era of Aviation” (Washington, DC, 2002), Slide 7.
\textsuperscript{587} Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, Decadal Survey of Civil Aeronautics, ix.
\textsuperscript{588} Ibid., 4.
policymakers stressed the need to “cultivate an R&D [research and development] environment that enables a globally competitive U.S. aeronautics enterprise” \(^{589}\). For example, “The government has an important role in assuring […]” the development of aeronautic “technologies that enable products and services to compete effectively in the global marketplace,” \(^{590}\) specialists reviewing NASA programs emphasised. \(^{591}\) Fostering trade and exports was a taken-for-granted imperative.

Through these representations of markets, experts established the preeminent importance of U.S. firms’ export performance. Representing their share of global markets for aircraft items as threatened, specialists participated in producing support to these manufacturers as a national imperative. \(^{592}\) Experts produced the sector as requiring policies that supported trade and promoted exports, rather than hindering them. In these analyses, the national interest was served by policies that enhanced the competitiveness of U.S. firms abroad, not policies that contained U.S. aircraft technology items within U.S. borders. Specialists elevated export promotion to a policy priority, implicitly subordinating other objectives, such as restricting dual-use technology transfers. Shared among policymakers and decisionmakers, these background understandings supported the maintenance of permissive U.S. export controls, which in turn allowed trade and industrial integration with Chinese partners to continue throughout this period.

### 3.3. Manufacturers as global and transnational


\(^{592}\) *Responding to the Call: Aviation Plan for American Leadership* (Washington, DC: National Institute of Aerospace, 2005), 1, 8.
A third way that aeronautic specialists in the United States produced the sector as global and transnational was by representing the world’s leading manufacturers of aircraft items as global and transnational entities. They described the manufacture of these products as a complex flow of global and transnational operations. Within these descriptions were implicit policy prescriptions for the sector. In describing these firms, experts conveyed the outlines of a domestic and international regulatory landscape conducive to their activities.\textsuperscript{593} Depictions of these global firms implicitly prescribed reducing barriers to international transactions and harmonising global standards for products.

Although experts still associated manufacturers with the country in which they were headquartered, they represented these firms as forming a single “global aircraft industry.”\textsuperscript{594} When specialists looked at their sector as a whole, they did not see competing national industrial bases compartmentalised by country borders, but the “global aeronautics industry.”\textsuperscript{595} Even when sectoral specialists defined industries as national, they characterised them as “global in scope.”\textsuperscript{596} While firms retained strategic relationships to their home states, the material dimension of aircraft production itself was transnationally distributed.

Experts depicted aircraft firms as de-territorialised configurations. Producers relied on global supply chains and existed by virtue of their location in worldwide manufacturing


\textsuperscript{596} Harrison, \textit{Challenge to the Boeing-Airbus Duopoly in Civil Aircraft: Issues for Competitiveness}, “Summary.”
networks.\textsuperscript{597} Even relatively small companies scattered their operations across facilities spanning the globe – design centers, assembly lines, and parts depots extending across continents. These features were commonplace. For instance, examining U.S. air industrial integration with Japan in 1994, a committee of specialists observed that “As markets, capital, and technological capabilities become increasingly global, international strategic alliances and other cross-border linkages have become a familiar feature of this industry.”\textsuperscript{598}

Some of the world’s leading firms were not only de-territorialised, but also dematerialised. The largest manufacturers often built the least hardware in their own facilities, specialising instead in development and final assembly and retaining hundreds of sub-contractors to do the actual serial production of elements. Dispossessed of in-house manufacturing facilities, prime contractors developed a core of competencies in the management of complex transnational supplier systems through virtual networks.\textsuperscript{599} For example, Boeing developed and produced the


\textsuperscript{598} Committee on Japan, National Research Council, High-Stakes Aviation, 1.

787 in the Global Collaborative Environment, a dedicated online platform. Engine maker Rolls Royce was also a leader in virtual manufacturing.

Specialists represented this situation as natural and desirable. Among the “formidable strengths” of U.S. producers, explained an expert panel assessing the industry, was “a global capability for service; massive investment in modern facilities; an infrastructure that in fact supports aircraft manufacture globally.” Global scope and a distributed presence were characteristic of the sector’s major manufacturers, reflecting their adaptation to an integrated transnational environment.

In these representations, integration with foreign partners did not weaken U.S. aircraft firms, but augmented them. Even in a context of overall declining market share, U.S. companies drew advantages from integrating their activities with foreign manufacturers. As one study explained, the “paradox” of collaboration between erstwhile competing manufacturers arises “because the benefits obtained through this collaboration are much greater than the inherent risks.” A priority for U.S. firms, wrote an expert panel to the U.S. Foreign Secretary, was Achieving the necessary selectivity to maintain dominance in strategic technologies in a world where total dominance across the board is no longer possible—or even desirable, i.e., retaining the overall U.S. lead in a situation of complex partnership with foreign firms.

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603 Ibid., 16.
Accepting this changed reality required “[l]earning to move from a position of global dominance to senior partnership with companies that have long chafed at the junior position in which U.S. dominance has placed them.” In short, successful firms would be those that leveraged, rather than resisted, foreign partners.

Describing leading firms in these ways, experts produced transnational industrial integration as not only inevitable, but also as harmless and even optimal. Depictions of manufacturers as globally networked entities called forth policies compatible with and supportive of the sector’s tendencies toward transnational industrial integration. In this logic, rather than contain national firms and keep production at home as in traditional manufacturing sectors, policies for the air sector should support the integration of national firms into global markets and networks.

For experts, the landscape beyond national borders was not intrinsically hostile or threatening, but rich in opportunities. Policies were there to help companies draw advantage from foreign partners with growing competencies and resources. In both China and the U.S., these representations supported maintaining minimal hindrances to trade, to outsourcing, to the establishment of manufacturing facilities abroad by domestic firms, and to the establishment of domestic operations by foreign manufacturing firms. In the United States, specialists’ authoritative depictions tacitly kept stricter export regulation off sectoral policymakers’ agendas, directing their attention instead to the competitiveness of U.S. firms. Their representations also rationalised measures to harmonise global standards and verification procedures for ensuring the quality and safety of traded products, producing as desirable programs and policies fostering

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606 Ibid., 16.
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bilateral cooperation in civil aviation. 607 Experts’ performance of their representational practices fixed these dominant meanings in both countries.

3.4. Aircraft items are global composites

A fourth way in which aeronautic experts discursively produced the sector as global and transnational was by representing specific items of aircraft hardware and knowledge as global and transnational goods. They described both tangible and intangible articles as assemblages of contributions from all over the world, the products of global networks of scientists, technicians, and workers. Development and production of these items was a transnational collaboration. Artefacts integrated material and intellectual inputs from throughout these networks. “Aircraft are naturally always a mix of several countries’ technology,” explained one industry analyst. 608

In so characterising artefacts, experts exposed the processes by which these were made. Their representations situated technologies in the processes and circumstances of their production and use. Aircraft were sums of human inputs, such as design choices and labour. As a committee of specialists focused on aircraft flightworthiness wrote,

The manufacture of modern jet transport aircraft is an organizational tour-de-force. Components of the aircraft—wings, tail and landing gear assemblies, fuselage sections, doors and latches, avionic and radio equipment—arrive at the assembly plant from all over the world. In hangars the size of several football fields, work crews tow the airplanes through a dozen or more


608 Interview with international industry analyst specializing in the Chinese commercial aircraft industry, Interviewee 02-16, Beijing, China, 2009: similar representations are also found in Rodriguez Monroy and Vilana Arto, “Analysis of Global Manufacturing Virtual Networks in the Aeronautical Industry”; Bowen Jr., “Global Production Networks, the Developmental State and the Articulation of Asia Pacific Economies in the Commercial Aircraft Industry”; Frear and Metcalf, “Strategic Alliances and Technology Networks.”
positions on the production line, until each finished airplane eases from the hangar ready for testing and approval for flights.\textsuperscript{609}

The airplane was not a finite closed black box, but a collective achievement of human actors. When experts represented their artefacts in these terms, they expressed their community’s tacit humanistic sociology of technology. Artefacts reflected their transnational development and production. They encapsulated their manufacturers’ adaptations to the offset requirements of national governments. The choices firms’ made about how to develop and produce aircraft articles determined their technical features, rather than reflecting them.

In a similar way, expert discourses located aircraft items in global air transportation webs.\textsuperscript{610} For example, U.S. technology was embedded in sociotechnical systems of flight all over the world.

Since the end of World War II, the United States has been a leader in the global aeronautics industry, and, in most cases, U.S. aircraft, engines, and parts have dominated both domestic and foreign markets for subsonic transports, general aviation, commuter, and military aircraft. The buildup of the global transportation infrastructure (i.e., airports and air traffic management systems) has also been driven by U.S. technology and products. The aeronautics industry, one of the largest positive industrial contributors to the U.S. balance of trade, plays a vital role in maintaining the safety and convenience of air travel throughout the world and provides important contributions to the defense of U.S. interests.\textsuperscript{611}

In specialist discourses, aircraft hardware embodied aeronautic knowledge, which was itself globalised and trans-boundary. The science of flight and the nuts-and-bolts work of aeronautic engineering were shared worldwide, knowledges and practices to which participants from different nation-states contributed. Thus, it mattered to experts that the United States led in

\textsuperscript{609} Committee on FAA Airworthiness Certification Procedures, National Research Council, \textit{Improving Aircraft Safety}, 49.
\textsuperscript{610} Ibid., ix, x.
\textsuperscript{611} Steering Committee for a Workshop to Develop Long-Term Global Aeronautics Scenarios, Commission on Engineering and Technical Systems, National Research Council, \textit{Maintaining U.S. Leadership in Aeronautics}, 9; see also Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, \textit{Decadal Survey of Civil Aeronautics}, ix.
“global aeronautics.” They stressed situating “U.S. aeronautics in a global context.” NASA, they wrote, “should provide world leadership in aeronautics research and development.”

Through their representations of aeronautic technology items, specialists produced them as objects of policy.

As specialists performed these discursive practices, they constituted aeronautic technologies as objects of policy. Built into these depictions were policy prescriptions. Global composites from their inception, manufactured in transnational settings and processes, built to common standards, and embedded in worldwide transportation systems, aircraft articles resisted compartmentalisation by country borders. They were intrinsically transnational items. Through these representations, U.S. experts created aircraft technologies as entities whose movement across borders could not or should not be restricted. In the process, they defined the parameters of U.S. export regulation for the sector. Specialist representations established maintaining permissive export controls on aircraft items as natural and desirable.

3.5. The cultural production of the sector as a natural site of trade and cooperation

Reproduced and circulated within both China and the United States, specialist depictions of the sector as global and transnational had a cumulative effect. Specialist representations of air transportation systems, markets for aircraft products, manufacturers, and aircraft hardware constituted the air sector as prone to transnational industrial integration. Through their

612 Steering Committee for a Workshop to Develop Long-Term Global Aeronautics Scenarios, Commission on Engineering and Technical Systems, National Research Council, Maintaining U.S. Leadership in Aeronautics, 9; Committee for the Assessment of NASA’s Aeronautics Research Program, National Research Council, NASA Aeronautics Research, 1; Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, Decadal Survey of Civil Aeronautics, ix.
613 National Aeronautics R&D Goals: Technology for America’s Future, 5.
representations, experts entrenched an understanding of cross-border collaboration as natural, necessary, and desirable. These specialists also created a common view of the international environment as benign. These depictions, produced in culturally specific representational practices, underpinned Chinese and U.S. policies conducive to bilateral trade, industrial integration, and civil cooperation.

In China, policymakers and specialists’ agreement on the transnational nature of civil-commercial air underlay their adoption of a sectoral strategy of integrating Chinese firms into the global aircraft-manufacturing industry. This strategy was summarised as “linking rails with world markets (跟全球市场对接).” Consensus on the global and transnational character of the sector also established joining and participating in international civil aviation processes as necessary and desirable goals for the sector. These two objectives translated into offset policies, national passenger jet programs, and civil aviation programs that fostered bilateral trade, industrial integration, and civil cooperation.

In the United States, policymakers and experts’ constitution of the sector as inherently global and transnational also supported the adoption of policies supporting these bilateral outcomes. This definition of reality underlay the view that “The Administration and Congress need to remove prohibitive legal and regulatory barriers” to trade and U.S. exports. Agreement on this need justified and sustained relatively permissive export controls on aircraft items, making trade and industrial integration with China possible. Consensus on this understanding of the sector also made it possible for policymakers to formulate and adopt programs and policies to

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615 Interview with Shenyang Aircraft Corporation senior manager responsible for international cooperation, Interviewee 12-25-26, Shenyang, China, 2010.
616 “Y-12 Certification a Case Study for FAA”; “FAA to Accept Type Certification on ARJ21-700”; Air China, Boeing and Industry Partners Conduct First Chinese Sustainable Biofuel Flight; “PetroChina to Team with Boeing to Develop Aviation Biofuels.”
cooperate with China in civil aviation. A common view of the sector, created and perpetuated in specialists’ common representational practices, provided the basis for both governments’ policies to foster bilateral trade, industrial integration, and civil cooperation in the air sector.

4. Representing commercial and defense technologies as separate

In the United States, a second point of consensus underpinning policies and programs conducive to trade and industrial integration with China was that civil-commercial and military-defense aircraft technologies were distinct and separate. Specialists discursively erected and maintained a boundary between civil-commercial and military-defense technology items. They achieved this conceptual separation through representational practices that reflected and conveyed their tacit philosophy of human-technology relations. Reproduced within sectoral policymaking circles, this understanding of aircraft technology produced an item-specific and gradated export control regime as feasible and desirable.

The export control regime based on this commercial-defense distinction in aircraft technology in turn allowed managed bilateral trade and industrial integration. Although specialists at times disagreed on the level of threat that any given export item posed, they agreed on the possibility of distinguishing between threatening and unthreatening exports in the first place. Their agreement on this view was a precondition to creating and maintaining rules that restricted exports of some items but not others, allowing trade in commercial and dual-use items but not defense items. Consensus among specialists on the possibility of differentiating aircraft items into these two categories made possible and sustained the permissive U.S. export controls that allowed bilateral trade, industrial integration, and civil cooperation in the air sector.

Experts produced civil-commercial and military-defense aircraft items as distinct in representational practices of two types. First, specialists represented aeronautic technology as a
collection of items of hardware with distinct design features. Specialists produced these items in isolation rather than situating them in a holistic technical and industrial base. Second, experts produced technology items as built to user needs, rather than having intrinsic functions applicable to multiple settings. Both these representational modes relied on an implicit humanistic sociology of technology and an agential anthropology.

4.1. Specific commercial and defense hardware items differ

Specialists established a conceptual separation between specific civil-commercial and defense aircraft items by representing the sum of aeronautic technology as reducible to a collection of particular hardware articles with distinct design features and properties. Focusing their distinct features foregrounded the differences between particular commercial and defense items. At the same time, it held out of view the similar and common capacities required of producers of these two types of items.

These specialist discourses took a common form. When discussing the transferability to defense production of commercial technologies that U.S. firms shared with their Chinese partners, sectoral participants pointed out that commercial and defense items were designed to different specifications. Systems and sub-systems on each side were built to distinct performance requirements, tolerances, and standards. Moreover, aeronautic experts often focused their illustrations of this point on concrete items of hardware, rather than intangible technology items, such as the knowledge of processes and other forms of know-how.

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618 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010; Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.

619 E.g. Cliff, Ohlandt, and Yang, Ready for Takeoff: China’s Advancing Aerospace Industry; Cliff, The Development of China’s Air Force Capabilities: Testimony Presented before the U.S.-China Economic and Security Review
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For example, experts deployed such representations when asked whether a U.S. firm co-producing commercial jet engines with a Chinese factory might assist in the development of Chinese engine technology applicable to a defense program. Under such circumstances, industry participants chose to contrast engines of the type co-produced in China with fighter engines. They responded that fighter engines must perform to vastly greater requirements than airliner engines. Because fighters have to fly much faster than commercial aircraft, often at supersonic or hypersonic speeds, the thrust requirement on fighter engines is very high. Fighters use low-bypass turbofan engines, which delivered this performance.

In contrast, specialists explained, commercial engines were designed to different requirements. Commercial aircraft flew at lower speeds. They used high-bypass-ratio turbofan engines, which delivered less thrust than fighter engines. The thrust delivered by a commercial engine fell far short of what a fighter would require, so a commercial engine was fundamentally distinct from a defense engine, said experts. Commercial engines were designed for less manoeuvrable aircraft. Commercial designs were different from defense designs. Learning how to build a commercial engine was “not enough” for a Chinese engine manufacturer to be able to produce a fighter engine. Exposure to commercial engine manufacture would, therefore, “not really” assist its efforts to develop fighter engine. By implication, the GE and Pratt &
Whitney’s engine-producing joint ventures in China were not strengthening China’s defense aircraft programs.

When experts represented aircraft items in these ways, they also disassociated them from the context of their historical development. Depictions of this type held out of view the origins of commercial aircraft technology in early military programs. Comparisons of specific design features made these larger commercial-defense connections appear remote. For example, descriptions of commercial jet engines overlooked that, like other early civil-commercial aircraft technologies, they derived from military aircraft development. As experts represented such articles apart from their developmental histories, they distanced them from defense technologies and reinforced their commercial status.

Aeronautic specialists described composite-material technologies in similar terms. Elements made of composite materials, such as carbon fibre, on the most sophisticated military aircraft differed from those on airliners. Parts made of composites on advanced fighters could include relatively large structures, built to tolerate high stresses. On commercial aircraft, composite elements were typically smaller and incorporated to marginally reduce weight. They were built to endure many hours of flight and for easy inspection. The composite structures on any given airliner were far different from those on high-performing defense aircraft. Learning to produce composite parts for a commercial airliner would not straightforwardly translate into the capacity to build composite elements for a fighter. By implication, when U.S. firms, such as Boeing, co-produced commercial composites in China, they did not impart technologies that had direct defense applications to their partners.

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624 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
625 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
626 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
Representations in this mode juxtaposed a specific commercial aircraft item with a specific defense item, isolating both from their common context in larger development and production processes. Comparing the features of isolated items of hardware rather than more diffuse and systemic processes established a sharp contrast between commercial and defense technologies. Disentangling artefacts from the webs of their common development and production systems helped establish their status as either commercial or defense items, reinforcing the conceptual boundary between the two types. The effect was to produce commercial and defense aircraft technology transfers as distinct and separate and as requiring different regulatory controls.

In contrast, representations that situated these same hardware items in the larger processes of development and production drew out areas of commercial-to-defense transferability. Examples of these are found in the technical and programmatic analyses cited in Chapter 5. The boundary between commercial and defense technology items, including intangibles, was blurry or sometimes simply absent in these areas. Specialists in industry, government, and academia acknowledged that commercial and defense processes shared commonalities. They also said that there was common “know-how” between the two streams. Some recognised that in these areas, U.S. firms were likely to share technology items that Chinese firms could use on defense programs. In spite of this situation, in the context of trade with China, experts often focused on specific items of hardware and overlooked the defense implications of processual and know-how transfers in how they talked and wrote about technology.

4.2. Technologies are defined by users and usage

A second, related way in which experts produced commercial and defense aircraft technologies as distinct was representing hardware as defined in use and by users. This mode of
representation tacitly assumed a humanistic philosophy of technology and concept of artefacts. For aeronautic specialists, user needs shaped and constituted technology items. Objects were context-bound, defined in action as part of sociotechnical systems led by human operators and users. These representational practices were the opposite of “black-boxing,” or defining technologies by their functions and attributing to them inherent capacities independent of their human users.627

Aeronautic experts performed these representational practices when they elaborated on the differences between commercial and defense hardware in use. In addition to specifying their distinct design features, experts represented aircraft articles as defined by different user needs. These user requirements not only guided the design of the items, but also constituted them as distinct products.

Aeronautic experts’ discourses about engine design illustrated these representational practices. Experts expressed their philosophical commitments when they described the differences between commercial and defense aircraft engines. In their descriptions of the hardware, user needs dictated their features and the design process. Engineers made design trade-offs to satisfy user priorities. For example, designers of fighter engines in general prioritised power and speed over fuel economy and safety.628 Because fighters sometimes needed to operate on shorter runways, their engines needed to rapidly generate substantial thrust at take-off. At the same time, users of fighters accepted high operational risks, so safety considerations often yielded to thrust requirements in design.629

627 This is adapted from a discussion of the scientific method and scientific instruments in Latour, Science in Action, 1–13.
628 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
629 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
The needs of commercial engine users were different, best served by a different product, explained industry and government participants. The design of airliner engines prioritised safety, reliability, ease of maintenance, and fuel economy over thrust. Commercial engines were designed to meet the highest safety demands. Their design needed to allow production and use with unshattering reliability and consistency. Every second that an airliner was grounded cost revenue, so commercial engines also had to be easy to maintain and repair quickly and with parts and expertise available anywhere in the world. Operating costs were a decisive factor in airlines’ engine purchasing decisions, so engines were designed to minimise these. As fuel costs grew as a proportion of airlines’ operating costs, commercial engine designs increasingly prioritised fuel efficiency at cruise speeds. Moreover, airliners needed to fly for hundreds more hours than fighters, so commercial engines were designed for endurance and reliability, rather than raw thrust. Customer demands, operating environments, and missions defined products. For aeronautic specialists, the common-sense way to think about an aircraft item was as a function of user needs.

When experts discursively produced an item of aircraft hardware as constituted by commercial user needs, they established it as an inherently commercial product. These representations held from view alternative applications for these same items in defense contexts. Depictions of aircraft items as reflecting specific user needs attached them to the contexts of their

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630 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
631 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
632 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
633 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
634 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010; Interview with senior technical expert in NASA’s Aeronautics Research Mission Directorate, Interviewee 10-23-19, Washington, DC, 2011.
intended uses and purposes. The properties of these artefacts did not inhere in them, but resulted from and existed only by virtue of larger networks of creation, application, and modification by users and operators. In these representations, aircraft items were not free-floating objects moving between users and settings. They did not have inherent properties that transcended their position relative to their users. The constitution of an artefact by commercial user needs established the item as intrinsically commercial. Expert representations in this mode obscured the applicability of commercial articles to defense programs. They overlooked the possible repurposing of particular items themselves. They also drew attention away from the development and production processes dually applicable to civil-commercial and military-defense production.

4.3. The cultural production of the commercial-defense divide in aeronautic technology

The effect of these various expert representations was to draw and maintain a conceptual boundary between commercial and defense aircraft items. With this delineation established, experts represented technologies as posing distinct levels of threat upon export. This reasoning supported a granular, gradated, and flexible export control order, rather than uniform restrictions on all aeronautic technology exports. To implement such a regime, government analysts examined, classified, and scheduled aircraft exports item by item, applying different degrees of control depending on the level of commercial or national-security threat each posed. 635

Agreement on the commercial-defense distinction in aeronautic technology made regulated bilateral trade and integration in the sector possible in the first place. Based on this conceptual boundary, U.S. aeronautic specialists and policymakers agreed on the possibility of distinguishing between threatening and unthreatening exports of aircraft items. Consensus on

635 Interviewee with Department of Commerce official based at U.S. Embassy in Beijing and closely familiar with the department’s compliance verification program, Interviewee 10-03-00, Beijing, China, 2010.
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this view was a logical precondition to establishing and maintaining rules that restricted exports of some items but not others. It underpinned U.S. policies that allowed trade with China in commercial and dual-use items, but not in defense items. By producing sectoral agreement on the possibility of differentiating aircraft items into these two categories, expert representations made possible and then sustained U.S. export controls that permitted regulated bilateral trade, industrial integration, and civil cooperation.

5. Producing technology transfer risks as manageable

In the United States, a third construction underpinning policies and programs conducive to trade and industrial integration with China in the air sector was the manageability of the technology transfer risks presented by these outcomes. As aeronautic specialists represented technology transfers to policymakers, they characterised the risks they posed and articulated them to national interests. Experts representations of bilateral technology transfers constituted them as objects that could be acted upon and manipulated. Implicit in specialist representations of transfers were prescriptions for state action. Experts’ representations implied that the risks of technology transfer could be managed through rules and institutions, in the progress defining regulated and managed bilateral trade and industrial integration as possible and desirable.

In both China and the United States, experts represented technology transfers as reflecting policies and institutions. In China, policymakers and other sectoral participants sought to foster in-bound technology transfers. They regarded transfers as enhanced by active participation of both technology holders and receivers. Simple items could be reverse-engineered from an artefact, but complex technology required the transmission of know-how and processual knowledge in person and learning by doing. Without the transferring party’s assistance, technology transfer to Chinese firms was limited, experts acknowledged. This understanding of
transfers sustained policymakers’ view that foreign technology holders needed to be incentivised to share. To achieve this outcome, policymakers adopted offset strategies toward foreign firms.

In the United States, specialists represented technology transfers as threats to be fought and risks to be mitigated. U.S. sectoral participants represented technology transfer risks arising in trade and industrial integration as manageable through rules and procedures. Their reasoning assumed that the diffusion of technology to new settings required human agents to actively participate in it. Transfers occurred when sectoral participants acted with the intent to transmit technology. In other words, they represented the transfer of technology as a process subject to human control, rather than inevitable or automatic.

In a sense, both U.S. and Chinese aeronautic specialists represented the likelihood of technology transfers occurring in bilateral trade and industrial integration as manageable through rules and procedures. Experts in both countries defined the optimal outcome for the sector as managed, regulated bilateral trade and industrial integration. Experts characterised their sector in these ways by performing representational practices that conveyed their background philosophical assumptions about human, society, and technology. First, they represented human agents as exercising control over technology diffusion, describing technology transfers as chosen, rather than inevitable. Second, by characterising firms’ and individuals’ actions as responsive to institutions and incentives, experts represented export controls as effective at controlling and managing technology transfer risks inherent in trade and industrial integration. Third, U.S. experts represented export controls as consistent with industry interests. As specialists reproduced and reinforced consensus around these views of the sector, they constructed as feasible a form of bilateral integration managed through controls on sensitive exports.

5.1. Technology transfers are chosen, rather than inevitable
The first way that specialists produced technology transfers as manageable was by representing them as chosen, not inevitable. Experts in industry, government, and academia constructed technology transfers as caused by human agents. In their depictions, the diffusion of technology to new settings was not an autonomous or inevitable process. Instead, it required active vectors. A laborious process, transfer could not occur without deliberate action. By implication, humans controlled and directed whether and how technology transfers occurred.

In these depictions, specialists expressed their instrumentalist concept of artefacts and the humanistic sociology of technical change shared within their community. In the sociotechnical systems of aircraft manufacture they described, humans possessed agency and capacity, while technologies were passive. Rather than back-seat participants in a technology-driven process, individuals and firms made deliberate choices that shaped technical outcomes. In this reasoning, the diffusion of technology to new environments was not a self-propelled technological process, but required human intent and action.

Adopting practices reflecting these underlying philosophical commitments, specialists in both countries described U.S. partners to joint ventures as choosing how much technology and know-how to share with their Chinese partners. In these depictions, even through their best efforts, Chinese firms could not acquire advanced U.S. technology without the complicity of their U.S. partners. For U.S. observers, firms needed to aid and abet proliferation, rather than simply turn a blind eye or passively release technology. U.S. companies were not completely in charge, since they might be incentivised or pressured to share items, but transfers could not occur in spite of them. Transmission did not elude their control.

Experts in both countries represented technology transfers as manageable and deliberate by describing how avoiding transfers was possible. In other words, for aeronautic specialists, transferring technology was a choice, because means to avoid transfers were available. Industry
participants and other experts described two approaches that foreign aircraft firms used to avoid sharing proprietary or sensitive technology with their Chinese partners. The first of these approaches related to manufacture. It consisted in the conceptual or physical compartmentalisation of foreign hardware and knowledge from Chinese participants during the manufacturing process. The second of these approaches related to design and development work, the innovative aspects of aircraft manufacture. It consisted in methods to either compartmentalise this process from Chinese participants or to separate it from the foreign company’s core interests.

Expert discourses about technology transfers through joint manufacturing in China described the means available to avoid and limit them. For example, specialists described how Airbus in practice limited technology transfers even while touting its final assembly line in Tianjin as contributing to developing China’s aviation sector. The most technologically sophisticated elements of the aircraft arrived at the facility preassembled, so local workers’ exposure to them was limited. The bulk of the work in Tianjin consisted in bolting, testing wiring, installing interiors, and painting exteriors, explained a senior manager at the facility. From a technical perspective, how to perform these tasks was “hardly a secret,” Lawrence Barron told Aviation Week in a story on the subject. Nevertheless, as discussed in chapter 3, this characterisation of the facility overlooked important transfers of processual know-how related to assembly, integration, and ground-based and flight testing that took place within it. In spite of this situation, in prevailing representations technology transfers were limited by the foreign pre-

636 Interview with China-based senior manager at a European aircraft manufacturer with joint ventures and facilities in China, Interviewee 19-22-00, Tianjin, China, 2009.
637 Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies,” 46.
638 Interview with China-based senior manager at a European aircraft manufacturer with joint ventures and facilities in China, Interviewee 19-22-00, Tianjin, China, 2009.
In other examples, experts noted that manufacturers of major electronics systems with joint ventures in China also had means to control technology sharing. Such firms could produce their hardware in China, but ship it back to the United States for loading with their sensitive software. They could also deliver preloaded items to Chinese facilities. In short, “core technology are [sic] kept in the USA,” said one government expert responsible for the sector.

Aircraft engine manufacturers who located assembly and other production work in China also had means to limit the transfer of sensitive know-how and technology. Engines were difficult to reverse engineer without development data and other information that the original equipment manufacturer retained. Compartmentalising these prevented the transfer of actual engine-building capability, protecting the company’s crown jewels, claimed specialists.

Specialists described how U.S. firms restricted engine technology transfers to China by maintaining key activities abroad.

U.S. specialists also represented technology transfer risks as manageable when they discussed research and development in connection with Chinese partners. The significance of this aspect of aircraft manufacture grew after 2006, when more U.S. invested joint ventures working on new products were established in China.

To avoid sharing the most technically demanding and sophisticated aspects of their new products and manufacturing processes, U.S. and other foreign firms invested in China-based joint ventures kept design and development work at facilities outside China, experts explained. For example, U.S. firms could satisfy some offset requirements by locating only work on older, widely circulated systems in China, avoiding the risk of sharing their next generation of

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639 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
640 Interview with senior Canadian diplomat responsible for Canadian aircraft industry interests in China and familiar with the Chinese aircraft manufacturing industry, Interviewee 16-16-00, Beijing, China, 2009.
641 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
Indeed, Chinese industry participants and experts complained that foreign firms resisted sharing the most advanced technology, imparting only those items that were losing value. However, as bilateral joint ventures undertook more work on the development of new products, industry participants found ways to represent their partnerships with Chinese firms of this type as also limiting technology transfers. U.S. participants argued that they collaborated mainly in new areas in which they did not have specific technology of their own to lose. For example, Boeing representatives explained that biofuel technology was a new area for both the company and its partners, so that it would not be transferring any U.S.-origin technology items to China in this cooperation project. A GE representative said that its partnership to development an avionics system with Avic Systems would not use GE’s own legacy technology in this area, because it did not have any. These representations constructed the establishment of new research and development programs in China as a means to protect U.S. technology.

By representing methods to stem transfers in these ways, U.S. experts established transfers as manageable. They defined the risks of transfers as finite, contained, and subject to manipulation. Rather than inhering in trade and industrial integration, technology transfers were contingent upon choices. Methods and procedures to control them were available. Transfers were avoidable and unnecessary. These representations supported the U.S. sectoral policymaking community’s agreement on the manageability of transfer risks, a precondition to accepting regulated bilateral integration as a feasible and desirable outcome for the sector.

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642 Cliff, Ohlandt, and Yang, Ready for Takeoff: China’s Advancing Aerospace Industry.
643 Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies”; Air China, Boeing and Industry Partners Conduct First Chinese Sustainable Biofuel Flight; “PetroChina to Team with Boeing to Develop Aviation Biofuels.”
644 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010; for context see also Dolven, “Dogfight over China”; Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies.”
5.2. Export controls are effective and robust

A second way in which U.S. aeronautic specialists discursively produced technology transfer risks as manageable was by representing export controls on aircraft items as robust and effective. In these representations, rules, institutions, and procedures were effective means of controlling the proliferation of sensitive U.S. technology to China. Export controls created an environment shaping the choices of U.S. firms, deterring them from illicitly sharing technologies even when doing so could bring them a commercial advantage.

Experts’ representations of the export control regime drew on their theory of the human actor, of society, and of technology. In their community’s sociology of technology, rules and institutions were robust and consequential, affecting every aspect of their work and business. Institutional structures shaped technical processes. For example, as discussed in the previous chapter, experts described regulations as important shapers of technical change in their industry. The development of new aircraft hardware, they wrote, reflected its “societal and regulatory constraints.”\textsuperscript{645} Safety requirements and environmental standards were among the main factors that determined how the U.S. aircraft industry innovated in areas ranging from engine design to advanced materials.\textsuperscript{646} Moreover, rules and institutions affected how firms and individuals behaved in other ways. For example, aircraft industry participants explained that the U.S. 

\textit{Foreign Corrupt Practices Act} constrained how firms could conduct business and forge


\textsuperscript{646} Ibid.
government relations in China. In short, laws and regulations mattered. Agents adapted to their institutional landscape.

Relying on these assumptions, aeronautic experts and policymakers represented technology transfers as technical processes also subject to control and manipulation through rules and institutions. Regulatory and institutional design became, in this view, the means to containing technological diffusion. As purposeful, rational actors, firms and individuals made choices in response to the incentives and disincentives provided by institutions. These background understandings underpinned U.S. export control ideas and practices. Sectoral policymakers and decisionmakers agreed that export controls and the threat of enforcement deterred U.S. aircraft manufacturers from sharing sensitive technology with their Chinese partners in trade and joint ventures.

Policymakers created and implemented procedures that allowed trade in U.S.-origin aircraft items with recognised defense applications. U.S. and foreign firms could export such dual-use items to China if they obtained a license, which often imposed conditions on the transaction, from the Department of Commerce. For some items, the rules required exporters to obtain end-user pre-approval, a procedure that allowed dual-use items to travel to China if they remained in the use and possession of approved Chinese end-users. These were usually civil or commercial entities separated from defense production by an organisational firewall. A Department of Commerce official operating in China verified compliance with these conditions by conducting periodic site visits. Under this system, precertification of Chinese end-users, inspections of their facilities by U.S. officials, and reporting requirements ensured that dual-use

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647 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
648 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010; Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
U.S. aircraft technologies were not diverted to defense programs. This regime presupposed a view of technology transfers as conditioned and constrained by their regulatory and institutional context.

Export controls, in this understanding, reduced the likelihood of threatening technology transfers to a tolerable minimum. Technology transfers were “limited to the civilian side in the first place,” explained one official. “U.S. firms are extremely cautious for fear of antagonising the U.S. government.” “End-user verification” and other “conditions on export permits” ensured that there was “no technology transfer of substance” from U.S. firms to their Chinese partners. Compliance verification programs in China and the threat of enforcement were designed to protect U.S. national security. Policymakers supposed that the regime was strict enough to ensure compliance even when firms might see a commercial benefit in non-compliance, according to a Department of Commerce official familiar with export controls.

Aeronautic experts even extended this reasoning about technology transfer risks to the subject of space cooperation with China. As a military aircraft expert representing the U.S. government in Hong Kong explained, with space cooperation “there is always a risk, but we did it with the Soviets. Risks can be managed.” Referring to the Soviets, he added, “If we were able to do it with them, then I don’t see why we couldn’t figure out how to do it with China.” In short, he was confident that, given the right design, rules and procedures could address technology transfer risks while allowing cooperation to occur.

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649 Interview with senior Canadian diplomat responsible for Canadian aircraft industry interests in China and familiar with the Chinese aircraft manufacturing industry, Interviewee 16-16-00, Beijing, China, 2009.
650 Interview with senior Canadian diplomat responsible for Canadian aircraft industry interests in China and familiar with the Chinese aircraft manufacturing industry, Interviewee 16-16-00, Beijing, China, 2009.
651 Interview with senior Canadian diplomat responsible for Canadian aircraft industry interests in China and familiar with the Chinese aircraft manufacturing industry, Interviewee 16-16-00, Beijing, China, 2009.
652 Interviewee with Department of Commerce official based at U.S. Embassy in Beijing and closely familiar with the department’s compliance verification program, Interviewee 10-03-00, Beijing, China, 2010.
653 Interview with government official attached to the U.S. Navy based in Hong Kong and with a background in naval aviation, Interviewee 04-13-00, Hong Kong, China, 2009.
The effect of experts’ continual performance of these representational practices was to maintain sectoral consensus on the manageability of technology transfer risks posed by bilateral trade and industrial integration with China. In expert representations, effectively devised rules and procedures for U.S. exporters and Chinese importers mitigated transfer risks, while allowing the two sides to trade and collaborate. U.S. controls on dual-use aircraft technology exports both permitted trade and protected national security, creating the conditions for safe, managed bilateral integration in the sector.

5.3. Export controls are consistent with industry interests

A third way in which U.S. aeronautic specialists produced agreement on the manageability of technology transfers was by representing export controls as consistent with firms’ commercial interests rather than in tension with them. In other words, specialists represented compliance with export controls as serving firms’ interests even in the absence of enforcement mechanisms. Industry and government participants sometimes acknowledged that the verification of compliance with export controls by U.S.-invested joint ventures in China and enforcement within the export control regime were weak. However, they insisted that this situation was inconsequential since U.S. companies’ compliance was in essence voluntary. In this view, export controls were all but self-enforcing.

In these representations, U.S. companies had as much, if not greater, an interest in safeguarding sensitive technology as regulators in the Department of State or Department of Commerce. Equipment manufacturers’ intellectual property was a valuable commercial asset that they did not want to share with their Chinese partners for fear of breeding competitors.\(^{654}\)

\(^{654}\) Interview with U.S. government official in the Department of Commerce responsible for the aviation sector and familiar with export controls, Interviewee 01-08-00-00, Washington, DC, 2010.
While U.S. firms may have had short-term incentives to cheat export controls – for instance, in order to win a major contract – it was in their long-term interest to limit technology sharing with Chinese firms.655

In general terms, these representations produced a harmony of interests between regulators and industry. The policy goals of protecting national security while promoting exports were not in tension, but complementary. Experts’ representations in this mode effectively erased the tension between commercial incentives for firms to share technology and the national interest in limiting sensitive technology transfers. Implementing policies to control sensitive technology transfers was, in these representations, virtually costless and effortless, since companies were incentivised to comply with them in the first place. These representations helped forge agreement on the sufficiency of export controls to manage the technology transfer risks associated with bilateral trade and industrial integration.

U.S. experts also fixed this meaning by equating national interests with aircraft manufacturers’ interests. Aeronautic policy should serve “the needs of industry and the nation,” they wrote. Specialists argued the policies to preserve a robust, competitive commercial aircraft industry did not just serve narrow special interests, but the nation as a whole. A government-industry “partnership” had been important throughout the history of aviation and brought tremendous benefits. Experts identified the needs of industry with those of the nation in several ways, including by emphasising the contributions of commercial aircraft manufacture to American society. The industry enhanced national security by supporting defense aircraft

655 Interview with government official responsible for aircraft-manufacturing industry at U.S. International Trade Administration, Interviewee 16-01-00, Washington, DC, 2011; Interview with U.S. government official in the Department of Commerce responsible for the aviation sector and familiar with export controls, Interviewee 01-08-00, Washington, DC, 2010.
It strengthened the U.S. economy by improving the balance of trade and creating high-quality jobs. The “aeronautics enterprise [was] an integral part of the nation’s economy,” policymakers agreed. “Flight [was] a mainstay of American life,” they wrote. “Mobility through the air is vital to economic stability, growth and security as a nation,” reiterated the 2006 National Aeronautics Research and Development Policy.

When experts represented the commercial aircraft industry as contributing to national defense and security, they produced the policy goals of promoting aircraft exports and protecting national security as mutually dependent. In these representations, trade interests did not subordinate to security interests. Nor were the two priorities in tension. Instead, both were priorities and complementary. Permissive export controls were necessary in order for trade to occur and for U.S. firms to be competitive exporters, which in turn allowed them to contribute to national security. With this view in mind, industry specialists explained that “export controls made sense in some areas,” but not others. Discerning between the two was necessary if policy would allow trade while protecting national security. Increasing exports of aircraft items, dominating the global markets on which these were traded, were national priorities on a par with security. Some even said that the forces of commerce exercised a pacifying influence on bilateral relations.

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656 Responding to the Call: Aviation Plan for American Leadership, 1–3.
657 National Aeronautics Research and Development Policy, 6; Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, Decadal Survey of Civil Aeronautics, 4.
658 National Aeronautics Research and Development Policy, 6.
659 Ibid., 7.
660 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
661 Interview with U.S. government official in the Department of Commerce responsible for the aviation sector and familiar with export controls, Interviewee 01-08-00, Washington, DC, 2010.
662 Responding to the Call: Aviation Plan for American Leadership, 1–3; Steering Committee for the Decadal Survey of Civil Aeronautics, National Research Council, Decadal Survey of Civil Aeronautics, 1–2; Committee on Aeronautical Technologies, National Research Council, Aeronautical Technologies for the Twenty-First Century, 1; Committee to Identify Potential Breakthrough Technologies and Assess Long-Term R&D Goals in Aeronautics and.
Through these descriptions, experts dispelled the tension between firms’ incentives to share sensitive aircraft technology and the national interest in limiting transfers. They framed commerce and security as complementary national interests. In this view, implementing policies to control sensitive technology transfers was unproblematic, since companies were incentivised to comply with them in the first place. The effect of many such depictions over the two decades was to produce export controls as sufficient to manage technology transfer risks.

5.4. Violations of export controls are isolated and tolerable

A fourth way in which experts produced technology transfer risks as manageable was in their representations of violations of the export control regime. Participants discursively reduced export control violations in the sector to isolated, minor, and even tolerable events. In their depictions, the impact of these offenses was confined to narrow areas and negligible in the long run. In spite of this, industry participants were often careful to explain that they did not regard violations of the law themselves as trivial. They often stressed that their companies had no choice but to comply with export controls. However, specialists in industry, government, and academia represented their sector in ways that diminished the impact of violations on U.S. national security, producing existing export controls as sufficient.

In specialists’ representations, violations did not threaten the export control order as a whole or signal its weakness, as they did to specialists in the space sector. At most, violations involving aircraft technologies indicated that particular export controls required adjustments. Breaches were incidental and occasional, not indicators of the regime’s weak fundamentals.


663 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft invested in joint ventures in China, Interviewee 10-02-00, Beijing, China, 2010.
There were exceptions, but most critics argued for a modernisation of the system rather than a tightening of controls.

Aeronautic experts depicted the consequences of export control violations as minor in several ways. The first of these was asserting that China’s aircraft industry either already possessed or had developed many controlled technologies. The second was asserting that, if China’s industry did not have the items already, it would soon. The third was claiming that if U.S. firms did not share given technology items, competing foreign firms would.

First, both industry and disinterested experts asserted that China’s aircraft industry already possessed or had developed on its own many items subject to U.S. export controls. In practice, then, sharing these items was of minor or no consequence. “China already had a lot of the controlled items, so [the system] needs to be a more dynamic, streamlined process,” explained a senior manager at a U.S. company with a joint venture in China supplying the ARJ21 and C919.\footnote{Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.} Owing to the fact that Chinese companies were continuously able to acquire new technologies on world markets, the export control regime needed “changes every few years,” this participant said.\footnote{Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.} At most, then, export controls, when they were respected, kept sensitive technology from China for a few years. Violations only marginally accelerated the Chinese aircraft industry’s progress.

Second, industry participants and experts with no stake in trade both explained that even if China’s industry had not already developed certain controlled items, it would soon. Some believed that China’s development of indigenous aeronautic technology was inevitable and
“certain.” The process was a matter of “just time.” “With or without help, China will build its own [avionics technologies,]” predicted one senior manager at a major U.S. manufacturer with a substantial joint venture to supply the C919. “Space is a very good example” of this process of indigenous substitution, they added. “In maybe just two years,” China will “get there on its own.” Once again, representations of this type minimized the national security impact of violations. Illicit exports could at most slightly accelerate China’s aircraft-industry modernisation.

Finally, specialists in industry and research institutions claimed that even if U.S. companies did not share controlled technologies with Chinese entities, their competitors would. Of the export control regime, one senior manager at a U.S. firm invested in a joint venture said “in some areas it makes sense, but in others there are holdovers that hamper the U.S.” If U.S. companies are prohibited from exporting their products, “France or Germany will sell them” to China, this participant explained. Export controls needed to adapt to a global marketplace that made more and more sensitive technologies available to Chinese buyers. Once again, the implication was that in the long run and the grand scheme, export control violations had a negligible net effect on U.S. security.

666 Interview with senior executive at a European aircraft components manufacturer with operations in China, Interviewee 05-03-00, Shanghai, China, 2009.
667 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010; for context see also Dolven, “Dogfight over China”; Mecham and Anselmo, “Aviation’s ‘Learnaholics’: China Has the Size, Money and Interest to Engage and Challenge Western Companies.”
668 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
669 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 13-12-00, Shanghai, China, 2010.
670 Cliff, Ohlandt, and Yang, Ready for Takeoff: China’s Advancing Aerospace Industry, 121–123.
671 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
672 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
673 Interview with senior manager at a major U.S. manufacturer of commercial and defense aircraft sub-systems invested in joint ventures in China, Interviewee 10-05-00, Shanghai, China, 2009.
These recurring specialist representations reinforced a tacit consensus that export controls on aircraft items did not need to be more strict. Experts and policymakers came to agree that additional restrictions on aircraft exports would not meaningfully strengthen U.S. security, but they would cost important trade opportunities and weaken U.S. firms relative to their European competitors.\(^{674}\)

This tacit consensus was reflected in weak enforcement and legislative action in response to evidence of illicit exports of aircraft technology. A major instance was documented in the 1999 report of the Cox committee, whose investigation found that federal agencies were slow and apathetic in their response to evidence of McDonnell Douglas’s violations.\(^{675}\) In the wake of its investigation, the Cox committee itself successfully pursued a drastic tightening of export laws on space items, but took no similar action on aeronautic exports.

### 5.5. The cultural production of technology transfer risks as manageable

Through representational practices reflecting their philosophical assumptions about humans, technology, and international politics, U.S. aeronautic specialists depicted the risk of technology transfer posed by trade and industrial integration with China as manageable. They reinforced agreement on this view through their representations of four aspects of technology transfers.

First, aeronautic specialists represented technology transfers as subject to human control and intervention. To produce technology transfers as controllable, they drew on their tacit models of the human actor as agent, of technology as passive, and of technical processes as human-led. The technical processes of technological diffusion to China were not inevitable, but

\(^{674}\) Interview with official responsible for trade in commercial aircraft at U.S. Federal Trade Administration, Interviewee 01-16-00, Washington, DC, 2011.

\(^{675}\) Select Committee, United States House of Representatives, “Manufacturing Processes.”
contingent upon choices and action. Methods and strategies to avoid technology transfers were available to U.S. firms, so whether or not to transfer technology while trading and integrating production was their choice and within their control.

Second, aeronautic specialists represented U.S. export controls as robust enough to deter firms and individuals from illicitly sharing controlled technologies with their Chinese partners. In articulating this view, experts drew on their community’s practice of representing institutions and rules as shapers of human conduct. In their depictions, a promising means of managing technology transfer risks was the institutional and regulatory design of export controls.

Third, aeronautic specialists represented export controls as consistent with U.S. firms’ commercial interests. In so doing, they produced the export control regime as unproblematic and virtually self-enforcing, fixing this understanding as fact. Agreement on this construction kept policymakers from considering or prioritising the tightening of restrictions on U.S. aircraft exports to China. As they depicted their sector in these terms, aeronautic experts expressed a liberal-internationalist theory of international politics built into their specialist culture.

Fourth, aeronautic experts produced technology transfer risks as manageable by representing violations of the export control regime as isolated events with no significant national security impact. These representations reinforced the view that export controls in place during the 1990s and 2000s were sufficient and did not require re-examination. They also established that managed trade and industrial integration were safe and desirable bilateral outcomes.

These understandings entrenched throughout the sector, U.S. policymakers and other sectoral stakeholders did not seek any tightening of the export controls on aircraft items. The rules continued to allow U.S. firms to establish joint ventures and share licensed dual-use aircraft technology items with their Chinese partners throughout the two decades.
Conclusion

In 1989, China-U.S. trade, industrial integration, and technical cooperation in the air sector was by no means easily predictable. Several factors, including the defense applications of commercial aircraft technologies, posed obstacles to the integration of the two countries’ manufacturing industries and their cooperation in civil aviation. In spite of these factors, policymakers in both countries adopted policies and programs that allowed and fostered managed bilateral integration, building a distinct bilateral order in this sector.

For an integrated and cooperative sectoral order to emerge between China and the United States in the first place, policymakers needed to agree that the sector required policies conducive to trade and cooperation. Experts’ representations of the sector produced this agreement. In the 2000s, this bilateral order came under strain as China-U.S. security relations deteriorated and concerns about Chinese theft of U.S. technology mounted. For this bilateral order to persist took continued agreement among policymakers on their sectoral policies and programs. Experts’ representations of the sector maintained and reinforced consensus that policies and programs allowing trade and cooperation were feasible and desirable. Without these specialists’ representational acts and their reproduction, bilateral relations were likely to deteriorate into security tension, mutual suspicion, and interstate competition, as they did in the space sector.

Specialists’ representations of the sector were not straightforward or neutral descriptions, but rather conveyed underlying philosophical commitments. As experts described the sociotechnical systems in their sector, they also implicitly prescribed policies consistent with their tacit philosophies. Expert representations constituted some policies as more commonsensical, feasible, and logical than others. Through this process, specialists defined the range of policies that decisionmakers in both countries considered.
These specialists drew on their community’s tacit social theories of technology and discursive practices to represent three aspects of the air sector.

First, specialists discursively produced the sector as intrinsically global and transboundary. They represented airspace and air transportation systems, markets, manufacturers, and aircraft hardware in these analyses. When experts characterised these entities as transcending national borders, they constituted the sector as a natural site of bilateral trade and integrated production. They also rendered the sector incompatible with tight restrictions on the transboundary movement of aircraft articles.

Second, U.S. sectoral experts produced commercial and defense technologies as distinct, providing the conceptual foundation for an export control regime that restricted only some aircraft exports to China. Experts perpetuated sectoral consensus on this commercial-defense divide in two ways. They focused their descriptions of sociotechnical systems on particular items of commercial and defense hardware that could be easily contrasted. They also represented technologies as designed to distinct commercial and defense end-user needs, in the process deflecting attention from the common capabilities required to develop and produce both types of items.

Third, U.S. aeronautic experts produced the technology transfer risks inherent in bilateral trade and industrial integration as manageable through rules and procedures. Their authoritative representations helped maintain consensus on this idea, even when violations of export control rules cast doubt on it. They represented technology transfers as resulting from human choices, not inevitable and automatic processes of technological diffusion. They represented export controls as effective and robust institutions and as consistent with industry interests. They represented export control violations as isolated and tolerable. Against this backdrop, U.S. policymakers did not actively consider tightening export controls on aircraft items.
Through acts of representation expressing their specialist culture, aeronautic specialists defined and constituted their sector as suited to regulated bilateral trade and industrial integration and to civil cooperation. These outcomes prevailed in spite of conditions at the end of the 1980s that made the sector an equally likely site of bilateral tension, hostility, and industrial competition. Overall conditions in the sector under-determined the course of bilateral relations at the start of this period. A stable, integrated, and cooperative bilateral order emerged and persisted because experts created and maintained consensus among sectoral participants on basic understandings conducive to this outcome. Experts built this consensus through representational practices that expressed their community’s sectoral culture. In this sense, bilateral order was produced in specialists’ cultural practices.
Part III:
Space
Part III: Chapter 8

The politics of severed bilateral trade and mounting tension in space

Introduction

Between 1989 and 2009, China and the United States did not engage in significant trade or in any industrial integration in commercial space. Nor did their civil space agencies engage in any substantial bilateral technical cooperation projects. In 1988, the two countries began a promising, if limited, trade partnership in launch services and satellites. On the basis of ad hoc bilateral agreements, this trade lasted over a decade. In 1999, it ended amid evidence that Chinese firms had illegally obtained U.S. space technology and concerns about Chinese technology theft. Over the course of the next decade, bilateral relations in the sector deteriorated into mutual suspicion of security motives and defense capabilities. By 2009, experts in both countries warned of an escalating China-U.S. competition and the likelihood of military confrontation in space. During those two decades, both governments adopted policies that hindered bilateral trade and cooperation by reorienting their national space sectors toward separate, parallel activities. Both governments also adopted policies and programs that aggravated mutual suspicion and tension over security issues.

This chapter examines the policies that the two governments adopted in space and the sectoral outcome that these fostered between 1989 and 2009. In other words, this chapter describes the phenomena this thesis aims to explain in the space sector. The first part introduces Chinese and U.S. space policy during this time. The second part traces the deterioration of bilateral relations in commercial space and national security space during this time, relating the policies adopted by each national government. The third part discusses the absence of bilateral technical cooperation in civil space during the same period.
1. Space policy in China and the United States

China and the United States each pursued different policies and programs in the space sector during the 1989-2009 period. These policies reflected their respective initial levels of space technology and their distinct national priorities and institutions. In spite of these differences, the two countries’ policies were based on similar fundamental understandings of the space sector and the international system. The Chinese and U.S. governments also shared a suspicion of trade, transnational integration, and reliance on foreign parties. Both countries’ policies, in their distinct ways, limited the prospects for bilateral trade, industrial integration, and technical cooperation, and then fostered mutual tension and suspicion.

1.1. Space policy in China

Throughout the two decades after 1989, China’s leaders made policy for the air and space sectors in similar ways. As in the air sector, space policy and programs consisted in the implementation of a technology development strategy, of which the broad outlines were decided in 1986. Several government organs were involved in making and implementing space policy. They included units that formulated policy and programs and others that produced space hardware. Space policy and programs engaged diverse interests and organs throughout the Chinese state.

As early as the 1950s, China’s top leaders took a personal interest in the country’s space sector.676 This situation persisted throughout administrations, from Chairman Mao Zedong to

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676 The idea that “the establishment of space consciousness starts from leaders (从领导开始树立航天意识),” with reference to the head of the Central Military Commission (also the Chairman of the Party), is discussed in Wang Wanchun (王万春) et al., March into Space (进军太空) (Beijing, China: Blue Sky Publishing House (蓝天出版社), 2008), 343–344.
Presidents Jiang Zemin and Hu Jintao. In 1986, when the central government adopted the large-scale national science and technology modernisation program known as Program 863, space was among the sectors prioritised for development. The program funded efforts to develop industrial, technical, and scientific capacity in civil and commercial space. These efforts centered on building large-scale technical systems for human spaceflight and space exploration.

In 2006, Program 863 was succeeded by and expanded under the national Medium- and Long-Term Plan. This strategy identified and funded sixteen unclassified technology mega-projects, including several large projects in space exploration, human spaceflight, and navigation satellite systems. The human spaceflight program progressed to a second stage focused on the launch of three small human-tended laboratory modules, with the on-orbit assembly of a larger space station planned for the period around 2020. The 2006 plan marked the start of work on the second generation of a global navigation satellite system, the Beidou constellation. It also funded the China Lunar Exploration Program (CLEP) (中国探月), a staged project to culminate with a robotic sample-return mission around 2020.

Under these strategies, China’s space sector made steady progress during the 1990s and 2000s. This period became one of many important Chinese firsts in space. The human spaceflight program (中国载人航天工程), Program 921, formally begun in 1992, reached

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678 Wang Wanchun (王万春) et al., *March into Space* (进军太空), 336–339.

several milestones. These included the country’s first flight of the indigenous Shenzhou crew capsule, first human space mission in 2003, and first extra-vehicular activity by a Chinese astronaut in 2008.

Throughout these two decades, the government’s strategy aimed to develop a national base of industrial, technical, and scientific capacity in the sector. Over the course of this period, this approach consistently emphasised the autonomous development of critical space capabilities. As in the air sector, the strategy for building capacity in the space sector reflected the long-term goal of fostering “indigenous innovation.” It also aimed to encourage the development of products to which Chinese entities owned the intellectual property rights. The guiding principle of civil-military integration, adopted formally by the Jiang administration in 1997, also applied to policies and programs for the space sector.

Space policies and programs figured in central-government plans for building a knowledge economy and increasing domestic consumption, in particular of high-technology goods. Developing space-related products and services served the center’s goal of transforming the economy and moving up to the higher value-added rungs of the export ladder. For the central government and the space industry, breaking into the global launch services market with the indigenous Long March series of vehicles was a priority throughout this period. The industry also began to export satellite systems to developing countries on concessional terms. The government created opportunities for foreign sales of Chinese launch services and, later, of satellites through government-to-government agreements.

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680 Chen Shanguang (陈善广), *Heroes of Spaceflight: Tracing Astronauts' Footsteps in the Sky* (飞天英雄--追踪航天员飞天足迹), First preface.
681 Wang Wanchun (王万春) et al., *March into Space* (进军太空), 339–341.
Space policies and programs also intersected with measures to reform the defense industries and large state-owned enterprises. The NDRC led the reform of large state-owned enterprises with the goal of developing globally recognised Chinese brands and high-technology companies competitive on world markets. Costind and, as of 2008, Sasac oversaw the reform of the country’s ten defense-industrial groups. These reforms aimed at improving the capacity of the defense manufacturers to supply domestic military, civil, and commercial end-users, reducing China’s long-run reliance on imports. Case and Casic underwent profound reforms and several rounds of restructuring after 1998. The objective behind these measures was the transformation of the two industrial groups into modern, efficient, profit-driven corporations comprising export-oriented businesses.

The 1986, 1992, and 2006 plans set objectives and outlined principles guiding how they should be pursued. In practice, when policymakers translated the visions into concrete programs, they defined and adjusted them to China’s evolving domestic and international circumstances in each area. Chinese space experts referred to a 40-year development of space as walking a road defined by China’s conditions and development mode (“近 40 年来，中国航天工业，从无到有，到较先进，走出了一条按中国条件和中国方式发展航天事业的道路。”) 683

Several state organs were involved in implementing the programs outlined in the long-term strategies during those two decades. As in the air sector, the main state entity involved in policy and technology development programs was Costind, succeeded by Sastind in 2008. Guided by the long-term strategies, Costind formulated and coordinated the implementation of policy between the large state-owned enterprises in the sector, military and other government end-users, research facilities, and concerned ministries. Ad hoc leading small groups joined Costind in

coordinating the execution of programs by other organs and ministries. The CNSA, a small bureaucracy charged with international relations and agreements in the sector, also played a formal role in policy coordination.

Critical space infrastructure, including the launch facilities of that period, and the day-to-day management of civil space operations were the responsibility of PLA organs. Within the PLA, the GAD played the most important role in space activities. The GAD led China’s major space technology development programs. In civil space, the GAD acted mainly through the China Manned Space Engineering Office (CMSEO) responsible for the human spaceflight program. The PLA Air Force played a role in astronaut training and medicine.

Two major defense-industrial groups built the hardware for these large projects: Casc and Casic. Their major clients were the government organs that ran the space program. Both the civil and military space budgets drained into these two companies. Casc and Casic were large state-owned enterprise groups that subsumed vast and diverse facilities and organisations performing research, development, and production of space systems. Their facilities were scattered across China, clustering around Beijing, Shanghai, and Harbin. Both industrial groups each comprised system integrators, sub-system integrators, and component makers. The larger of the two, Casc, focused on more powerful launch vehicles and larger satellites. Casc subsidiary Great Wall was responsible for marketing Chinese launch services and satellites abroad. The smaller Casic focused on missiles and smaller satellites. Casc and Casic both developed and manufactured civil, commercial, and defense space technology and both were also involved in commercial industries other than space. In addition to these two major players, a number of

684 Besha, “Policy Making in Chinaâ€™s Space Program.”
685 Ma Xingrui (马兴瑞), Space Science and Technology Personnel’s Journey to Maturity (航天科技人才成长之路) (Beijing, China: China Astronautics Publishing House and China Aerospace Science and Technology Corporation, 2011), 4.
small and medium-sized enterprises emerged as users and processors of space-derived data and space-based services during this period. The CSSAR under CAS and universities built scientific instruments and payloads for missions.

Together these actors coalesced around specific policies and programs for implementing the visions outlined in Program 863, Program 921, and the Medium- and Long-Term Plan. Their strategies reflected a commitment to autonomously developing key national space capabilities. At the same time, policymakers encouraged actors in the space sector to pursue opportunities in international markets and for international civil space cooperation when such collaborations would develop China’s space industrial base, rather than substitute for the development of indigenous capabilities.

1.2. Space policy in the United States

In the United States, space policymaking was more diffuse and fragmented. In the wake of the Apollo program, U.S. space policy was not guided by an overarching long-term strategy, but evolved with successive administrations. Each administration issued a comprehensive national space policy, emphasising distinct priorities and sometimes re-allocating responsibilities across organs within the sector.

The national space policy and specific policies for civil, commercial, and national security space were decided by the office of the President with input from agencies. The National Security Council and OSTP usually led the formulation of the national space policy through an inter-agency process. Within this system, these entities within the executive office of the

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President, the office of the NASA administrator, organs within the Department of Defense, and other departments and agencies contributed to the design of aspects of the policy. Specific programs implemented by NASA and other federal agencies were defined in negotiation with the Congress. Within the legislative branch, influential committees of the House and Senate oversaw and funded the major federal agencies involved in space. Decisionmakers in both the executive and legislative branches sought input on policies and programs from space experts through formal and informal channels. Together, these institutions created the environment of policies facing and shaping the U.S. space industry.⁶⁸⁸

Although, no single lasting vision for civil and commercial space guided U.S. policy during this period, successive national space policies defined similar aspirations and principles to guide space activities. These included strengthening the nation’s leadership in space, ensuring that space capabilities are available to support national security, homeland security, and foreign policy objectives; ensuring access to and freedom of operation in space; fostering innovation and the competitiveness of space exports; pursuing human and robotic exploration to extend human presence across the social system; making scientific discoveries; and ensuring that space capabilities are available for environmental activities and scientific Earth observation. These policy priorities shifted throughout administrations, but the major themes remained consistent.

A few major NASA programs also defined the direction of civil space activities during these two decades. The largest of these consisted in the development and operation of the space shuttle crew transportation system. The shuttle was the cornerstone U.S. capability for building, participating in, and utilising the ISS. NASA also ran long-term programs in space science, human and robotic exploration, and Earth observation. In addition to NASA, several other agencies acted in civil space. The National Oceanographic and Atmospheric Agency (NOAA)

was a major civil space operator and user, providing data on the weather, the climate, and the oceans to the government and public. The FAA was responsible for regulating commercial spaceflight launch operations. The largest government users of space were the military and the intelligence agencies within the Department of Defense.

The U.S. space industry remained the world leader in technology during those two decades, but it gradually lost market share and some of its technological advantage to European companies. The space industrial base formed a tiered pyramid of firms. A handful of integrators of satellites and launch vehicles occupied the top tier. These included Hughes Satellite Company (Hughes), Space Systems Loral (Loral), Boeing Satellite Development Center (later Boeing Commercial Satellite Systems), Lockheed Commercial Space Systems, and Martin Marietta. In the wake of the Cold War, this tier consolidated into a few large entities: Lockheed Martin, Boeing, Loral, and Orbital Sciences. These companies produced commercial communications satellites for operators around the world. They also made mission-specific satellites and sub-systems for U.S. government customers, including NASA and agencies within the Department of Defense. The Lockheed Martin and Boeing companies also had divisions that produced launch vehicles, which the two behemoths combined to form the joint venture United Launch Alliance (ULA) in 2006. The second tier of the pyramid consisted of integrators of sub-systems, including rocket engines. Among them were Pratt & Whitney, Aerojet, and Rocketdyne. The third tier comprised suppliers of small spacecraft sub-systems. At the base of the pyramid were hundreds of firms supplying the upper tiers with specialised components. These different types of companies were tied into each other and into global satellite- and launch vehicle-manufacturing networks through sub-contracting relationships. With the exception of ULA,

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nearly all of these firms relied on export markets in some way. In addition to these established firms, a new generation of so-called “commercial” space firms emerged during this period. They were often private entrepreneurial ventures oriented toward commercial business.\textsuperscript{690}

Several government agencies regulated U.S. exports of space items whose foreign sale or transmission affected national security or foreign policy interests. Export controls over particular space items changed throughout those two decades. During this entire period, launch vehicle technologies were classified as defense items and controlled as missile technologies by the Department of State. Listed on the U.S.ML, these items were subject to ITAR and the \textit{U.S. Arms Export Control Act} that implemented it. In the 1980s, commercial communications satellites were also classified as defense items and scheduled on the U.S.ML, but were later reclassified several times. In the mid-1990s, commercial satellites and their components appeared on the CCL, administered by the Department of Commerce under the \textit{Export Administration Regulations}. These evolving rules allowed bilateral trade in space items until 1998, when Congress passed a law that moved all space items to the U.S.ML and abruptly ended it.

2. The cautious start and abrupt end of bilateral trade in space

From the 1980s onward, the Chinese and U.S. governments each adopted policies that defined the course for bilateral relations in the space sector. However, U.S. government actors made many of the most important decisions, including in particular when they modified export controls on space items, often in response to developments within China. This section traces how bilateral relations evolved with changes in both capitals, from the Deng through to the Hu administrations in China and from the Reagan to the second Bush administration in the United States.

\textsuperscript{690} Bromberg, \textit{NASA and the Space Industry}, 2–3.
China enters global launch markets

During the last decade of the Cold War, the administrations of Deng Xiaoping and Ronald Reagan cooperated against the common threat they faced in the Soviet Union. Strategic priorities dictated both governments’ decisions in these areas, ideological differences taking a backseat to their contingently aligned interests. The U.S. government allowed substantial exports of weapons systems to China. In space, the U.S. Air Force and Chinese authorities agreed to the placement of U.S.-operated instruments on Chinese territory to detect Soviet missile and space launches.

Around the same time, China’s reformers and science and technology bureaucrats began to reorient China’s economy toward entering high-technology export markets. In 1985, the Chinese space industry responded to this opportunity. Calt, represented abroad by Great Wall, began to launch foreign-made commercial satellites on the Long March-series vehicles from the Xichang launch center in western China. China also imported satellites during this time. The government made purchases of foreign-made satellites conditional upon their launch on a Chinese vehicle.

Meanwhile, in the United States, the launch segment of the space industry contended with the unintended consequences of policies for Space Shuttle utilisation and defense payload launches. The demands of catering to large civil and defense space programs and other constraints weakened the launch industry’s position in commercial markets. U.S. commercial launches grew expensive, scarce, and unpredictable, while U.S. policy still required satellite manufacturers to launch on U.S.-made vehicles. Regulations restricted the travel of U.S.-made commercial satellites abroad for launch. At the time, communications satellite exports were controlled under ITAR as defense items. By the late 1980s, U.S. launches were in such short
supply that satellite manufacturers saw their own competitiveness suffer and pressed the administration for access to international alternatives.

Facing these industry demands, the Reagan administration in 1988 concluded an agreement with the Chinese government allowing U.S.-made satellites to travel to China for launch on Long March rockets. These “deemed exports” of U.S.-made satellites to China for launch were subject to negotiated conditions on the price and number of the launch service and on technical safeguards. The Reagan administration waived license requirements on these exports. The bilateral trade in space items began.

**The Tiananmen Sanctions**

When the first Bush administration came to power, it extended its predecessor’s policies by negotiating new launch agreements with China. The space trade continued in this manner until Tiananmen Square crackdown of 1989, when the U.S. Congress legislated a tightened prohibition on exports of defense items to China. The Tiananmen Sanctions Law prohibited the Department of State from licensing exports of all defense items, including satellites, to China. The Bush administration then reclassified some commercial communications satellites from defense items to dual-use items, or items designed for commercial use but with potential defense applications. This designation placed them under the licensing jurisdiction of the Department of Commerce. The trade in launches and satellites continued.
The end of the Cold War and trade expansion

The collapse of the Soviet Union and the Clinton administration’s entry into office brought a reorientation of U.S. foreign and export policy. Facing a newly benign international environment and high expectations of a peace dividend, the new administration prioritised promoting trade and exports, goals that had been subordinated to strategic interests during the Cold War. Industry got the Clinton administration’s ear.

President Clinton continued his predecessor’s policy of authorising launches of U.S.-made satellites from China under the cumbersome waiver process. The new administration initially reversed some of the Bush administration’s changes to controls on commercial satellite exports. However, after its own inter-agency review processes, the Clinton White House reclassified more commercial satellites as dual-use items, further expanding the Department of Commerce’s licensing authority under the more permissive Export Administration Regulations. By the mid-1990s, the Commerce Department issued licenses for exports of U.S.-made satellites to China, easing the way for expanded trade in space items between the two countries.691

This evolving regime of bilateral agreements, controls, and waivers allowed trade in space items with China for over a decade. Under the 1988 agreements and their successors, some 30 U.S.-made satellites launched from Xichang by 1999, 28 of which were successfully placed in orbit in 20 launches.692

Export control violations and federal investigations

Over the course of this trade, three Chinese launches of U.S.-made satellites failed. Each of these failures caused the total destruction of its payload. In 1992, the Long March 2B failed

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691 Zelnio, “A Short History of Export Control Policy.”
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shortly after lift-off while carrying the Optus 2b communications satellite, built by Hughes. In 1995, the same vehicle failed again, carrying the Apstar 2 communications satellite, also made by Hughes. In 1996, the Long March 3B failed with the Loral-built Intelsat 708 communications satellite on board. Both U.S. companies participated in technical investigations into the causes of the launch failures. These technical investigations occasioned technology transfers, which triggered the legislative process that ended the space trade between the two countries.

In 1998, evidence that Hughes and Loral had violated export control laws by sharing controlled information with Chinese personnel reached the U.S. government. Federal agencies began investigations. The companies Hughes and Loral made voluntary disclosures that they had unintentionally violated export controls when they participated in investigations of the launch failures with the Chinese launch vehicle provider.

Congressional investigations

In 1998, a New York Times article reported that government agencies were investigating whether export control violations by Hughes and Loral had led to the transfer to China of space and missile information that compromised national security. These investigations still underway, the Congress turned its attention to the U.S. policies that allowed satellite exports to China for launch. Each of the two chambers of Congress established a committee to investigate the allegations reported in the press.

The bipartisan Senate Select Committee on Intelligence, led by Republican Senator Craig Shelby of Alabama, conducted the first of these investigations. The committee’s May 1999 report, titled *Report on Impacts to U.S. National Security of Advanced Satellite Technology Exports to the People’s Republic of China*, concluded that the launches of U.S.-made satellites from China had compromised U.S. national security by allowing the transmission of technical
information to the Chinese space industry.\textsuperscript{693} The committee advocated strengthening technical safeguards during launch campaigns and gradually phasing out the policy of allowing U.S.-made satellites to launch from China. Although lauded as a sober and substantiated analysis, this report was soon eclipsed by a second, more influential investigation.\textsuperscript{694}

The House of Representatives conducted this second, larger, and more influential investigation. Republican Representative Christopher Cox of California chaired the specially created bipartisan committee that led the investigation.\textsuperscript{695} The Cox committee’s inquiry was greater in scope than the Senate investigation. In addition to satellite transfers, it also examined also other cases of technology transfer and theft related to China, including at the national nuclear weapons laboratories. Its findings were released in preliminary form in 1998 and in a final report released to the public in December 1999 under the title \textit{U.S. National Security and Military/Commercial Concerns with the People’s Republic of China}. The declassified version of the three-volume report is 772 pages long. Of the eight chapters that examined transfers in particular technical areas, five are dedicated to space products and services.\textsuperscript{696}

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\textsuperscript{693} Ibid.
\textsuperscript{694} Joseph Cirincione, “Cox Report and the Threat from China” (presented at the Cato Institute, Washington, DC, June 7, 1999).
\textsuperscript{695} \textit{U.S. National Security and Military/Commercial Concerns with the People’s Republic of China}.
Findings of the House investigation and controversy

The Cox investigation found that Hughes and Loral endangered U.S. national security when they disclosed technical information about the launch failures to their Chinese partners. The committee found that the companies broke the law by providing a defense service and communicating controlled technical knowledge to Chinese nationals when their employees participated in the failure investigations with Calt. The Cox report concluded that sharing the failure analyses could have led to improvements of China’s Long March rockets. The committee also found that the sharing of the failure analyses could improve Chinese ballistic missiles, which used or could in the future use technologies similar to those of its commercial launchers. These findings provided the basis for the committee’s conclusion that controls on space exports to China should be tightened and that the trade in space items with China should end.

The committee’s findings were controversial. Technical experts disagreed with the investigators’ characterisation of the technologies at stake and their policy conclusions. Responses attacking the report’s technical arguments and conclusions about a range of technologies were published by researchers affiliated with Stanford University, Harvard University, the Lawrence Liverpool National Laboratory, the Cato Institute, the Carnegie Endowment for International Peace, and the Federation for American Scientists.697 U.S. critics of

the Cox investigation spanned the U.S. political and ideological spectrums. China’s State Council also issued an English-language response to the report that identified errors and provided its own version of events, sometimes citing U.S. experts. Most of the controversy centred on the Cox committee’s analysis of China’s nuclear arsenal development, but extended to its claims about space technology.

Among U.S. observers, most of the contention centred on the Cox committee’s analysis of China’s nuclear arsenal development, but extended to its claims about space technology. Detractors tended to bring three major critiques against the Cox investigation and report.

First, they criticized the committee for technical errors, both large and small, in the report and investigation. U.S. experts disagreed with the technical analysis and the characterisations of the rocket technologies in the report. In particular, they disagreed with the report’s finding that the transferred information about launch vehicles could be applied to future Chinese missiles. Critics argued that the fairings and inertial measurement units used on the Long March vehicles were not suitable for missile applications.

Second, detractors criticised the report for its hostility to the Clinton administration. Many saw in the report a strong partisan bias and a smear campaign against the President. The committee suggested that the Clinton administration was beholden to PLA associates who had

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made campaign contributions.\textsuperscript{700} However, these critiques overlooked that the committee itself comprised members from both parties, including senior Democrats on other committees responsible for intelligence and national security. These figures were unlikely to have been cowed into endorsing a report by their Republican colleagues. The composition of the committee also made it improbable that the committee would produce a report that pandered to narrow specialist interests in the launch industry aligned with Republican representatives.

Third, some critics characterised the committee’s conclusions as reflecting its interest in supporting the U.S. launch industry from Chinese competition. However, the launch industry itself did not have the interest in measures to restrict U.S. purchases of Chinese launches that these critics alleged. The major U.S. launch provider of that period, the joint venture between Boeing Launch Services and Lockheed Martin Space Systems known as ULA, was oriented toward servicing government launch needs. In the market for government launches, ULA faced no competition, either domestic or foreign. Prioritising government contracts, ULA lost most of its commercial business to European and Russian providers. As a result, protection from an even more competitive Chinese supplier would not have made an impact on ULA’s market share or business.

On the contrary, the joint ventures’ partners shared an interest in permissive export controls. Both Boeing and Lockheed Martin had profitable satellite-manufacturing divisions that

\textsuperscript{700} \textit{U.S. National Security and Military/Commercial Concerns with the People’s Republic of China}. Both critics and supporters of the Cox investigation described it as part of a Republican effort to weaken support in the looming presidential election for the Democratic Party, who opponents saw as politically vulnerable in the wake of the Monica Lewinsky scandal. A knowledgeable observer who worked on space policy in the Clinton White House called the Cox report a “political campaign” and a “smear job,” Interview with executive in major international commercial space company, Interviewee 18-04-00, Colorado Springs, CO, 2012; Interview with former technical analyst in the Department of Defense and contributor to the Cox investigation, critical of the Clinton administration, Interviewee 08-19-00, Washington, DC, 2011.
benefited or would have benefited from the opportunity to sell their products to China. The 1999 change cost them these opportunities. Boeing, which acquired Hughes after the scandals, had in its possession a satellite built for a Chinese customer in 1998, Chinasat-8, that it could not deliver because of export rule changes that the Cox report would provoke. Lockheed-Martin had sold at least one communications satellite to the Chinese government before these changes. Moreover, Cox himself was from a part of California where the satellite industry was among the most powerful interest groups, employing 25,000 people in that state. These factors make it improbable that the technical analyses in the Cox report were manipulated to serve either partisan or industry interests.

1999 legislation of tighter export controls

The Cox committee’s findings that Hughes and Loral’s disclosures during the launch failure investigations compromised U.S. national security became the basis for its policy recommendations. On the basis of its preliminary investigation, the committee concluded that U.S. companies should be prohibited from exporting U.S.-made satellites to China for launch. The basis for this conclusion was not solely the committee’s view that Hughes and Loral had breached export controls, a fact that had yet to be separately established by federal investigations. The violations alone did not warrant a new law, since the institutions intended to verify compliance functioned. “The system worked the way it was supposed to,” said a senior U.S. government official familiar with the cases, pointing out that the violations were caught and

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702 Harvey, *China’s Space Program: From Conception to Manned Spaceflight*, 128–130.
704 Ibid., 170.
705 Interview with senior Department of Commerce official who had participated in the launch campaigns in China in the 1990s and in the investigations of the violations, Interviewee 11-23-00, Washington, DC, 2010.
investigated. Reaching further, the committee argued that the violations and the likelihood that they would occur again posed intolerable risks to national security, concluding that the policy required wholesale abolishment. Protecting national security required not only punishing the offenders in these specific cases, but also prohibiting export transactions that could occasion to future transfers.

The Cox committee’s release of its findings led to the passage of a law that made the controls on satellite exports to China far stricter. In 1998, the committee circulated a preliminary report of its ongoing investigation among lawmakers. This initial report urged tightening restrictions on exports of U.S. satellites to China for launch, including the restoration of commercial satellites to the U.S.ML, the list of export-controlled defense items administered by the Department of State. Classified as defense items, satellites could not be legally exported to China without special exemptions, such as a presidential waiver. Legislators wrote this recommendation into law, adding a provision requiring, the President to certify to Congress 15 days in advance that any transfer of satellite technologies to China would not harm U.S. launch companies or help China’s missile technology development if granted a waiver. The export control changes were included in the Strom Thurmond Defense Authorization Act, passed in 1998 to take effect in 1999.

The law drastically changed export controls on space items. First, the new regime reclassified all space items as requiring the same tight level of control. Commercial items formerly regulated as dual-use became subject to the same strict licensing process as defense items. Strom Thurmond grouped all space items under Category XV of the U.S.ML. Under ITAR and the Tiananmen sanctions, State could not grant an export license for any U.S.ML item

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706 Interview with senior Department of Commerce official who had participated in the launch campaigns in China in the 1990s and in the investigations of the violations, Interviewee 11-23-00, Washington, DC, 2010.
destined for China. These conditions applied uniformly to all U.S.ML items, regardless of their features or applications.

The legislation removed the authority from the executive branch of government to create item-specific export controls. A blanket, uniform restriction prohibited the export to China of space items, regardless of their level of sophistication, availability on the global marketplace, or their similarity to other freely traded items. As a State Department official responsible for Category XV export controls explained, a bolt on a satellite was in practice export controlled as strictly as a missile. A former Commerce official who negotiated the bilateral agreements said the Cox report removed the “granularity” from the space export control regime.707 When Congress passed Strom Thurmond, it used a blunt instrument to redress the delicate balance of trade and national security interests in export control policy, a move comparable to “swatting a fly with a sledgehammer.”708

The Strom Thurmond provisions focused explicitly on China as the destination of space exports to be more strictly controlled. However, the effects of the legislation extended to space exports to other countries. The new rules significantly reduced export opportunities in many markets, including those of U.S. allies. The legislation’s emphasis on China complicated efforts at export control reform for the next decade and beyond.

Although the legislation had a substantial impact, it was not the main reason that the space trade with China ceased. The 1999 changes did not establish a new export control regime for space items, but rather restored features of the one in place until 1993 and under which satellite exports to China had occurred. Exports remained possible under the new rules, but they

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707 Interview with former Department of Commerce official responsible for negotiating the bilateral launch agreements, Interviewee 04-23-00, Washington, DC, 2011.
708 Interview with former Department of Commerce official responsible for negotiating the bilateral launch agreements, Interviewee 04-23-00, Washington, DC, 2011.
required a significantly more onerous process. A company wishing to export a satellite to China could still apply to State for an exemption to licensing. If this request was approved internally by the export control organs of the Department of State and if the Secretary agreed to put it before the President, he could, possibly following an interagency review of the implications, waive the restrictions, as had happened for launches in 1988 and 1992. 709

What made a waiver unlikely after 1999 was not the export control process per se, but a new political climate created by the Cox report, in which the export of a satellite to China was regarded as imperilling national security. In order for the President to have granted another waiver, each of several levels of departmental export control administration and the Secretary of State would have had to be willing to bring the request to their superiors. Both career civil servants and political appointees within the Department regarded this course of action as unlikely to succeed and as an inappropriate use of authority, time, and other departmental resources. 710 The most significant effects of the 1999 provision were therefore not on formal export controls, but on the new understanding of space items and the space trade with China it created. 711

While the space trade was in principle still possible under the stricter rules, the influential Cox report transformed prevailing understandings of space items and the risks of their export to China, creating a political atmosphere that made trade with China in space items impossible. The Cox report made an indelible impact on decisionmakers and the public, shaping how they thought about trade with China for over a decade. 712 It was the first authoritative presentation of a pattern

709 Interview with management-level export licensing official in the Directorate of Defense Trade Controls of the Department of State, Interviewee 20-04-00, Washington, DC, 2011.
711 Harvey, China’s Space Program: From Conception to Manned Spaceflight, 128–130.
of systematic Chinese espionage against the most sensitive U.S. national security targets. The investigation entrenched an understanding of the trade in space items with China as threatening U.S. national security and impossible to manage through regulation. After Cox, space experts focused on how minor technology transfers could bring previously overlooked incremental and hypothetical improvements to Chinese systems, expanding the range of transfers that raised national security concerns. These factors combined to make bilateral trade in space items all but inconceivable to many U.S. experts after 1999.

Alongside these developments, federal investigations into the violations by Hughes and Loral continued. Investigators later determined that the companies had repeatedly violated export controls. These findings resulted in fines against the satellite manufacturers.

Mounting costs of space export controls

In the years after Congress passed Strom Thurmond, evidence mounted that the tightened export controls harmed the U.S. space industry, but neither the second Bush administration nor any actors in Congress sought to change it.

Some experts warned early on that the provisions would be disastrous for the U.S. satellite industry, but lawmakers hastily passed the law in spite of them. While space exports to China were straightforwardly illegal, the new rules also limited and complicated export transactions to other destinations. After the re-classification, the State Department licensed space exports under strict conditions and denied license applications more often than in the past, even to users in U.S.-allied nations. License application processing grew slow and cumbersome, the risks of a license being denied added uncertainty to time-sensitive sales, and restrictive conditions

with former congressional staffer, contributor to the Cox investigation, and technical analyst in the Department of Defense, Interviewee 08-19-00, Washington, DC, 2011.
attached to licenses prevented U.S. satellite makers from sharing the technical data about their products that potential customers sought. The system dissuaded many satellite makers from seeking export opportunities in the first place.

These effects gradually grew noticeable. At first, U.S. satellite manufacturers were buoyed by orders from domestic customers, so the effects of the new rules on the industry as a whole were not apparent. For a period, the lack of international alternatives to U.S. components also shielded the satellite manufacturers from the impact of the new controls. Over the years, however, U.S. satellite makers began to lose global market share to European competitors and other foreign concerns. In response to customer demands, European satellite manufacturers began to market “ITAR-free” satellites entirely devoid of U.S. components, which could be sold abroad unfettered by the cumbersome and unpredictable State Department process.

The harm to U.S. manufacturers grew and grew. Corporate leaders lobbied and advocated for a repeal or modification of the strict rules, complaining before Congress of customers lost to competitors because of the export controls. Lost sales that “would have otherwise been” were difficult to document, so these arguments remained counterfactual and anecdotal. U.S. satellite manufacturers also faced a cyclical dip in domestic demand that made it difficult to extrapolate the magnitude of the impact that export regulations inflicted. Evidence that export controls were hurting U.S. interests mounted, but failed to compel decisionmakers to action.

By the mid-2000s, this situation had begun to change. Respected think tanks, academics, and even government agencies began to study the impact of export controls and attempt to measure it. These studies agreed that export controls placed U.S. manufacturers at a disadvantage. A consensus emerged in these circles that ITAR-style export rules were anachronistic, products of a bygone era of East-West antagonism and ill suited to the increasingly globalised space industry. The satellite industry seized upon these findings as it continued to
lobby for reforms. Small bipartisan coalitions of lawmakers even tried to initiate reviews or modifications of the *Strom Thurmond* provisions.

In spite of these developments, the majority of Congress, the Bush administration, and the Defense and State bureaucracies resisted any change that would relax controls on exports of space items to China or any other market. These actors maintained this stance through the end of the decade even as evidence mounted that export controls were not only harming satellite makers and their suppliers, but also failing to curb the proliferation of space technologies to new countries. The U.S. satellite industry’s decline continued.

The *Strom Thurmond* provisions also had effects beyond the United States. The 1999 export controls decimated China’s budding space export industry. Nearly all satellites sold on world markets contained U.S. components, so their movement to China was subject to U.S. rules even if the satellite integrator was not a U.S. company. Moreover, U.S. export controls applied beyond U.S. borders to users and resellers of U.S.-originated technology. Foreign firms violating U.S. export laws faced the denial of future licenses to import the controlled U.S.-made components on which they depended. After *Strom Thurmond*, no foreign-made satellites containing U.S.-made parts could legally travel to China for launch or be sold to a Chinese operator. As a result, Calt was shut out of the global commercial launch business.

The new controls also prohibited sales of satellite technology to Chinese buyers. They denied China’s space users access to any communications satellites made with U.S. components. Given the weakness of China’s domestic satellite manufacturing, this change set back government plans to expand space-based services and develop space-based applications, said a former employee of a Chinese operator that sought to purchase U.S.-made satellites before the
Denied access to foreign systems, China’s space industry redoubled on efforts to meet the country’s space technology needs.

**China’s anti-satellite weapon test**

As the 1999 U.S. law curtailed China’s space export industry and access to foreign satellites, it galvanised Chinese leaders’ commitment to autonomously development advanced national space capabilities. Under President Jiang Zemin, the central government had already significantly invested in accelerated space programs throughout the 1990s. When the Hu administration ascended to power in 2001, it continued and expanded Jiang’s technological modernisation effort. In 2006, the central government issued the *Medium and Long-Term Plan*, which announced additional resource commitments for several space mega-projects. Cast produced satellites and Calt produced launchers to meet domestic program needs.

Chinese leaders did not give up on space exports altogether. Top leaders and industry representatives continued to advocate for bilateral trade in space items in private meetings and public fora, such as conferences and gatherings within international organisations. In parallel, China’s space industry sought out export opportunities in markets underserved by major U.S. and European companies. These markets included cash-poor developing countries and countries to which U.S. exports of defense items were restricted. While fostering international collaborations of this type, Chinese policymakers prioritised the autonomous development of comprehensive national space capabilities by establishing, supporting, and accelerating large and multiplying programs.

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713 Interview with consultant-broker to China’s Ministry of Post and Telecommunications and the entity that later became ChinaSat, Interviewee 11-11-12, Beijing, 2010.
In 2007, one of China’s long-term space technology development programs reached maturity. In January of that year, the PLA GAD conducted the country’s first test of a kinetic anti-satellite weapon. An interceptor launched on a modified missile struck and destroyed its target, an aging Chinese weather satellite in low-Earth orbit (LEO). Fragments from the impacted satellite created a thick trail of persistent debris in already crowded LEO, increasing risks and costs to other users of the orbit.

The test itself and the debris consequences shocked the international community. Foreign governments responded with condemnations and critiques of the test in multilateral settings, such as UNCOUPOS. The U.S. defense establishment in particular was alarmed by the test, although the U.S. defense and intelligence communities had known of earlier attempts at intercepts and observed preparations for the launch. Recognising that the U.S. military had grown reliant upon satellites for every aspect of its operations, analysts in the Defense Department, experts within the Bush administration, and Congress saw in the test undeniable evidence that China intended to target the soft underbelly of U.S. military power.

**Aggravating security concerns and tensions on both sides**

After the 2007 test, the possibility of reforms to controls on space exports grew even more remote. Advocates of space trade and cooperation with China, few to begin with in U.S. policy circles, were marginalised and lost credibility. The test lent authority and weight to defense intellectuals and analysts suspicious of Chinese intentions and sympathetic to the Cox committee’s conclusions, bolstering the influence of these figures within agencies and among the public. Because the topic of space export control reform was bound up with the China question and the Tiananmen sanctions, both the administration and Congress stayed clear of it. Earlier
efforts at changing the rules, however modest, were shelved, none seeing these as likely to succeed or worth any expenditure of political capital.

Security tensions over space issues between the two countries worsened again in 2008, when the U.S. military performed a similar intercept to the Chinese anti-satellite test of the previous year. Called “Burnt Frost,” the mission’s official goal was to destroy a malfunctioning U.S. satellite, U.S. 193, whose uncontrolled descent toward Earth posed a public safety threat.

Scientists and experts in the United States, China, and other countries, including Russia and India, met the official justification for the intercept of U.S. 193 with scepticism. Chinese observers interpreted this U.S. manoeuvre as a response to their country’s anti-satellite test of the previous year, reinforcing their conviction that U.S. hostility was growing. Chinese analysts represented the decision to shoot the satellite down as a message that the U.S. would not let its hegemonic position be threatened. In this view, the Bush administration decided to intercept the satellite to show China’s leaders that the U.S. military also had the capability to destroy other countries’ space assets. In this act, Chinese experts saw an implicit but unmistakeable threat to their country’s access to and use of space.

After Burnt Frost, tension and suspicion of the other’s space activities mounted on both sides. Chinese analysts predicted an arms race in space and a new round of international space competition, some warning that a space war loomed. U.S. experts similarly argued that a war with China in space was an imminent reality. With experts in both countries convinced that space was the next battleground in their rivalry, bilateral cooperation and trade in the sector became inconceivable to the U.S. government, including the administration, lawmakers, and space experts in major departments. Policymakers in the United States determined to maintain

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strict controls on space exports to China and to further restrict technical cooperation between the two countries' civil space institutions.\textsuperscript{715} Chinese leaders resolved to pursue and demonstrate comprehensive autonomous commercial, civil, and defense space capabilities.

3. No technical cooperation in civil space

In parallel to their deterioration in commercial space and national security space, bilateral relations in civil space also withered and floundered over the course of the two decades. Weak at the beginning of this period, technical and scientific space cooperation between the two countries all but vanished after the 1999 *Strom Thurmond* act.

Following the Tiananmen Square crackdown, U.S. and Chinese space organisations engaged in limited civil cooperation. These consisted primarily in data-sharing proposals and bilateral expert consultations. The two sides undertook no major joint technical projects during this time. For much of this period, NASA’s interest in technical space cooperation with China was low. The agency was preoccupied with the ISS and the shuttle program. Chinese space capabilities in critical areas were less developed than those of NASA’s traditional partners in Europe, Japan, and Canada, making China a less attractive partner.\textsuperscript{716}

After 1999, the combination of new export controls and a hostile political climate blocked bilateral cooperation in civil space. NASA was bound by its internal technology sharing rules for many technology items that it developed in house. Other export controls on items relating to U.S. national security also applied to the agency. The two sides undertook no major joint bilateral

\textsuperscript{715} Interview with senior U.S. defense official familiar with national security space policy, Interviewee 07-19-00, Arlington, VA, 2010; Interview with senior U.S. diplomat familiar with U.S. space policy, Interviewee 06-18-00, Washington, DC, 2010.

\textsuperscript{716} Interviews with U.S. State Department official responsible for bilateral science and technology exchange, Interviewee 10-19-00, Beijing, China, 2009 and 2010.
technical projects. Instead, NASA and Chinese space organisations conducted annual meetings of expert working groups, which discussed potential cooperation projects in space science.\textsuperscript{717}

The United States consistently opposed major technical projects that required sharing hardware with China throughout this period. After China’s first human space mission in 2003, Chinese space officials expressed interest in technical cooperation with the ISS. One of their proposals was to dock the Shenzhou capsule with the station. For example, Yang Liwei, China’s first astronaut and then the Deputy Director of the CMSEO, told reporters that, although the Shenzhou’s docking system was not compatible with the ISS’s berthing mechanism, there was no major technical obstacle to docking the two spacecraft with an adaptor.\textsuperscript{718} Other official sources repeated explicit proposals for major cooperation projects with the ISS.\textsuperscript{719} In spite of repeated Chinese overtures, successive U.S. administrations steadfastly rejected Chinese participation in the ISS program.

Throughout this period, NOAA remained a small exception to this trend in civil space. The organisation maintained low-level, but stable, bilateral communication and coordination with space organisations in China.\textsuperscript{720} The two sides cooperated by sharing data on weather and climate, resources critical to NOAA’s mission.\textsuperscript{721} NOAA international cooperation unit also sought to share real-time oceanographic data during this time.\textsuperscript{722} These efforts progressed but

\textsuperscript{717} Interviews with U.S. State Department official responsible for bilateral science and technology exchange, Interviewee 10-19-00, Beijing, China, 2009 and 2010.
\textsuperscript{719} Interview with U.S. State Department official responsible for bilateral science and technology exchange, Interviewee 10-19-00, Beijing, China, 2009 and 2010; informal consultation with individual in the CMSEO familiar with bilateral communications, Beijing, 2011.
\textsuperscript{720} Interview with U.S. Department of Commerce official responsible for international cooperation at NOAA, Interviewee 13-08-00, area of Washington, DC, 2011.
\textsuperscript{721} Interview with U.S. Department of Commerce official responsible for international cooperation at NOAA, Interviewee 13-08-00, area of Washington, DC, 2011.
\textsuperscript{722} Interview with U.S. Department of Commerce official responsible for international cooperation at NOAA, Interviewee 13-08-00, area of Washington, DC, 2011.
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were stymied by the U.S. agency’s strict technical security process. Given their statuses as space users rather than hardware builders, both the Chinese and U.S. organisations involved in these exchanges did not cooperate on technical space projects.

The 1999 export controls also ended or curtailed space-related academic and other research and technical cooperation between the two countries. The most affected organisations in China were the Beijing University of Aeronautic and Astronautics (Beihang), Tsinghua University, and CSSAR under CAS.

Conclusion

In commercial space, China and the United States engaged in limited bilateral trade during the two decades after 1989. Their spacecraft manufacturers engaged in no bilateral industrial integration. In civil space, the two countries’ agencies did cooperate on any technical projects.

In 1988, China and the United States began a trade partnership in launch services and satellites that lasted over a decade. In 1999, the U.S. Congress abruptly outlawed this bilateral trade when it learned that Chinese firms had illegally obtained U.S. space technology and grew alarmed at technology transfers to China. Once traded ended, bilateral relations went on a downward slide. The two governments grew suspicious of each others motives and capabilities in the space domain. By the end of the decade, experts in China and the United States predicted

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723 Interview with U.S. Department of Commerce official responsible for international cooperation at NOAA, Interviewee 13-08-00, area of Washington, DC, 2011.
724 Interview with U.S. Department of Commerce official responsible for international cooperation at NOAA, Interviewee 13-08-00, area of Washington, DC, 2011.
725 Interview with professor of space science who served as a principal investigator on research projects with international partners at Beihang, Interviewee 03-10-00, Beijing, 2010; Interview with senior space scientist in management position at the Center for Space Science Applications and Research in the CAS, Interviewee 23-10-00, Beijing, 2010; Interview with former CNSA official responsible for international cooperation, Interviewee 26-25-00, Beijing, 2010.
that tensions between the two countries would grow into a space war. Over the course of those twenty years, both governments adopted policies that hindered bilateral trade, industrial integration, and technical cooperation, although the Chinese government sought out certain opportunities for trade and cooperation. The two governments set their national space sectors on separate development tracks. Both governments also adopted policies and technology development programs that fostered suspicion and aggravated tensions over security interests between them.
The prospects for bilateral relations in space

Introduction

The deterioration of China-U.S. relations from cautious but mutually beneficial trade to mounting security tension and suspicion in the space sector between 1989 and 2009 was hardly given at the start of this period. That the erstwhile trade partners should become hostile and suspicious competitors in the sector could not have been predicted by any observer on the basis of their relations in 1988, when they concluded their first bilateral space trade agreement. Instead, the civil-commercial space sector presented a mix of factors shaping the prospects for relations between the two countries during this time. Some of these factors were conducive to trade, industrial integration, and civil cooperation, while others made competition and mutual suspicion of their defense programs likely. No preponderance of factors determined the relationship’s course toward either integration or competition. As the integration of the two economies across different high-technology sectors deepened and the costs of strict controls on U.S. space exports grew throughout the 2000s, the persistence of these policies blocking trade and cooperation grew less probable. In spite of these changes, however, the U.S. government maintained measures to block trade and cooperation.

This chapter examines the factors conducive to and hindering trade, industrial integration, and civil cooperation between China and the United States during those two decades. The first part of this chapter examines the factors that made bilateral trade, industrial integration and civil cooperation likely sectoral outcomes during that period. The second part examines the factors that made these outcomes unlikely and instead made bilateral suspicion and competition probable.
1. Factors making trade and cooperation probable

Like the air sector, the space sector was a promising site of trade, industrial integration, and civil cooperation between China and the United States. Several factors made both governments likely to adopt policies conducive to these outcomes. These factors included: the two countries’ complementary demand for and supply of launches; the two countries’ complementary demand for and supply of communications satellites; the economics of satellite and launch vehicle development and production; the role of European and other international space actors in China’s space sector; and the high cost of tight U.S. export controls on space items.

1.1. Complementarity of supply and demand in satellite launch

A major factor making China and the United States likely trade partners in the space sector was the complementarity of U.S. demand for and Chinese supply of satellite launches. Throughout these two decades, the launch and satellite industries were closely related. Satellite operators usually bought a satellite in a package with a launch service and insurance against failure. Launch opportunities were an important determinant of a U.S. satellite manufacturers’ competitiveness, both within the United States and in export markets.

In the late 1980s, the U.S. space industry faced a shortage of domestic launch opportunities. As a result of policy decisions taken throughout the 1980s, launches by U.S. providers were expensive compared to international launches and subject to unpredictable schedules. U.S. satellite manufacturers launched their satellites on European-made Ariane rockets. By the late 1980s, the Ariane’s manufacturer, Arianespace, had become the world’s
leading commercial launch provider. U.S. manufacturers began to chafe under their reliance on this single launcher, a situation they regarded as posing both commercial and technical risks.726

China had by that time become a competitive supplier of commercial satellite launches. Chinese launches were inexpensive, reliable, and timely, making it an attractive partner to U.S. satellite manufacturers. Since placing the country’s first geostationary satellite into orbit in 1984, the institution by then known as Calt had developed and operated a series of Long March vehicles capable of carrying a range of payloads, including most commercial communications satellites.727 Long March launches sold at prices two to four times lower than U.S. launches.728 The vehicles also began to build a record for reliability with a string of consecutively successful launches. Moreover, Long March rockets were subject to fewer schedule slips than U.S. launchers. Chinese launches were attractive to U.S. satellite manufacturers not only because of these features, but also because they promised to reduce their reliance on Arianespace. These factors induced bilateral launch cooperation in 1988.

Access to Chinese launches brought not only commercial benefits to specific U.S. satellite makers, making their products more attractive in export markets, but also larger benefits to the industry and to the security of the United States. The U.S. Senate Intelligence Committee considered these advantages in a 1998 report. While noting that the launch trade could adversely impact a small segment of the U.S. space industry, the Committee observed the substantial commercial and economic benefits to certain corporations, their suppliers and subcontractors, and the communities where satellite and related equipment are produced. These benefits take the form of corporate

727 Zeng Qinglai (曾庆来), Introduction to the Management of Spaceflight Model Research and Development (航天型号研制管理概论), 1–2.
728 May et al., The Cox Committee Report: An Assessment, 18.
income, salaries, high-technology/high-wage employment, and tax revenue.\textsuperscript{729}

The report also pointed out the “national security advantages” that the bilateral launch trade brought the United States.\textsuperscript{730} These included

the fact that, to the extent PRC launch services contribute to a healthy and dominant U.S. satellite industry, they may also contribute to U.S. national security by assisting in the maintenance of a U.S. technological edge and continued U.S. dominance in the international commercial satellite and telecommunications market.\textsuperscript{731}

In spite of these benefits, U.S. restrictions limited the number of and price inducements on Chinese launches. Under the agreements first reached in 1988, Calt and Great Wall charged higher prices of U.S. satellite manufacturers than they would on unregulated world markets. This requirement was an anti-dumping measure implemented to avoid harming the struggling U.S. commercial launch industry.\textsuperscript{732} The effect was to deny U.S. satellite manufacturers the most competitively priced launch opportunities and to limit the scope of the bilateral launch trade.

Moreover, U.S. export controls blocked any form of China-U.S. industrial integration in launch vehicle manufacture. Bilateral integration of this type was conceivable, since U.S. policy allowed some industrial integration between U.S. launch vehicle makers and Russian and Ukrainian manufacturers during the two decades following the end of the Cold War.\textsuperscript{733} These arrangements were driven by the Soviet Union’s collapse. Faced with the likelihood of Soviet experts leaving their dissolving space industry for black-market missile and rocket proliferation

\textsuperscript{730} Ibid., 23.
\textsuperscript{731} Ibid., 23–24.
\textsuperscript{732} Interview with former Department of Commerce official responsible for negotiating the bilateral launch agreements, Interviewee 04-23-00, Washington, DC, 2011.
work, the U.S. government undertook to prop up and sustain a civil-commercial space sector in these post-Soviet states by allowing its collaboration with U.S. firms.\footnote{Dana J. Johnson, Scott Pace, and C. Bryan Gabbard, \textit{Space: Emerging Options for National Power}, Product Page (Santa Monica, CA: The Rand Corporation, 1998), 23.} The overarching priority guiding U.S. space policy remained strengthening a national space industry that was not tightly integrated with that of any other country. Only in exceptional circumstances, such as the launch shortage and the crumbling of the Soviet space sector, did U.S. policy depart from this goal.

In spite of the obstacles posed by the 1999 U.S. export control changes, Chinese policymakers planned for their national industry’s return to commercial launch markets. Leaders in government and industry consistently emphasised this objective in official statements throughout the years after 1999.

A shortage of competitive U.S. commercial launch solutions persisted throughout the 1990s and 2000s. U.S. satellite manufacturers continued to rely on Ariane and Russian launches, both of which were more expensive than Chinese launches. These favourable conditions made China-U.S. trade in launch services likely to continue and even expand after 1999. The complementarity of U.S. demand for launches and Chinese supply of launches made the two countries likely trade partners in the sector.

\subsection*{4.2. Complementarity of supply and demand in satellites}

A second factor that made the two countries promising trade partners was the complementarity of Chinese demand for and U.S. supply of satellites. At the end of the 1980s, China itself was an attractive market for U.S. manufacturers. Throughout the following decades,
the Chinese space industry was not able to produce satellites that equalled imports in quality and capacity.

China’s demand for satellites grew rapidly in the 1980s and 1990s. The major domestic satellite operators expanded their delivery of space-based services, including in particular television broadcasts, across the country. Advanced foreign communications satellites presented the best technical solutions to China’s needs in this area. At that time, major satellite operators and users of satellite services within China, such as the Ministry of Post and Telecommunications, formed an influential constituency. These users advocated importing satellites to meet pressing needs, rather than waiting for the national industry to develop domestic equivalents. 735 These circumstances created the likelihood that China’s internal demand would be met with more advanced imports.

The United States was by far the world’s leading manufacturer of communications satellites at the end of the 1980s. U.S. manufacturers Hughes, Loral, and Martin Marietta had opportunities to sell satellites to Chinese state-owned enterprises and government agencies. 736 Satellite manufacturers depended on export markets and the growth of Chinese demand for satellites coincided with a dip in demand in the mature space-using economies of North America and Europe. 737 Pairing U.S.-made satellites with affordable, reliable, and timely Long March launches also made them more attractive in export markets. Moreover, as part of a sectoral offset policy, the Chinese government demanded that imported satellites launch on Long Marches. This offset requirement did not burden U.S. manufacturers, since Long March launches were

735 Interview with consultant-broker to China’s Ministry of Post and Telecommunications and the entity that later became ChinaSat, Interviewee 11-11-12, Beijing, 2010.
Inexpensive. In short, the Chinese market presented U.S. space firms with attractive opportunities on favourable terms.

After 1999, China’s demand for satellites continued to grow, making the country a promising destination for U.S. exports. The 2000s saw China’s usage of space-derived products and services explode, as new users of space products and services emerged. Central government agencies and large state-owned enterprises grew into even more important users of space-derived data. In addition, local and provincial governments and small and medium-sized enterprises began to use more space applications during this time. As civil and commercial space applications grew, so did the demand for satellites within China.738

Instead of imports, indigenous satellites met these needs. Their country denied access to nearly all foreign-made satellites by the 1999 U.S. export controls, China’s economic planners accelerated the development of the domestic satellite industry to keep pace with national needs. The Chinese and U.S. space industries were poised to benefit from trading in satellites. The complementarity of supply and demand for both satellites and launch vehicles between the two countries made them ideal sectoral trade partners.

1.3. Economics of space technology programs

A third factor making China-U.S. trade, industrial integration, and civil cooperation probable outcomes in the space sector consisted in the economics of space programs. Space programs presented many of the same features as aircraft programs. In both sectors, the economics of technology development and production created pressures and incentives for trade

and transnational integration between firms. 739 Similar factors also compelled technical cooperation and integration between national space agencies. 740

A body of research in economics and management studies examined how the economics of space programs compelled transnational integration in Europe. 741 Several examples of transnational integration in commercial and civil space illustrated these tendencies. In commercial space, the European conglomerate EADS comprised Astrium, the continent’s leading satellite manufacturer with multinational operations. France’s Arianespace, the world’s leading commercial launch service provider, was partly owned by EADS, with the rest of its ownership distributed across ten European countries and its suppliers scattered throughout the region.

In civil space, European countries also integrated their programs and engaged in technical cooperation. Several national space agencies consolidated into the ESA, allowing them to jointly undertake larger projects than they could on their own. The European Space Research Organization integrated space science efforts across the continent. The Galileo global navigation system brought multinational participants into a long-term partnership on a large satellite constellation. From the 1970s onward, Europe’s integrated civil-commercial space sector was a microcosm of the global space sector, where firms and agencies from different countries began to integrate their activities into larger wholes.

Beyond Europe, transnational industrial integration also took place between more unlikely bedfellows. For example, in commercial space, Lockheed-Martin, Khrunichev, and Energia in 1995 formed the U.S.-Russian joint venture International Launch Services to market launches of the Russian Proton vehicle from Kazakhstan. That same year, four companies from

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740 Ibid.
Norway, Russia, Ukraine, and the United States formed the Sea Launch consortium. Sea Launch integrated not only firms and investments from different countries, but also sensitive space hardware, including U.S. and Russian missile technology.\footnote{Kempton and Bale, \textit{High Seas Satellite Launches: Paragon of Post–Cold War Cooperation or Unregulated Danger?}; Lee, “Legal Analysis of Sea Launch License: National Security and Environmental Concerns.”}

The factors behind trade and transnational industrial integration in space were similar to those behind trade and industrial integration in aircraft manufacture. Space activities presented firms and agencies with important economies of scale and high risks. Major space systems featured important economies of scale because their development costs tended to represent a high proportion of overall program costs. That launch vehicle manufacture costs were sensitive to volume was widely recognised throughout the global industry during this period.\footnote{Lai, “National Subsidies in the International Commercial Launch Market,” 21, 24, 28, 32; Detelin S. Elenkov, “The Russian Aerospace Industry: Survey with Implications for American Firms in the Global Marketplace,” \textit{Journal of International Marketing} 3, no. 2 (January 1, 1995): 77; Bernard Kutter, “Commercial Launch Services: An Enabler for Launch Vehicle Evolution and Cost Reduction,” in \textit{Space 2006} (presented at the Space 2006, San Jose, CA: American Institute of Aeronautics and Astronautics, 2006).} Launch vehicle manufacture presented important economies of scale associated with both the development and production program phases. In long production runs, manufacturers also experienced learning effects in assembly, integration, and testing and in launch operations, allowing them to further reduce costs and increase vehicle reliability.\footnote{Walter Edward Hammond, \textit{Space Transportation: A System Approach to Analysis and Design} (AIAA, 1999).} Moreover, insurance premiums dropped on vehicle designs as their launch records lengthened, making the total satellite-launch-insurance package more attractive to customers as the number of launches of a vehicle grew.

Satellite manufacture also featured some of these volume effects. Although analysts differed on the magnitude of economies of scale in satellite production, they recognised that these were sufficient in the development of new satellite platforms to cause the future consolidation of
several international manufacturers into a regional or even global duopoly.\textsuperscript{745} Moreover, for satellite integrators, the largest portion of costs was subcontracted to suppliers and, at high production volumes, integrators could realise economies in the procurement process itself.\textsuperscript{746} These aspects of the program economics of launcher and satellite manufacture induced transnational industrial integration.

High risks in commercial space technology development programs also fostered transnational industrial integration. Global demand for satellites and, with them, launches, was difficult for manufacturers of both types of systems to predict. For example, in the 1990s, the U.S. space industry overinvested in some areas on the basis of misleading predictions about an imminent upturn in demand for launches.\textsuperscript{747} The entry of new players, such as India, into the global commercial launch business also complicated market predictions. Introducing further risk still was uncertainty about the shape of future space architectures. As in the air sector, in many space product areas firms’ development costs were high and growing, raising their commercial and economic risks.\textsuperscript{748} Joint ventures and alliances allowed partners to spread and mitigate some of this risk. These factors made the space sector a likely site of transnational industrial integration, including bilateral China-U.S. industrial integration.

National civil space agencies also faced high risks and program costs that compelled international cooperation. Partnerships allowed space agencies to spread the risks on large projects, reducing the burden on any individual participant. International cooperation also


\textsuperscript{748} Koenig and Thietart, “Managers, Engineers and Government: The Emergence of the Mutual Organization in the European Aerospace Industry.”
allowed smaller space agencies to pursue large, costly missions that they could not undertake alone. And integration prevented the duplication of costly technical efforts in parallel national programs. These conditions made the space sector a likely site of international technical cooperation and program integration, including bilateral cooperation between Chinese space organisations and NASA.

In spite of these factors, for the United States the benefits of partnering were smaller and fewer than for other countries. Far larger and more capable than any other space agency, NASA could often undertake missions alone at a lower cost to it than through an international collaboration. Nevertheless, there were missions that required NASA to collaborate, such as the very large ISS or Earth observation missions that required input from foreign satellites. There were also missions for which international cooperation was in and of itself an objective. The ISS, for example, was a project intended to demonstrate post-Cold War collaboration. Even when program economics per se did not dictate cooperation for NASA itself, the agency participated in many large-scale multinational collaborations in space. China was in several respects a well matched partner to NASA during this period, especially after 2003.

In addition to factors stemming from the economics of space programs in general, conditions specific to the China-U.S. bilateral context made technical cooperation in civil space between these two countries likely. Five factors made bilateral cooperation promising and probable: China’s growing space capabilities; complementarities between Chinese and U.S. space capabilities; China’s growing space budgets; NASA’s constrained budgets; and concrete projects areas in which the two countries’ space communities shared an interest.

First, bilateral cooperation was probable because China had developed significant technical capacity in space by the late 1990s. In a string of milestones that began in 1999, China became only the third country to develop a human-rated launch vehicle, to place a human in orbit
on its own vehicle, to test an indigenous spacesuit, and to begin building a space lab.749 Developing these systems and performing these missions made Chinese space organisations more capable partners than many of NASA’s traditional collaborators, such as ESA.

Second, the prospects for China-U.S. civil space cooperation were enhanced by specific complementarities between the two countries’ capabilities. An example of this situation is found in crew transportation systems. For several years following the Columbia shuttle disaster in 2001, the Russian Soyuz was the only vehicle available to ferry astronautics to and from the ISS. Until the shuttle returned to flight in July 2005, the ISS was only one Soyuz failure away from becoming inaccessible. This situation presented important risks to astronaut safety and mission goals. At the same time, as of 2003, the Chinese Shenzhou vehicle and Long March launcher formed a human-rated and test-flown system.750 Several U.S. and international experts argued that the Chinese system could form a back-up transportation capability to the Soyuz. Chinese space experts also expressed interest in this possibility.

Third, China was an attractive partner to the United States in civil space because it was the only major spacefaring country whose budgets for space activities grew during the 1990s and 2000s. China’s spending on space activities was in essence pegged to a rapidly growing gross


750 Qi and Li, *Shenzhou Overview: Uncovering the Secrets of Manned Spacecraft (巡天神舟—揭秘载人航天器).*
domestic product. At the same time, costs were in many ways controlled and inflation checked in China’s still largely non-market space sector. As a result, the country’s nominal spending on space yielded far greater programmatic output than similar levels of spending in other economies.

Jeffrey Logan, examining the pros and cons of bilateral civil space cooperation with China in a 2007 report to Congress, found that “China now has the economic standing to support joint space cooperation.”

A fourth factor that made bilateral cooperation probable under these circumstances was the budget constraint on NASA activities. As the agency came under growing budget pressure following the end of the Cold War and during the costly building of the ISS, it was forced to cancel other programs and scale back operations. A reduction in NASA’s activities in turn affected the U.S. space industry, which supplied the agency’s programs. NASA’s traditional partners fared no better during this time. Space budgets in Russia dwindled during the 1990s. European and Japanese spending on space was constrained throughout these two decades. In China, NASA had a funded and capable partner at a time when the global space sector experienced decline. In his report to Congress, Logan listed “cost savings” as one of the benefits of bilateral cooperation with China.

A fifth factor enhancing the prospects for China-U.S. cooperation were specific opportunities in several areas for agencies from the two countries to cooperate on technical projects, both large and small. These areas of possible cooperation included: human spaceflight, such as crew transportation to the ISS and astronaut rescue; space science missions, such as

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751 Interviews with retired PLA office in GAD responsible for human spaceflight, Interviewee 08-26-03, Beijing, China, 2010; Interview with space engineering professor and researcher at Beihang, Interviewee 03-19-25, Beijing, China, 2010.
752 Interviews with retired PLA office in GAD responsible for human spaceflight, Interviewee 08-26-03, Beijing, China, 2010.
754 Ibid.
jointly funding and building large telescopes; and exploration missions, in which they could share the cost of a vehicle carrying instruments from both countries to a distant destination; and bilateral space data-sharing projects.\textsuperscript{755} Chinese space experts recognised and proposed project opportunities of these types.\textsuperscript{756} In sum, generous Chinese government support to both its civil space agencies and its commercial manufacturers made them attractive partners to NASA and U.S. space firms in specific areas.

The economic features of commercial and civil space programs presented inducements for transnational integration. These circumstances made the space sector a likely site of China-U.S. industrial integration and civil cooperation. Economies of scale in key products and high risks created opportunities for international partners reduce costs and distribute burdens amongst each other. Space specialists recognised that in Europe and in other international contexts these conditions did in fact motivate the transnational integration of commercial and civil space activities. However, these same conditions were insufficient to motivate bilateral trade, industrial integration, or civil cooperation between China and the United States.

In addition to these features of space program economics in general, circumstances specific to the China-U.S. context made the two countries suited to bilateral industrial integration and cooperation. China had improving capabilities and substantial budgets to dedicate to space activities, making it a well-matched partner to a technically advanced but resource-strapped NASA. China’s state support to its space industry promised benefits to U.S. firms that traded or collaborated with Chinese partners.


\textsuperscript{756} Zhou, “Perspectives on Sino-US Cooperation in Civil Space Programs,” 6–7.
1.4. Chinese partnerships with non-U.S. space agencies and firms

A fourth factor making the space sector a likely site of China-U.S. trade, industrial integration, and civil cooperation was the role of European and other international firms and agencies that traded and cooperated with China. After 1999, European space firms took advantage of opportunities in China’s civil and commercial space programs, while U.S. policy denied U.S. firms these same opportunities. These missed opportunities grew after 2005, when the Chinese government funded new missions with foreign space agencies and industry partners. As collaborations between Chinese and non-U.S. actors expanded, the costs of export controls to U.S. firms grew, making their loosening probable.

China’s commercial and civil space projects with foreign partners during this period were few and limited, but growing.\footnote{Cliff, Ohlandt, and Yang, \textit{Ready for Takeoff: China's Advancing Aerospace Industry}, 89.} Because the European space industry relied on many U.S. components, U.S. export controls restricted European and other international technical cooperation with China in civil and commercial space. The areas in which European and other international firms could undertake projects with China were few and narrow.

In spite of these constraints, as China’s space capabilities developed, European actors grew more interested in trading and cooperating with Chinese organisations. Moreover, as European firms themselves grew less reliant on U.S. technology over those two decades, the areas in which they could cooperate with Chinese partners expanded.

These changes were significant because European firms were the most important foreign competitors to U.S. companies. European firms challenged U.S. firms in both satellite and launch vehicle manufacture. At the system-integrator level, European and U.S. firms competed in the global market for commercial communications satellites. Europe’s Thales Alenia Space (formerly Alcatel Alenia Space) and Astrium competed with the U.S. firms Boeing Satellite
Development Center (formerly Boeing Satellite Systems), Lockheed Martin Commercial Space Systems, Space/Systems Loral, and Orbital Space Sciences. Firms from both continents also competed at the sub-system and component levels.

In time, U.S. restrictions on trade and cooperation with China had the unintended consequence of benefiting certain European firms at the expense of U.S. firms. While U.S. policy kept NASA and U.S. firms isolated from their Chinese counterparts, European actors were in time able to engage Chinese space actors and establish growing commercial and civil space partnerships. Europe’s gradual engagement of China in space raised the costs to the United States of maintaining its restrictions on bilateral trade and cooperation with China, making these policies likely to soften or change.

1.4.1. European and Chinese collaborations in the commercial space sector

In certain specific areas, U.S. export controls gave European competitors access to opportunities in China and other advantages while denying them to U.S. firms.\(^\text{758}\) The most important of these opportunities was launches. European manufacturers, seeing benefit in inexpensive Chinese launches, designed commercial communications satellites and components deliberately devoid of U.S. export-controlled technology.\(^\text{759}\) For example, as of around 2004, Thales Alenia Space deliberately produced satellites to be free of U.S. components so they could in principle travel to and launch from China unrestricted by U.S. laws. Thales positioned itself to seize the opportunity presented by the inexpensive Long March. As these developments loosened the de facto U.S. export controls on non-U.S. firms, they reduced the benefit to the

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\(^{758}\) Zelnio, “The Effects of Export Control on the Space Industry.”

\(^{759}\) Deputy Assistant Secretary of Defense for Space Policy, Ambassador Gregory Schulte, discussed the need to reform export controls in order to prevent ITAR circumvention during a presentation at the April 2012 National Space Symposium in Colorado Springs, CO, as reported in Dan Leone, “US Report Supports Sweeping Reform of Satellite Export Rules,” Space News, April 18, 2012.
United States of keeping the barriers to trade and cooperation with China in place and increased the costs of maintaining them.

By the end of those two decades, this circumvention of U.S. export controls was widely recognised in the United States. In 2008, the House Permanent Select Committee on Intelligence produced its Report on Overhead Architecture, in which it pointed out the benefits of the export controls to European companies doing business with the Chinese space industry, such as Thales Alenia Space. The committee found that

Government and industry participants described how ITAR has motivated European companies to establish an international (non-U.S) collaborative R&D environment where ITAR-banned technologies are produced indigenously, thereby defeating the premise of ITAR.  

In the 2009 and 2010 versions of the annual Industrial Capabilities Report To Congress, technology analysts in the U.S. Department of Defense made similar observations. They noted the challenge to the U.S. space industry posed by ITAR-free satellites.

In the vacuum left by U.S. companies in international markets, foreign firms have been energized to fill the void and even create “ITAR-free” products that have no U.S. components that might prevent exporting to third countries. The cost and difficulty of export licensing becomes a competitive disadvantage to lower-tier U.S. firms with fewer financial resources.

Evidence mounted that U.S. export controls were fostering China-Europe trade and cooperation that excluded U.S. firms. The growing costs and implications of these new partnerships on U.S. entities made their removal or reform more and more likely throughout the 2000s.

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762 Annual Industrial Capabilities Report To Congress 2010, 68.
1.4.2. China’s international civil space cooperation

Facing a NASA unwilling to engage in technical space cooperation, Chinese agencies pursued other international partnerships in civil space after 1999. The European and Russian space programs offered Chinese firms and agencies an alternative to U.S. partners. The Chinese government expanded and developed international civil space cooperation with ESA, individual European countries, and Russia. Chinese space organisations undertook and expanded technical cooperation with both European and Russian partners. For example, in 2003, ESA and CSSAR initiated Double Star, a program to measure the effects of solar weather on Earth.\(^{763}\)

Chinese organisations also began major new space cooperation projects with Russian partners during this time. In general, U.S. export controls did not constrain Roscosmos and Russian companies, which were not major importers of U.S. components. Russia’s space industry was eager to sell know-how and systems to China during the years following the collapse of the Soviet Union, when the new federation’s space budget all but evaporated.

After 1999, China-Russian civil space cooperation expanded to include an exploration mission to Mars and its moon Phobos.\(^{764}\) China contributed to the program the first Chinese-made Mars probe, Firefly 1 (萤火一号).\(^{765}\) When the delayed mission launched in November

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\(^{763}\) Interview with academician Dr. Liu Zhenxing of the CAS Center for Space Science Applications and Research and founder of the Double Star mission, Beijing, China, 2010; Interview with principal investigator in the Double Star program and professor at Beihang University, Interviewee 00-00-00, Beijing, China, 2010.


2011, its Russian rocket failed to reach its transfer orbit and its operators lost control of it. In spite of this setback, China and Russia committed to expanding their cooperation to lunar exploration, joint deep space research, and human spaceflight by 2012. In addition, Chinese space experts participated in the international Mars 500 project, a psychosocial research study begun in 2007. Conducted outside Moscow, the experiment consisted in a 500-day-long Earth-based simulation of an international crew’s round trip journey to the planet. Chinese space actors continued efforts to explore Mars with international collaborators after 2009.

During those two decades, Chinese space organisations also initiated or continued bilateral cooperation missions with other countries. Under a program begun in the 1980s, the China-Brazil Earth Resources Satellite mission collected data from a constellation of Chinese and Brazilian Earth-observation satellites. The Chinese space industry also oriented itself toward supplying satellites and launches to users in developing countries under bilateral agreements.

After 1999, NASA’s traditional partners grew to regard China as a capable and attractive partner and a viable alternative to the United States. European policymakers described a turn toward China, indicating their intention to explore potential for cooperation across every major area of civil space. When a reorientation of NASA’s exploration activities in 2009 led to the

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768 Interview with official responsible for international cooperation in the Chinese Academy of Sciences Center for Space Science Applications and Research, Interviewee 26-25-00, Beijing, China, 2010.

769 Interview with senior official responsible for international cooperation with China in ESA’s organisational headquarters, Cape Town, South Africa, 2011.
cancellation of projects with European partners, ESA’s interest in expanding collaboration with China increased.\textsuperscript{770}

These projects with China excluded NASA, an outcome that U.S. space experts regarded as undesirable. For example, Joan Johnson-Freese and Andrew Erickson of the U.S. Naval War College saw the Chinese-European partnerships as a “geotechnological balancing” of the United States in space.\textsuperscript{771} More concretely, these partnerships had programmatic effects on NASA. Each space agency had a limited budget to dedicate to international cooperation projects and particular mission areas, so new partners reduced opportunities for cooperation with traditional partners. NASA risked being displaced. As U.S. restrictions caused cooperation between traditional U.S. partners and China that excluded NASA, these measures became more costly to sustain, making them in likely to soften or change.

1.5. The high cost of strict regulations on U.S. space exports

A fifth factor that made China and the United States likely to adopt policies conducive to trade in space items was the high cost of doing otherwise. During the ten years following 1999, restrictive U.S. export controls on space items grew more and more costly to sustain. The rules cost U.S. firms commercial opportunities, a situation arguably reflected in their declining global market share.

During this time, government and think-tank reports began to document the costs to U.S. industry and the impact on other U.S. national interests of maintaining the controls. Space experts converged on several findings. First, the controls denied U.S. satellite manufacturers

\textsuperscript{770} Interview with senior official responsible for international cooperation with China in ESA’s organisational headquarters, Cape Town, South Africa, 2011.

access to many export markets and made them less competitive. Second, although the export controls were intended to protect U.S. security, they in fact compromised U.S. security by weakening the U.S. defense industrial base. Third, U.S. export controls benefitted the European space industry at the expense of the U.S. space industry. Fourth, as the export controls pushed China to pursue international partnerships excluding the United States, they cost the United States strategic influence in China’s space sector.

1.5.1. Export controls cost U.S. manufacturers competitiveness

The 1999 export controls cost U.S. satellite manufacturers export opportunities and made them less competitive in foreign markets. Over a dozen reports by think tanks, research institutes, and government agencies documented the effects of the tightened export controls on the U.S. space industry. The effects they observed included shrinking market share, dropping revenues, and missed sales opportunities.

According to the Satellite Industry Association, a U.S. trade group, the “U.S. share of global satellite exports [dropped] from about 75 percent in 1995 to between 35 percent and 50 percent” in the seven following years. Experts at the Space Foundation and the Center for Strategic and International Studies (CSIS), a major think tank, reached similar estimates. All these groups cited restrictive export control policies as a major factor behind this decline.

Only a year after the tightened controls took effect, the consultancy Booz Allen & Hamilton predicted that the U.S. commercial satellite manufacturing industry “could lose up to $1 billion of sales annually if the export control issues are not resolved.”

In 2006, space industry analyst Robert Zelnio estimated direct, demonstrable losses to the U.S. satellite manufacturing industry resulting from the 1999 legislation at up to USD 6 billion. He found that, had the export control regime not changed, satellites sales in that amount for the period after 1999 were probable for companies like Hughes, Loral, Lockheed Martin, and Boeing.

In their 2007 assessment of the impact of export controls on the U.S. defense industrial base, the U.S. Air Force and Department of Commerce found that, since 1999, the U.S. share of satellite manufacture had decreased 20 percent for all commercial communication satellites sales and 10 percent for geosynchronous orbit communications satellites. They researchers attributed part of this decline to export controls. The report cited interview data to support this finding:

A Tier 2 company commented, ‘ITAR restrictions and limits are a major impediment to be able to respond to proposal requests and subsequently sell products in foreign markets.’ A Tier 3 company ‘...is withdrawing from the space business due to a sustained absence of profitability and a refusal of some foreign customers to procure equipment that requires U.S. ITAR licensing.’

In 2008, the National Security Space Office of the Department of Defense published a study of U.S. space companies. Of the nearly 200 small U.S. companies it surveyed, 70 percent

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779 Ibid., 13.
reported that ITAR restrictions hindered their ability to compete for international business. The study found that small enterprises, which constituted most of the space sector by workforce, were the most affected by this regulatory burden.\footnote{Competing for Space: Satellite Export Policy and U.S. National Security, 19.}

That same year, a major industry association, the Space Foundation, published a paper on export controls and the U.S. space sector. It concluded that

ITAR restricts the ability of U.S. firms to compete because foreign companies do not operate under equal restrictions. Technology remains on the USML, even when it is commercially available in other countries, because lists of critical U.S. military technologies are seldom updated.\footnote{ITAR and the U.S. Space Industry, 2.}

 Shortly thereafter, CSIS, the prominent think tank, released a study on the space industrial base, which found that

Export controls are adversely affecting U.S. companies’ ability to compete for foreign space business, particularly the second and third tier. And it is the second and third tier of the industry that is the source of much innovation, and is normally the most engaged in the global market place in the aerospace/defense sector.\footnote{Ben-Ari and Chao, Health of the U.S. Space Industrial Base and the Impact of Export Controls, 10.}

By 2011, the cumulative effect of export controls made their reform a priority at the highest levels of government. The Obama administration expressed its commitment to export control reform in its National Security Space Strategy. Jointly produced by the Department of Defense and the Director of National Intelligence, the policy stated that export controls affect the health and welfare of the industrial base, in particular second- and third-tier suppliers. Reforming export controls will facilitate U.S. firms’ ability to compete to become providers-of-choice in the international marketplace for capabilities that are, or will soon become, widely available globally, while strengthening our ability to protect the most significant U.S. technology advantages.\footnote{“National Security Space Strategy (Unclassified Summary)” (U.S. Department of Defense and Office of the Director of National Intelligence, January 2011), 7.}
Also in 2011, the Heritage Foundation, a conservative think tank and early critic of the 1999 changes, released a report titled on the implications of China’s space activities for U.S. security. The author, space and China expert Dean Cheng, endorsed reforms:

[The United States] is seeking to reform export controls and the International Trade in Arms Regulations, which have harmed the international competitiveness of American satellite manufacturers. These efforts, as long as they continue to address specific security concerns and do not slight the continued need to protect key American technology advantages, deserve support from Congress and Secretary of Defense Leon Panetta.\(^\text{784}\)

Academic studies of the export control regime reached similar conclusions. For example, Dr. Henry Hertzfeld, a space law expert at the George Washington University’s Space Policy Institute, described the “imposition of very strict export controls on space systems and high technology products” as hindering the U.S. space industry and U.S. “spacepower” on the global stage.\(^\text{785}\) In a journal article, space expert Joosong J. Lee summarised what by 2008 had become a consensus position on the “detrimental effect on the competitiveness of the US space industry” of the 1999 export rule change.\(^\text{786}\)

1.5.2. Export controls weaken the U.S. defense industrial base and foster proliferation

Although the 1999 export controls were intended to protect U.S. security, by the late 2000s U.S. experts argued that they in fact compromised national security by weakening the space industrial base. This industrial base included indispensable suppliers of space products to government users of space, firms that were hurt or even forced out of business by the regulations. Government and think-tank researchers found that, through these effects, the restrictions


compromised the integrity of the national supply chain, on which the defense and intelligence communities relied for acquisitions of new systems and for parts. In parallel, experts in national research bodies, government agencies, and industry found, Category XV export controls unintentionally fostered the diffusion of space capabilities to new countries.

Experts’ concerns over controls on space exports reflected a growing awareness of the impact of export controls across technology sectors in the United States. In 2009, the National Academies published an influential report examining the broader effects of export controls on science and technology titled “Beyond ‘Fortress America.”’

In 2007, a think-tank called the Institute for Defense Analysis produced a study titled Export Controls and the U.S. Defense Industrial Base. Examining space items, its authors reported that

In interviews with individual firms it is apparent that U.S. companies are already being constrained in supply chain choices by export control restrictions. In some cases export control measures are actually encouraging R&D and capital investment overseas, as well as discouraging R&D partnerships with U.S. firms and the DOD.

The study cited the loss of Canada’s Telesat. This major customer announced it would permanently move away from U.S. manufacturers because U.S. export controls on space items introduced complications and limited access to cheap Long March launches.

Experts in the defense and intelligence communities observed that restrictions on access to U.S. technology fostered the development of alternative sources in other countries. In a 2008 report to Congress, a group of space policy experts forming the Independent Assessment Panel on the Organization and Management of National Security Space found that

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789 Ibid., 13.
A critical factor in the developing threat to U.S. space supremacy is the accelerating proliferation of space technology. The growth in international space design, production, and operations spurred in part by U.S. restrictions on the export of space technology [under ITAR] is leveling the playing field so that many nations now compete with the United States in space.\textsuperscript{790}

Similarly, in a report on export controls titled \textit{Tipping Point}, the AIA concluded that

At a time when the U.S. government should be encouraging growth across all sectors of the economy, export controls are limiting growth in the space sector, especially among component suppliers. In the absence of a healthy, cutting-edge U.S. space industrial base our government may be forced into reliance on foreign suppliers for key components, accelerating the loss of U.S. leadership in space.\textsuperscript{791}

By the late 2000s, U.S. policymakers were aware of the export control challenges facing the U.S. space industry and their impact on U.S. national security. For example, in 2009, the House Committee on Foreign Affairs Subcommittee on Terrorism, Nonproliferation and Trade held a hearing on export controls on satellite technology. Chairing the hearing, Representative Brad Sherman from California, stated in his opening remarks

the space industry has made credible arguments that the International Traffic in Arms Regulations, known as ITAR, has hurt business and the space industrial base. This claim is echoed in private at least by the Intelligence Community who sometimes find it more and more difficult to source satellite-related equipment domestically.\textsuperscript{792}

In time, a consensus among space experts and policymakers on the national security costs of the 1999 export controls on space items. The strict rules not only hurt particular commercial interests, but in the process also compromised U.S. security. These factors made their repeal or reform probable.

1.5.3. \textit{Export controls cost the United States influence in China’s space sector}


\textsuperscript{791} \textit{Tipping Point: Maintaining the Health of the National Security Space Industrial Base} (Arlington, VA: Aerospace Industries Association, 2010), 14.

As U.S. export controls pushed China to pursue international partnerships that excluded the United States, they cost the United States strategic influence in China’s space sector. For example, space policy experts Dr. Joan Johnson-Freese and Dr. Andrew Erickson of the Naval War College argued that by withdrawing from the Chinese space market, the United States effectively lost a source of leverage over China on space issues. Because U.S. allies did not join the United States in applying these restrictions and allowed their national industries to trade and their space agencies to cooperate with China, their own influence in the Chinese space sector grew at the expense of the United States. This situation worsened as European space policymakers grew to think of China as a promising future close “partner” in civil and commercial space. Naval Postgraduate School Professor and space policy expert James Clay Moltz also found that the China-specific restrictions in the space export control regime imposed strategic costs upon the United States.

Other experts pointed out that the 1999 export controls cost the United States influence and leverage over Chinese decisionmakers by strengthening the Chinese space community’s resolve to develop autonomous capabilities. As Dr. Gregory Kulacki, senior analyst and China project manager at the Union of Concerned Scientists, observed

An ironic consequence of the concerted US effort to isolate the Chinese space community and inhibit Chinese access to advanced space technologies may be an acceleration of China’s ability to produce these technologies on their own. China made significantly more progress in the eight years since the Cox Report then they did in the eight years prior.

793 Zhang Qingwei (张庆伟), “Exploring Diversified International Cooperations for China’s Space Industry (积极探索多元化航天国际合作之路).”
794 Johnson-Freese and Erickson, “The Emerging China–EU Space Partnership.”
795 Johnson-Freese, Heavenly Ambitions, 106.
796 Interview with senior European space official responsible for international cooperation projects, Interviewee 14-16-00, Cape Town, South Africa, 2011.
Over the decade that followed Strom Thurmond, the costs to the United States of controlling all space items as defense items became apparent. A consensus emerged within the specialist community that the decline of U.S. satellite exports owed to the tightened controls, which closed markets to U.S. manufacturers and made them less competitive than their foreign counterparts. The U.S. space specialist community also recognised that the export controls paradoxically made the United States less secure by weakening the U.S. defense industrial base that supplied the military and intelligence community. Experts noted that the U.S. export controls benefitted European companies at the expense of U.S. manufacturers. Becoming less reliant on U.S. components, the satellite industries of U.S. allies were able to circumvent ITAR. Finally, some experts grew concerned that the United States lost influence and leverage over China’s space sector because of the export controls. Space experts throughout the U.S. government, industry, and academia shared these conclusions with policymakers in reports, presentations, and testimony. U.S. export controls imposed high costs and brought meagre benefits, making their reform and softening probable during the years after 1999. As policymakers recognised that these measures were self-defeating, they grew more likely to transform them into rules that allowed more trade and even industrial integration between U.S. firms and international partners.

Together, these six factors made the space sector a probable site of trade, industrial integration, and civil cooperation between China and the United States. The two countries featured complementarities of supply and demand in two major product areas, launches and communications satellites. The economics of technology development and production created incentives for the two national industries to integrate their operations. The economics of civil space programs created incentives for the two national space agencies to integrate their activities. Competition to U.S. firms from European companies selling products to China and taking
advantage of inexpensive Long March launches created pressures for U.S. policymakers to allow U.S. firms to do the same, making U.S. export controls likely to change. In spite of these conditions, the strict controls remained in place for over a decade, blocking bilateral trade.

2. Factors making bilateral trade, integration, and cooperation improbable

While the factors discussed above created inducements for China-U.S. trade, industrial integration, and civil cooperation, other factors made these outcomes unlikely. These factors also made bilateral tensions over security issues probable. Factors making these outcomes unlikely included: the strategic status of the sector itself; technology transfer risks inherent in bilateral integration and cooperation; the applicability of commercial technology to defense programs; concurrent advances in China’s defense technology programs in the sector; and export control violations by U.S. and Chinese space firms engaged in business together.

2.1. The strategic status of the civil-commercial space sector

The first factor making trade, integration, and civil cooperation between China and the United States unlikely in the space sector was the strategic status of civil and commercial space technologies. Space systems played a strategic role in the economies of both countries. Space technologies were also embedded in their national infrastructures, making both societies reliant upon them. These features of space technology made the sector an unlikely site of trade, integration, and cooperation between countries in tense security relationships.

Both governments considered the civil-commercial space sector to occupy a strategic node in the national economy. The space sector played a strategic economic role in several ways. First, the commercial fabrication and operation of space systems, including satellites and launch vehicles, was an industry with important first-mover advantages and presenting high barriers to
entry. Successful early entrants could enjoy economic rents. These brought national welfare benefits, including high-wage jobs. For some governments, these benefits justified state support to domestic firms competing in international markets.\textsuperscript{799} Governments also coordinated civil space efforts with industrial policy goals for the sector.\textsuperscript{800}

Second, the manufacture of space systems generated positive economic externalities in the form of innovations. Space programs consisted in long-term collaborations between scientific and technical experts clustered in local innovation economies, directly and indirectly generating new technologies with commercial applications in other areas. NASA experts identified spin-offs in areas as far-ranging as orthodontics, sports gear, and medical diagnostics.

Third, the manufacture and operation of space systems brought beneficial spill-overs by supporting secondary industries and enabling other economic activity. Space communications facilitated business transactions. The Global Positioning System (GPS) constellation supported not only the receiver manufacture industry, but also an entire mobile internet-based economy. Investors saw a future in new offshoot industries, such as space tourism and in-space manufacturing. Both the Chinese and U.S. governments regarded space activities as strategic areas of the national economy.

Moreover, civil-commercial space technologies were part of basic and critical national infrastructures in both countries. Launch vehicles provided access to space, lifting crews and cargo into orbit. Satellites, in turn, supported public services and a way of life on the ground. GPS satellites provided the world’s most reliable and precise timing signal – the only universal referential time and the backbone of virtually every global network. From the operation of stock markets to personal transactions at teller machines, networked financial systems relied upon GPS

\textsuperscript{799} Lai, “National Subsidies in the International Commercial Launch Market.”
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satellites to function. Satellites were built into the internet itself. Earth observation satellites performed essential public safety functions, such as weather forecasting and law enforcement. Satellites monitored hurricanes, floods, and earthquakes. Satellites mapped and surveilled borders and waterways. In these many ways, space systems underpinned the economies and basic infrastructures of both China and the United States.

The strategic status of the civil-commercial space sector made it an improbable site of trade, industrial integration, and civil cooperation between countries whose governments were suspicious of each other. Such governments were unlikely to adopt policies allowing their national industries to trade in space technologies or their agencies to cooperate on technical projects. In this respect, the sector’s strategic status seemed to predispose it toward tight export controls and limits on trade and cooperation.

2.2. Technology transfer risks inherent in bilateral trade and cooperation

A second factor making China-U.S. trade, industrial integration, and cooperation in the space sector unlikely was the risk of technology transfers that these outcomes presented. The risk of technology transfer between U.S. and foreign firms inhered in trade and industry partnerships. While this condition was likely to hinder trade and cooperation between the two countries, its impact on relations in the sector was mitigated by other factors and varied across time. In spite of transfer risks, U.S. firms traded in space items with Chinese firms for over a decade and with Russian and Ukrainian firms for over two decades after the Cold War ended.

Trade and industrial integration in the sector posed varying levels of technology transfer risk. These risks depended on the nature of the traded items and the way in which the trade or collaboration occurred. In principle, a range of space technology items could be legally or illegally shared between two countries engaged in trade and industrial integration. These
included tangible articles, such as rocket engines, satellite solar panels, and satellite antennae. Items that could be transferred also included intangibles, such as coupled-loads analysis techniques used in satellite-launcher integration, launch site safety practices, and methods for reconstructing anomalous events from telemetry data. Under the bilateral agreements defining the terms of the launch trade, legally shared space technology items were few. They included intangible items, such as “form, fit, and function” data about the satellites, necessary for the integration of the payload with the launcher. Although articles of hardware, such as the satellites themselves, also travelled to China under the agreements, these items were in principle secured so that Chinese personnel did not have unsupervised access to them.

Beyond the exemption for “form, fit, and function” data, all sharing of technical information by the U.S. side to the Chinese side was effectively prohibited by either the bilateral agreement or U.S. export control laws. In this context, for a U.S. firm to share even publically available technical information about launch vehicles, such as information drawn from a widely distributed textbook or a public website, consisted in a violation of U.S. export controls. Under the Arms Export Control Act, the sharing of such information with a foreign commercial partner constituted the provision of a “defense service,” a violation punishable with fines by the Department of State and criminal prosecution by the Department of Justice.

Even with rules, compliance monitoring, and other safeguards in place, the limited bilateral trade occasioned illegal transfers of U.S. space technology items to Chinese entities. These included the transferred items examined by the Cox committee, such as expert findings about the launcher fairing’s design and observations about the follow-up frame on the inertial

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measurement unit. Participating U.S. firms were incentivised to share technical information with their Chinese partners in violation of the law. This situation arose because U.S. satellite manufacturers and the Chinese launch vehicle manufacturer, Calt, shared an overriding interest in the success of their launches. A launch failure would raise insurance premiums and set back both the satellite and launcher manufacturers. To ensure the success of the launches, satellite manufacturers were compelled to share technical information about launch site practices and the satellite-launcher integration process for which they did not have export licenses. Moreover, when a launch failure did occur, the U.S. satellite makers and Calt shared an interest in producing a persuasive analysis of the failure to their insurers. This circumstance incentivised U.S. satellite manufacturers to share technical data related to failure analysis with their Chinese counterparts, even without the necessary licenses or even when the transfers could not be licensed. Bilateral trade created opportunities for U.S. firms to obviate export controls.

Space technology transfers from U.S. to Chinese firms remained a controversial and sensitive subject. Technology transfers were inherently difficult to document, assess, and characterise. Equally credible experts reached different conclusions about the effect or significance of particular technology transfers. This was true even of the illegal technology transfers detailed in the Cox report, which many industry specialists and technical experts in academia and government believed exaggerated the impact of the transfers. In some cases,

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particular transfers of U.S. space technology to other countries, even if illegal, could at most lead to marginal or negligible improvements in foreign systems, a situation that made it difficult for observers to reach agreement on how strictly violators should be punished.

The nature and level of technology transfer risk posed by a given form of trade or industrial partnership depended on how much hardware and how much specialised knowledge its participants would share. In some cases, the movement of hardware across the U.S. border and into China posed a smaller risk of technology transfer than the sharing of specialised technical knowledge. A given item of advanced U.S. hardware could be contained and secured while it travelled to China. For example, U.S. monitors could in principle guard a U.S.-made satellite while it was on the ground in China in preparation for launch. Moreover, even if a hardware item was shared with no special restrictions, its movement to China would not necessarily entail the transfer of any industrial capabilities, since many articles were difficult to reverse engineer.

Transfers of intangible technology sometimes carried greater consequences. The specialised technical knowledge that trade participants shared was often product-specific, but could also assist in the development of new capabilities. This impact was likely to be greater in a context such as China’s, where the space industry began to trade while still at a relatively low level of technical capacity. Different modes of bilateral trade and integration posed different degrees and forms of technology transfer risk. In spite of this situation, U.S. policymakers regulated all possible transactions in an equally strict manner, imposing a blanket prohibition on bilateral trade in all space items.

In the space sector, ambiguity and contention over the risks and effects of technology transfers was resolved by policymakers, who, fearing even minor transfers, decided to impose the strictest controls. Space policymakers preferred to err on the side of caution by overzealously blocking trade that could occasion illicit technology transfers to erring on the side of commercial
interests by adopting permissive controls that imperilled national security. In the air sector, the ambiguity and contention surrounding the assessment of technology transfer risks and effects prevented a tightening of U.S. export controls on aircraft items. Policymakers preferred to err on the side of allowing some technology transfers to erring on the side of over-regulating U.S. industry. Policymakers resolved the same fundamental uncertainties in favour of trade in the air sector and in favour of national security in the space sector.

U.S. policymakers were from the start reluctant to regulate space items in the same permissive and nuanced way as aircraft items. Forced by circumstances, U.S. policymakers experimented with item-specific export controls for over ten years, making limited trade possible during that time. Opposition to this solution remained. The likelihood of technology transfers posed an obstacle to continued bilateral trade.

2.3. Benefits of bilateral trade to China’s defense capabilities

A third factor making the space sector an unlikely site of China-U.S. trade, industrial integration, and civil cooperation was the risk that these outcomes would assist China’s development of military-defense space capabilities. Civil-commercial and military-defense space technologies were closely related. Technologies transferred in the course of bilateral trade, integration, or cooperation could be legally or illegally applied to Chinese defense programs. During those two decades, the U.S. government aimed to maintain a technological advantage in defense space systems over China. After 1999, these concerns grew as security relations between the two countries deteriorated. Preventing U.S. firms from bringing any assistance to the development of China’s defense space capabilities was the main motive behind the 1999 legislation that prohibited bilateral trade in the sector.
The Cox committee’s assessment of U.S. satellite manufacturers’ illegal transfers was controversial. Technical experts were divided on the impact of the transfers on U.S. national security. Some believed that the transfers could at most bring a marginal improvement or acceleration to a Chinese space system that had a defense application or aspect. In addition, some of the Cox committee’s claims about the impact of transfers on Chinese space technology program were conjectural propositions, rather than demonstrable occurrences. For example, the Cox committee argued that Hughes’ disclosure would improve Chinese missiles if, in the future, the country produced a specific new type of missile.  

Technical experts dissented from this analysis, characterising this outcome as a remote possibility. Finally, any particular technology transfer might have only a diffuse and indirect impact on China’s military-defense space activities. Some items of transferred technology, such as launch site safety practices, had no specific defense application. They could contribute in a general sense to building capacity in China’s integrated commercial-defense space establishment. To many experts, such individual transfers had at most minor or even negligible effects on China’s defense programs. In spite of this contestation, U.S. policymakers adopted an expansive view of space technology transfers, characterising even minor or indemonstrable technology transfers as strengthening China’s defense industry and imperilling U.S. national security.

U.S. policymakers also understood that the Chinese state intended to foster the absorption of commercial technologies by its national defense manufacturers, which included Casc and Casic. Many U.S. experts in industry, government, and academia agreed that commercial space activities could strengthen China’s military-defense space industry in several ways. Three

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808 Select Committee, United States House of Representatives, “Satellite Launches in the PRC: Hughes.”
810 Sun Laiyan (孙来燕), “Peacefully Use Military Technology, Spur on Economic and Social Development (和平利用军工技术，促进经济社会发展).”
major aspects of commercial space activities had the potential to assist China’s defense programs: 1) dual-use space hardware and skills; 2) manufacturing and launch processes applicable to defense programs; and 3) the economic and organisational benefits of trade to defense programs.

### 2.3.1. Dual-use space hardware and related knowledge

Commercial space programs with foreign partners did or could enable Chinese firms to acquire or develop specific items of space hardware applicable to defense programs. Particular items of commercial space hardware could be repurposed for defense applications with only minor modifications. These items included entire systems, such as launch vehicles. They also included sub-systems, such as sensors on satellites, that could be applied or adapted to intelligence missions. Dual-use technologies also included many smaller components, such as amplifiers and radiation-hardened electronic elements. As a RAND study of China’s aerospace sector conducted for the U.S.-China Economic and Security Review Commission explained,

> Like aviation technologies, many space technologies are inherently dual-use. The development of capabilities to produce civilian space systems, therefore, contributes to China’s capability to produce military space systems. Launch vehicles can be used to launch military as well as civilian satellites, and communications, weather, earth-observation, and navigation satellites can be used for military or civilian purposes.\(^{811}\)

These dual applications were apparent to Chinese experts and policymakers, who advocated using commercial off-the-shelf technology to modernise and develop the defense industries. While stressing autonomous development, sectoral policies and directives guided Casc and Casic to resort to commercial solutions available on world markets when indigenous

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\(^{811}\) Cliff, Ohlandt, and Yang, *Ready for Takeoff: China’s Advancing Aerospace Industry*, 89.
defense technologies were not available.\textsuperscript{812} U.S. space experts and sectoral policymakers were keenly aware of opportunities for diverting commercial space technologies to defense ends. These opportunities existed with respect to both launch vehicle and satellite technology. The most important example of dual-use hardware was the launch vehicle. Commercial launcher hardware could be applied to defense missions. Launch vehicles were transports, like cargo airplanes or troop-carrier helicopters. They could carry commercial or defense payloads.

These multiple applications of civil-commercial space transportation systems were familiar to U.S. space policymakers, who had for several decades attempted to coordinate and integrate civil-commercial and military-defense launch programs. For example, in the 1980s, policymakers intended for NASA’s civil space shuttle to ferry astronauts to the ISS and lift Department of Defense payloads, an initiative that floundered on operational constraints. In the 1990s, policymakers similarly saw promise in ULA’s plan to achieve economies of scale by serving both defense and commercial customers with the same vehicles, a strategy that also proved unworkable. In one or another way, U.S. policymakers had for decades sought to leverage the dual applicability of space systems to commercial and defense activities.

Trade or industrial integration could have brought benefits to China’s commercial launch hardware and practices, which would have translated into advances in its defense programs, especially those that relied on an identical or similar launch vehicle. First, industrial integration with foreign partners could have allowed Chinese manufacturers to build larger and more capable launchers, able to carry larger payloads to more distant orbits. As a result, they would have grown more able to serve a range of military or intelligence missions. Second, importing launch vehicle components or sub-systems could have allowed Calt to modernise or upgrade its Long

\textsuperscript{812} Ruan Ruxiang [阮汝祥], Theory and Practice of Civil-Military Integration with Chinese Characteristics [中国特色军民融合理论与实践].

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March series, which was applicable to both commercial and defense programs. Co-assembling, co-producing, or co-developing a commercial launch vehicle with foreign firms would have allowed Calt to apply the hardware itself or the knowledge derived from the process to the transportation of defense payloads. These applications of commercial launcher hardware to the launch of military payloads made bilateral trade and industrial integration improbable.

In addition, civil and commercial satellite hardware had defense applications. These dual uses were apparent in the areas of communications, Earth observation, and global navigation satellite systems. By 2011, the U.S. military’s communications needs were overwhelmingly served by leasing bandwidth from commercial satellite operators, such as Intelsat. Imaging data from drones, for example, travelled between military users through these commercial satellites.

Some Earth observation satellites could also perform both civil-commercial and military-defense missions. Optical imaging satellites could collect data about the Earth’s surface for commercial, civil, or defense users, such as intelligence agencies. Ocean-observing synthetic aperture radar satellites, for example, could provide civil agencies with data on fisheries and the weather, but also provided coast guards and navies with enhanced maritime domain awareness. The most technically demanding elements of such remote-sensing satellites were their instruments, including the cameras and radars mounted on them. China’s satellite manufacturers lagged behind the world’s leading U.S., Canadian, and European firms in these areas. Transnational trade and industrial integration in commercial remote-sensing satellite manufacture and international cooperation on civil Earth observation programs could have allowed China’s defense industries access to superior foreign-made satellite systems and instruments. Remote-

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813 By 2012, nearly 80% of the U.S. government needs for satellite imagery were met by two commercial remote-sensing satellite operators, GeoEye and DigitalGlobe, which also sold the data to commercial users.
sensing satellite manufacture was an unlikely area for China-U.S. trade and integration. Global navigation satellite systems also had both civil-commercial and military-defense applications.\(^\text{815}\)

The ease with which some civil-commercial space hardware could be repurposed toward defense programs made trade, industrial integration, and cooperation between China and the United States improbable. Both launch vehicle and satellite hardware had such dual applications.

### 2.3.2. Manufacturing and launch processes applicable to defense programs

A third form of assistance that international trade and civil cooperation in the space sector did or could bring to China’s defense programs was the transfer to Chinese firms of technical knowledge about manufacturing and launch processes applicable to defense programs. Technology items that could be transferred through bilateral trade included general knowledge of manufacturing processes common to both commercial launch vehicle and missile programs.

Both commercial launch vehicles and missiles transported payloads through space. As a result, they shared conceptual, functional, and technical similarities. Launchers and missiles shared general common features at the levels of systems and major sub-systems.\(^\text{816}\) Launcher technologies were not identical to missile technologies, but improvements in Calt’s launcher manufacture could bring improvements in the company’s missile manufacture. As in the aircraft sector, even though items of commercial and defense space hardware differed in their particular features, China’s defense programs could benefit from improvements to processes on commercial programs. U.S. export control policy defined missile-related knowledge expansively to include all technology items related to launch vehicles. Actual and potential transfers of launch vehicle

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\(^{816}\) Cliff, Ohlandt, and Yang, *Ready for Takeoff: China’s Advancing Aerospace Industry*, 89.
technology items to China’s defense programs were the main justification provided by U.S. policymakers for restrictions on trade in space items with China.

While general commonalities made some launcher manufacture technologies applicable to missile manufacture, differences between the two types of vehicles limited this applicability. By the 1990s, launch vehicles and missiles were designed to distinct specifications, tolerances, and performance requirements. Missiles generally used “different types of rocket motors and launch methods than space launch vehicles,” observed Cliff et al.\(^{817}\) Their technical features differed at the levels of smaller sub-systems and components. The payload fairings and inertial measurement units on launcher guidance systems, about which Hughes and Loral illegally transferred information, were built to operational requirements and specifications different from those of their equivalents on missiles.\(^{818}\) In a practical sense, the information that Hughes and Loral transmitted about small sub-systems and components was not applicable to missiles, because these elements differed on the two types of vehicles.

In spite of these differences, U.S. laws and policies consistently defined all commercial launch vehicle technologies as missile technologies, classifying them as defense items. This classification per se did not prohibit trade, which occurred in spite of it for over ten years. However, the designation of all launch vehicle technology as missile technology rendered the impact of Hughes and Loral’s disclosures severe. To U.S. policymakers and the public, the two companies shared missile technology with China when they disclosed insights into commercial launchers. Technical knowledge regarded as common to both launcher and missile manufacture motivated U.S. policymakers to first limit, then prohibit, bilateral trade.

\(^{817}\) Ibid.

\(^{818}\) Franklin, “A Critique of the Cox Report Allegations of PRC Acquisition of Sensitive U.S. Missile and Space Technology.”
Beyond manufacturing processes, launch processes were common to commercial and defense satellite programs. Launch preparations comprised the integration of the payload with the launcher and launch site operations. These processes were similar or identical for launches of both commercial and defense satellites. Improvements’ to Calt’s commercial launch processes to result from bilateral trade could have improved its launches of defense payloads.

2.3.3. **Economic and organisational benefits of dual development**

A third way in which China-U.S trade in space items could assist the development of China’s defense industry was through the economic and organisational benefits of concurrently developing commercial and defense space programs. Bilateral trade generated commercial opportunities for China’s space industry. Simultaneously pursuing commercial and defense space activities brought synergies, complementarities, and economies at the levels of individual facilities and of the industry as a whole. Casc units were poised to capture these benefits because they made both commercial and defense products. These benefits existed in both launcher and satellite manufacture.

In the industries of major spacefaring nations, firms and programs benefitted from the integration of their commercial and defense activities on an organisational level. In the United States, the major commercial communications satellite manufacturers, Boeing and Lockheed Martin, also built a range of other satellite platforms for NASA and the Department of Defense. The same was true of major U.S. manufacturers of satellite sub-systems and components.

The picture was different in the launch segment of the U.S. space industry, where U.S. launch providers tended to serve government customers, having lost the commercial market to firms in other countries. This situation, however, owed to a peculiar history of U.S. space transportation policy choices and most observers recognised it as inefficient. As discussed above,
throughout those decades, both U.S. policymakers and specialists believed there were important complementarities and synergies between the commercial and defense launch segments, in vehicle manufacture, but failed to realise them. In Europe, the world’s commercial leader, Arianespace, also launched civil and military satellites for government agencies all over the world. Moreover, later entrants into the U.S. space sector, such as SpaceX the forerunning “commercial” space launch company of the 2000s, also sought to serve both commercial and defense customers with the same vehicles.

As in these firms, the concurrent pursuit of commercial and defense programs promised economies and organisational benefits to Chinese companies. Launch vehicle and satellite manufacture was sensitive to volume. Manufacturers sought to capture the highest possible market for any given product, using common vehicles/platforms to carry both commercial and defense payloads where possible. The parallel, concurrent, and coordinated implementation of commercial and defense programs promised synergies, complementarities, and economies in the manufacture of launchers and satellites. In both types of products, the benefits of dual development were threefold. They resulted from economies of scale, returns on capital investment, and modularisation.

First, manufacturing common commercial-defense launchers and satellite technologies promised economies of scale and risk reductions in development and production for Chinese firms. Overall, space transportation featured important volume effects, recognised by U.S. and international space experts, As Bernard F. Kutter, the Senior Staff Manager on the Atlas Evolution program with Lockheed Martin, summarised, “Due to the extremely high fixed

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infrastructure costs of typical launch systems, rate has a very profound effect on cost of space access.”

Similar effects obtained in the narrower area of launch vehicle and satellite system and sub-system manufacture. As production volumes for a given vehicle or satellite platform rose, average unit costs dropped. Development costs were very high for new vehicles and platforms. Transaction costs involved in reaching agreements with sub-system and component suppliers were high. At high volumes, these costs were distributed over a larger number of launches or satellites. Producing launchers or satellite platforms for export could increase the total production volume of a given article, reducing its average unit cost. This cost reduction could benefit both the commercial and defense sides of the integrated satellite manufacturing industry.

At higher volumes, experience effects also kicked in. These brought further cost reductions and other benefits. Learning effects in launch vehicle manufacture, launch operations, and flight operations were significant. Practice was an important determinant of launch vehicle program success. Launch failures themselves provided major learning opportunities. In addition, the more times a vehicle had flown, the longer its record for reliability. Reliability was a priority in operators’ choice of launch solutions for military and intelligence payloads, because these were of high value or often not insured. Reliability was also a concern to commercial users, who were sensitive to launch insurance rates. Using common vehicles to launch both commercial and defense payloads was a means for Chinese manufacturers to capture these economies of scale and experience effects.

Satellite platform and component makers also benefited from experience effects attained at high levels of production. For example, both commercial and defense satellite users preferred

821 e.g. Cristina T. Chaplain, Briefing on Commercial and Department of Defense Space System Requirements and Acquisition Practices (DIANE Publishing, 2010), 39.
platforms with a reliable track record of smooth operation. The higher the volume of satellites using a given platform flown, the greater this particular form of experience effect for the manufacturer. Using proven platforms also reduced design and development risks on specific projects. Increasing the overall volume of satellite production by expanding commercial production through trade could have benefitted China’s defense satellite programs.

A second form of benefit from integrating commercial and defense manufacture of launchers and satellites had to do with capital investments and fixed costs. These factors were closely related to economies of scale, but their effects not confined to particular products. Maintaining assembly, integration, and testing facilities for launchers and satellites was costly. Retaining skilled personnel as demand for either commercial or defense products fluctuated also imposed high fixed costs. For manufacturers facing these burdens, consolidating production of commercial and defense articles in the same facilities was optimal. These conditions created economies of scale and scope.

A third set of economic and organisational benefits to result from dual commercial and defense space development had to do with modularisation in launcher and satellite manufacture. High production volumes allowed Chinese companies to make the most of modular designs and to serialise production. During those two decades, these benefits were most accessible to China’s launch-vehicle industry, but they also existed for satellite manufacturers. Developing modular designs brought efficiencies in production and flexibility. When manufacturers adopted modular designs, they could serialise more of their fabrication and

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823 Interview with senior manager responsible for international trade at Case, Interviewee 24-20-00, Beijing, 2010.
824 Interview with senior manager responsible for international trade at Case, Interviewee 24-20-00, Beijing, 2010.
reduce their costs.\footnote{Interview with senior manager responsible for international trade at Case, Interviewee 24-20-00, Beijing, 2010.} Modular designs also allowed more efficient assembly and testing of launch vehicle and satellite systems and sub-systems.\footnote{Interview with senior manager responsible for international trade at Case, Interviewee 24-20-00, Beijing, 2010.} To deliver the greatest advantages, modularisation and serialisation required production at a high volume. Taking advantage of commonalities in commercial and defense hardware to achieve a higher volume of production on a given satellite platform, launcher, or element allowed firms to reap the economic and organisational benefits of modularisation.

The benefits of simultaneously pursuing commercial and defense programs in launch vehicle and satellite manufacture made commercial partnerships between Chinese and U.S. firms unlikely. U.S. policymakers sought to prevent U.S. firms from indirectly strengthening China’s defense programs or industrial base by engaging in commercial activities that benefitted them.

Bilateral trade, industrial integration, and civil cooperation could assist China’s defense space programs in three areas. First, bilateral trade and integration could allow Chinese firms to acquire or gain exposure to dual-use space hardware and skills, which in turn would improve its defense space programs. Second, the commercial launch trade could allow China’s launch providers to refine their manufacturing and launch processes, improving their missile programs and their ability to launch both civil-commercial and defense satellites. Third, bilateral trade could allow Chinese space firms to develop commercial activities in parallel to defense programs, reaping the economic benefits from the complementarities between the two segments. Together, these factors made the space sector an improbable site of China-U.S. trade, industrial integration, and civil cooperation. The U.S. government was unlikely to adopt policies that allowed U.S. firms to engage in bilateral trade or integration that could result in improvements to China’s dual-use space capabilities.
2.4. Advances in China’s defense space programs during this period

A fourth condition dimming the prospects for China-U.S. trade, industrial integration, and civil cooperation was the technological advances that China’s defense space programs made during this period. These achievements had two effects on the course of bilateral relations. First, they provided China’s leaders with further evidence that the autonomous development of defense space capabilities was possible. China’s policymakers maintained this strategy and their interest in bilateral trade and industrial integration waned. The second effect of advances in Chinese defense space programs was to arouse concerns among U.S. policymakers. In particular, they worried about China’s long-term interests in space and the vulnerabilities that China’s new counter-space systems created in U.S. systems. As U.S. policymakers observed Chinese defense space capabilities grow after 1999, they more staunchly resisted any bilateral trade or cooperation. The relaxation of the export controls blocking bilateral trade grew nearly unthinkable to the U.S. space community. The resort to presidential waivers or other carve-out mechanisms to allow sectoral trade with China under the rules in place also grew improbable.

Progress in China’s defense space programs was rapid. Before 1988, the only Chinese satellites were recoverable film satellites and low-capacity communications satellites. By 2009, the space industry had developed and deployed a vast range of weather satellites, medium- and high-capacity communications satellites, remote-sensing satellites, and potential electronic intelligence satellites, many of which were dual-use or dedicated military systems. The 2011 RAND study of advances in Chinese aerospace by Roger Cliff et al. found that

China’s space capabilities have made remarkable progress over the past two decades. Its satellite capabilities, in particular, have gone from rudimentary
to near-state-of-the-art in some areas. [...] The capacity and reliability of China’s space launch vehicles have increased as well.\textsuperscript{828}

During those two decades, Casc and Casic, led by the PLA’s GAD, completed several defense technology development programs begun in the 1980s and 1990s. These programs culminated in the testing, demonstration, and operation of major new systems. The advances in China’s defense space programs spanned four major areas. The first of these was global satellite navigation. The second was space-enabled military communications. The third was defense Earth observation satellites. The fourth was counter-space systems.

In 1994, China’s space industry began to develop and build the Beidou navigation satellite system (北斗卫星导航系统), a constellation of PNT satellites serving civil, commercial, defense needs.\textsuperscript{829} Around 2006, China’s leaders initiated Beidou’s expansion to a second-generation system, also known as Compass, to provide a global service by 2020.\textsuperscript{830} Beidou would provide the position, navigation, and timing signals necessary for China’s wholesale military modernisation on the ground, at sea, and in the air.\textsuperscript{831} The satellites were to become nodes in China’s evolving network-centric military, essential elements of the PLA’s larger process of informatisation. The system’s timing signals could be used to synchronise automated data links, enabling the high-volume data exchange needed to make full use of space assets in military operations. Building the Beidou system was a precondition to arming China’s aircraft,

\textsuperscript{828} Cliff, Ohlandt, and Yang, Ready for Takeoff: China’s Advancing Aerospace Industry, 107–108.
naval vessels, and other platforms with precision-guided munitions. Most importantly, the Beidou system would be unaffected by a disruption in the GPS signal.\footnote{Pace, “The Strategic Significance of Compass”; Bounds, “China Looks to Rival Galileo and GPS with New Satellite.”}

In order to meet the PLA’s growing communications needs, China’s space industry developed and launched two military communications satellites and a high-capacity “strategic communications” satellite in geosynchronous orbit by 2009.\footnote{Cliff, Ohlandt, and Yang, Ready for Takeoff: China’s Advancing Aerospace Industry, 93–112.} Though only a fraction of the U.S. Department of Defense’s fleet of communications satellites, these assets were the linchpin of the PLA’s evolution to a modernised, network-centric military with enhanced capabilities in Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR). In 2007, the CMSEO began operating the country’s first data relay satellite, increasing the speed at which ground stations could receive data from space assets.\footnote{Ibid., 94–95.} This change allowed Chinese forces to begin focusing on the operational, real-time use of space-derived data in battle offshore.

Over the course of those two decades, the space industry developed, launched, and initiated the operation of various remote-sensing satellites with defense applications.\footnote{Ibid., 100–101.} They comprised dual-use weather satellites\footnote{Ibid., 97.} and military imagery reconnaissance satellites.\footnote{Chinese Academy of Spaceflight Technology (中国空间技术研究院), Beacons on the Sky Road: Legendary Stories of China’s Satellite Spacecraft (天街明灯:中国卫星飞船传奇故事); Cliff, Ohlandt, and Yang, Ready for Takeoff: China’s Advancing Aerospace Industry, 100.} In addition to these three dedicated military series and weather satellites, the space industry developed and launched a range of other Earth observation and experimental satellites that...
international observers judged to have intelligence applications.\textsuperscript{838} By 2011, China operated at least 10 imagery reconnaissance satellites and as many as six or more electronic intelligence satellites.\textsuperscript{839} These numbers were comparable to the numbers of satellites of these types that the United States possessed during this time, although experts noted that the capabilities on Chinese satellites “undoubtedly fell well short of those of the United States.”\textsuperscript{840}

The effect of the advances in these three areas was substantial. “The space capabilities China now possesses have the potential to significantly increase the effectiveness of its military operations,” wrote Cliff et al. in 2011.\textsuperscript{841} As more Chinese satellites entered into service over the years, the fleet’s global coverage increased, such that any given location was likely to have received several passes by different types of satellites per day.\textsuperscript{842} Moreover, advances in data relay, ground systems, and data processing made the observations collected by these satellites more usable by China’s military and intelligence actors than ever before.

Over time, the implications of these advances for the Chinese military’s strength in particular scenarios grew apparent to U.S. observers. China’s optical reconnaissance satellites had “sufficient resolution to detect and identify types of ships, aircraft, and ground vehicles.”\textsuperscript{843} The synthetic aperture radar satellites, whose operation was unaffected by cloud cover or night darkness, likely had “sufficient resolution to at least determine the presence of aircraft at an airfield and distinguish broad types of ships.”\textsuperscript{844} The supposed electronic intelligence satellites

\textsuperscript{840} Cliff, Ohlandt, and Yang, \textit{Ready for Takeoff: China’s Advancing Aerospace Industry}, 110.
\textsuperscript{841} Ibid., 108.
\textsuperscript{842} Ibid.
\textsuperscript{843} Ibid.
\textsuperscript{844} Ibid.
could perhaps “detect and identify radio-frequency emitters such as radio communications equipment and radar based on their frequency and waveforms.”

To U.S. analysts, these changes made the modernising PLA a more formidable opponent in a confrontation ver Taiwan. As intelligence, weather, navigation, and communications satellites launched, it became apparent to U.S. experts that progress in Chinese satellite manufacture and operations had concrete implications for U.S. security interests.

By 2009, China’s space industry and military space users had also concluded some decades-long efforts at developing offensive and defensive counter-space capabilities. Begun in the 1980s, these programs tracked earlier U.S. and Soviet technology development programs.

U.S. experts closely monitored these advances and reported them to policymakers. The 2008 Department of Defense’s report to Congress on China’s military power described these programs.

The PLA has developed a variety of kinetic and non-kinetic weapons and jammers to degrade or deny an adversary’s ability to use space-based platforms. China also is researching and deploying capabilities intended to disrupt satellite operations or functionality without inflicting physical damage. The PLA is also exploring satellite jammers, kinetic energy weapons, high-powered lasers, high-powered microwave weapons, particle beam weapons, and electromagnetic pulse weapons for counterspace application.

According to U.S. defense analysts, China’s major potential counter-space systems spanned four types: signal jammers; ground-based lasers; manoeuvring satellites with anti-satellite applications;

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845 Ibid.
and direct ascent kinetic anti-satellite weapons. In the 2000s, Chinese space specialists and U.S. government reports indicated that the Chinese defense industry and GAD were developing electromagnetic interference and jamming technologies with counter-space applications.\(^{850}\) These systems threatened the GPS signals on which the U.S. military and economy relied.\(^{851}\)

The development of interference systems targeting space assets was part of a larger strategy and series of capabilities focused on electronic warfare adopted by the Jiang and Hu administrations. The 2009 Department of Defense report to Congress on Chinese military power surveyed progress in this area over the preceding decade, describing efforts at “Competing for Dominance of the Electromagnetic Spectrum.”\(^{852}\)

A second type of counter-space system reportedly under development during those two decades in China was ground-based lasers. The Chinese military reportedly led the development of and tested lasers for tracking satellites during this time,\(^{853}\) effectively testing a capability that could degrade or destroy U.S. space assets.\(^{854}\)

A third potential counter-space system consisted in manoeuvring satellites. The CMSEO developed rendez-vous and docking capabilities within the space laboratory program. These tools could be adapted to perform up-close visual inspections of or to physically interfere with valuable U.S. intelligence and military satellites.\(^{855}\) In this same context, the CMSEO conducted

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\(^{852}\) “Annual Report to Congress. Military Power of the People’s Republic of China 2009” (Office of the Secretary of Defense, 2009), VIII.


\(^{855}\) Ibid., 15; Weeden, “Dancing in the Dark: The Orbital Rendezvous of SJ-12 and SJ-06F.”
activities that some U.S. observers interpreted as possible tests of parasitic co-orbital satellite weapons.\footnote{Weeden, “China’s BX-1 Microsatellite: A Litmus Test for Space Weaponization.”}

The defense industry’s most significant counter-space advance was in the area of direct-ascent kinetic anti-satellite weapons. On 11 January 2007, the PLA tested such a system on a target in space. The test consisted in the launch on a ground-based missile of a homing vehicle that intercepted and destroyed an aging weather satellite by direct impact. With this intercept, China became only the third country after the United States and the Soviet Union to demonstrate this anti-satellite capability. Three years later to the day, the PLA conducted an anti-ballistic missile test in a different orbit, which verified the same capabilities as those required for a kinetic anti-satellite weapon.\footnote{Grego, \textit{A History of Anti-Satellite Programs}, 13.} More than any other advances, these alarmed U.S. observers and made the U.S. government unlikely to reform policies blocking bilateral trade and cooperation.

U.S. space and defense experts monitored these advances in China. Throughout these two decades, they communicated their observations and findings to policymakers. The Department of Defense, for example, began its annual report to congress on China’s military power in 2000.\footnote{“Annual Report to Congress: Military Power of the People’s Republic of China 2000.”} Specialists testified about China’s military and intelligence space programs to the Congress and related institutions.\footnote{Cheng, \textit{China’s Space Program: Written Testimony Submitted to the U.S.-China Economic and Security Review Commission}; Mark A. Stokes with Dean Cheng, \textit{China’s Evolving Space Capabilities: Implications for U.S. Interests}; Cheng, \textit{China’s Space Program: A Growing Factor in U.S. Security Planning}, August 16, 2011; Kulacki and Johnson-Freese, “Significant Errors in Testimony on China’s Space Program.”} These experts also briefed policy specialists in executive departments and agencies.

After the 2007 anti-satellite tests, policymakers and space experts’ concerns grew into alarm at the threat Chinese weapons posed to the fragile satellites upon which the U.S. military relied. Already tense bilateral relations deteriorated further, as both countries grew suspicious of
each others’ evolving defense systems. As China’s defense space programs advanced, the likelihood of bilateral trade and cooperation grew even more remote. In response to growing Chinese space capabilities, U.S. policymakers steadfastly resisted any bilateral trade or cooperation after 1999. Few to begin with, U.S. advocates for engagement of China and bilateral cooperation in space were marginalised after the 2007 anti-satellite test. The relaxation of strict export controls that prevented bilateral trade became all but unthinkable to the U.S. space community.

2.5. Illegal transfers to China of defense-relevant space technologies

A fifth factor making the space sector an unlikely site of China-U.S. trade or civil cooperation was a series of export control violations that resulted in the illicit transmission to China of U.S. space technology. The most important of these offenses were committed by U.S. firms that participated in the launch trade in China. It was when evidence of the most serious of these violations surfaced that the Congress passed legislation to re-categorise all space items as munitions, blocking their export to China.

U.S. firms violated export controls during routine Chinese launches, but committed their most significant violations following launch failures. Over the course of this trade, three launches of U.S.-made satellites failed. Each of these failures caused the total destruction of its payload. In 1992, the Long March 2B failed shortly after lift-off while carrying the Optus 2b communications satellite, built by Hughes. In 1995, the same vehicle failed again, carrying the Apstar 2 communications satellite, also made by Hughes.860 In 1996, the Long March 3B failed with the Loral-built Intelsat 708 communications satellite on board.861 Both U.S. companies

860 Select Committee, United States House of Representatives, “Satellite Launches in the PRC: Hughes.”
861 Select Committee, United States House of Representatives, “Satellite Launches in the PRC: Loral.”
participated in Calt’s technical investigations of the failures. During the analyses, Hughes and Loral shared controlled information with Chinese personnel in breach of export control laws.

Evidence that Hughes and Loral had had broken the law reached the U.S. government in 1998. Federal agencies began investigations. The companies made voluntary disclosures that they had unintentionally violated export controls when they participated in investigations of the launch failures with Calt. According to statements by Hughes and Loral employees on the congressional record, after the failures, insurers refused to cover any more launches until they obtained analyses of the causes of the accidents. To meet these demands, Calt’s parent company, Casc, asked Hughes and Loral to assemble teams of their engineers to investigate the failures. Hughes put together the first two of these teams and Loral the last. The groups cooperated on the failure investigations and shared their analyses with Calt.\footnote{Select Committee, United States House of Representatives, “Satellite Launches in the PRC: Hughes”; Select Committee, United States House of Representatives, “Satellite Launches in the PRC: Loral.”}

In time, federal investigations determined that Hughes and Loral violated export controls when they sent their launch failure analyses to Calt without a license from the Department of State allowing them to share technical data. Separate investigations also found that lesser violations occurred on site in China during routine launches.\footnote{Report on Impacts to U.S. National Security of Advanced Satellite Technology Exports to the People’s Republic of China (PRC).} These investigations resulted in fines against the companies. In 2002, Loral agreed to pay USD 14 million to settle the charges it violated export controls. In 2003, Boeing paid USD 32 million to settle the role in the violations of Hughes, which Boeing had by then acquired.\footnote{Zelnio, “A Short History of Export Control Policy.”}

Before the federal investigations of these breaches had concluded, the House of Representatives established the Cox committee to examine the incidents and the policies that allowed trade with China in launch services. The committee concluded that Hughes and Loral
endangered U.S. national security when they disclosed technical information to their Chinese partners. The committee found that the companies broke the law by providing a defense service and communicating controlled technical knowledge to non-nationals when their employees participated in the investigations of the launch failures with Calt. The Cox report determined that sharing the failure analyses could have led to improvements of China’s Long March rockets. The committee also found that the sharing of the failure analyses could improve Chinese ballistic missiles, which used or could in the future use technologies similar to those of its commercial launchers. In addition, the committee found that U.S. satellite maker Martin Marietta violated export controls when its employees improperly shared technical information related to launch site practices during launch campaigns in China. These findings provided the basis for the committee’s policy recommendation that controls on space exports to China should be tightened and that the trade in space items with China should end.

These five factors combined to make the space sector an unlikely site of China-U.S. trade, industrial integration, or cooperation. The strategic status of the space sector, the risks of technology transfer inherent in trade and cooperation, the applicability of civil and commercial space technologies to defense programs, advances in China’s defense space programs, and export control violations all worsened the prospects for bilateral relations in the sector. These circumstances made the U.S. government unlikely to adopt or maintain policies that allowed significant space trade or cooperation throughout this period. They also made both governments likely to be suspicious of each others’ motives and capabilities in space, causing bilateral relations in the sector to deteriorate.

While these factors made interstate security tension and competition likely, they did not determine these sectoral outcomes. Similar conditions obtained in the air sector and yet bilateral relations there followed a different course. Despite the same obstacles, the two countries saw
their trade, industrial integration, and civil cooperation in the air sector grow and accelerate during these two decades. By 2009, bilateral integration and cooperation was taken for granted by both countries’ policymakers in the air sector, while the opposite outcome seemed irreversible to both countries’ policymakers in the space sector.

**Conclusion**

The civil-commercial space sector presented a mix of factors shaping the prospects for China-U.S. trade and cooperation during the 1989-2009 period. Some conditions made trade, industrial integration, and cooperation between the two countries probable outcomes. Other conditions made these bilateral outcomes improbable and increased the likelihood that the mutual suspicion, security tension, and competition between the two countries would grow.

Several factors made bilateral trade and civil cooperation likely. The two economies featured an ideal complementarity of demand for and supply of launch services. The two economies also featured a complementarity of demand for and supply of communications satellites. In these respects, China and the United States were optimally matched sectoral trade partners. The economics of spacecraft manufacture and civil space programs, in both the launch vehicle and satellite segments, presented actors in the two countries’ with incentives to trade and integrate their industrial activities and civil programs. China’s partnerships with European and other international actors expanded during this period. While these entities, some of them U.S. competitors, benefited from their collaborations with Chinese space organisations, their U.S. counterparts were denied the same opportunities. Finally, after 1999, the costs to the U.S. space industry of tight controls on space exports grew. As this situation persisted, U.S. policy grew more likely to change toward facilitating space trade and cooperation with China.
These developments gave U.S. policymakers and decisionmakers reason to re-evaluate the restrictive export controls and other policies that prohibited bilateral trade, industrial integration, and civil cooperation after 1999. In spite of these conditions, U.S. policies blocking these outcomes remained in place. Chinese policy encouraged Chinese firms and agencies to seek international opportunities, but over the course of these two decades, increasingly emphasised the autonomous development of core space capabilities.

Several factors also made bilateral trade and civil cooperation improbable sectoral outcomes. The status of the space sector as a strategic node in national economies and infrastructures made it an improbable site of trade and cooperation between two countries in a tense security relationship. Technology transfers inhered in trade and cooperation. Civil and commercial space items were applicable to China’s defense programs, a circumstance that hindered the prospects for bilateral relations. Advances in China’s defense space programs during this period alarmed U.S. policymakers, making any relaxation of export controls unlikely. Finally, illicit transfers of space technology to China during those two decades provided U.S. policymakers with evidence that bilateral trade posed unmanageable risks of technology transfer. These developments gave U.S. policymakers reason to initially allow only limited, tightly controlled bilateral trade and then to abruptly end it altogether.

The space sector presented a mix of incentives and disincentives for bilateral trade and cooperation similar to the air sector's. However, in the contrasting air sector, both governments, facing similar hindrances, adopted and maintained policies that allowed trade, industrial integration, and civil cooperation. Policymakers in the air sector judged that the benefits of bilateral trade and cooperation outweighed their costs and risks, while policymakers in the space sector reached the opposite conclusion. In the space sector, technology transfer, non-proliferation, and national security concerns guided U.S. policy toward China. Trade and economic priorities
yielded to security concerns. Chinese policymakers stressed the autonomous pursuit of core national capabilities and reducing reliance on foreign suppliers and markets. The following two chapters examine how this bilateral order in the space sector emerged and evolved as both countries adopted policies over the two decades.
The space specialist culture

Introduction

During the latter half of the Cold War, civil and commercial space activities on a large scale spread from the Soviet Union and the United States to several other countries, including throughout Europe and East Asia. Usage of space-based services expanded across the globe during this period, but the manufacture of major space systems remained concentrated in a handful of regional hubs. Individuals working in civil and commercial space in these different regions shared a technical and professional culture unique to their sector. This sectoral culture consisted in a set of basic assumptions about humans and technology. Space specialists expressed these philosophical commitments in their representational practices. These practices consisted in common habits of speech and writing they used to represent the sociotechnical systems of spaceflight.

In the course of their work, space specialists represented these sociotechnical systems in operation, configurations of space technologies and humans in action. For example in discussing human spaceflight policy, a space expert might represent the ISS in spoken and written words, images on their PowerPoint presentation slides, and three-dimensional maquettes. They would describe the station as an in-space laboratory, comprising facilities, equipment, scientists, institutions, intergovernmental agreements, and national space policies, drawing connections between these diverse elements. The habits that space experts used to represent the connections between the human and technical elements of the ISS, producing it as a system in action, reflected basic philosophical understandings. These basic philosophical understandings formed a coherent set of ideas about humans and technology. Space experts conveyed this set of ideas in their habits of representation. As they described relationships between the different parts of their
sociotechnical systems, they performed common representational practices. Circulated throughout the specialist community and expressed in specialists’ representational practices, this tacit philosophy of human-technology relations constituted a sectoral culture.

This common specialist culture was neither inherent in experts’ technical work nor given by the technologies themselves. Instead, this culture was a historical artefact, the product of several currents of thought and representational practice converging in the space specialist community. Space experts absorbed these and reproduced them in their habits of speech and writing. These discursive practices circulated between national space communities, spreading throughout the global space sector. By the 1990s, space experts in different countries shared a single transnational specialist culture, expressed in their common discursive practices. Several channels and mechanisms diffused the content and expression of this culture throughout the global space community after the launch of Sputnik. Assimilated and appropriated across national communities of space experts, this specialist culture was maintained and reproduced in representational practices. Transnational dialogue in various forms, including via specialised publications, conference presentations, and intergovernmental processes, facilitated the movement of cultural practices between spacefaring countries.

Space experts in both China and the United States depicted the sociotechnical systems of spaceflight by performing common representational practices, conveying the same background philosophical assumptions about how humans relate to their human-built world. These assumptions were about the relationships between humans and machines, between society and technology, and between technology and international politics. In other words, they constituted a tacit anthropology, sociology of technology, and theory of international politics.

In space experts’ representations, agency was distributed across both the human and non-human elements of sociotechnical systems. Artefacts constituted and enabled their human users.
Devices possessed their own distinct capacities and effectiveness. The “technology factor” shaped society and international politics, deciding the outcomes of power struggles between countries. These conceptual relationships structured how experts represented sociotechnical systems in the space sector to policymakers.

Space specialists in both China and the United States contributed their expertise to policymaking in their country. Drawing on their representational practices, they interpreted and explained the sector for policymakers. In the process, they created it as an object for policy and an arena for state action. As experts represented sociotechnical systems in spaceflight, they expressed their tacit anthropology, sociology, and theory of international politics.

During the two decades after 1989, space specialists adopted their view of the human-technology relations from currents of thought about technology from fields outside of their contemporary space sector. Several currents of thought coalesced in the space specialist culture. The origins of these currents were diverse, ranging from visions of space development proposed in the 1800s to 1990s discourses about the changing nature of war. Specialists in government, industry, and academia expressed these tacit theories in images of the sector they repeated.

This chapter examines the content and origins of the specialist culture shared among Chinese and U.S. space experts. The first part describes the background knowledges and representational practices constituting the specialist culture shared by members of this community. The second part traces the content of this specialist culture to its sources in fields of practice related to, but outside, the civil-commercial space sector. The third part illustrates how space experts conveyed and performed this specialist culture by reproducing specific images and constructions of the space sector in their discourses during the 1989 to 2009 period.
1. Space culture and human-technology relations

Underpinning space specialists’ representational practices was a basic conception of agency as inhering in both humans and their devices, a view from which other basic assumptions also derived. As experts described assemblages of human and technical systems, they characterised the relationships between these elements, expressing their tacit assumptions. They conveyed these assumptions in their representations of individuals, the nation-state, and technology in their sector. Together, these assumptions formed an informal anthropology, a sociology of technology, and theory of international politics.

1.1. The space specialist’s anthropology

In representations of their sector, space experts conveyed a distinct anthropology of technology made up of basic assumptions about the individual, society, and technology. Depicting their sociotechnical systems, specialists expressed how humans related to their technologies and how individuals related to society.

1.1.1. Humans and their tools

In the space specialist’s anthropology, technologies were effective and constitutive of their human users. In representing sociotechnical systems, experts depicted agency as coursing through the human and technical elements of these assemblages. Specialists shared a conception of agency as residing in both people and devices. As experts described particular human-machine systems, they produced artefacts as having a potential and efficacy of their own that was sometimes in tension with human agency. The autonomous life of machines intrigued and inspired space experts. They made agents of their artefacts. In some situations they represented, humans were derivatives of their tools. In other cases, space experts were preoccupied instead
with the non-compliance of machines with human designs. Technical systems smarted against their human masters.

To distinguish space experts from specialists in other fields, it is helpful to remember that, for space specialists, the question of non-human agency presented itself in literal terms. The space community was divided over the very utility of a physical human presence in the sociotechnical systems of spaceflight. This debate had surfaced in several areas since the dawn of the space age. Military services and intelligence agencies disagreed over whether manned platforms or unmanned systems were best suited to intelligence collection in space and near space. Constituencies of the space exploration community disagreed over the appropriate roles for humans and robots at distant destinations, such as asteroids and Mars. Lurking behind these disagreements was a conception of machines as capable of taking over human functions and of humans as ceding roles to machines. The technical analysts in the U.S. Congress’s Office of Technology Assessment (OTA) expressed this understanding in a report on exploration.

A central mission of automation and robotics (A&R) technology is to provide a high level of autonomy, or decisionmaking capability, to robotic devices that will enable more effective management of spacecraft, landers, rovers, and other instruments of discovery. Human team members can then guide at any level, and from both small and large distances, because the robot members will have increased capacity for making decisions, as well as increased mobility and manipulative skill. More effective robotics would leave humans free to reason and to control at the most effective level for discovery.

Space expert language produced machines as agents. Robots were “members” and “partners” in space activities. The underlying supposition of machine agency was most clearly expressed in

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experts’ representations of the future, in which they extrapolated from current trends to what they believed were their logical outgrowths.

In the most effective exploration program, people and machines would function as interactive partners, with people on Earth or perhaps on the surface of the Moon or Mars, as need and funding allow. […] In the past, A&R technologies have received relatively little emphasis, in part because they have lacked capability. In the future, giving A&R technologies a more central role in exploration activities could greatly enhance scientific understanding and contribute to increased human productivity in other parts of the economy. Congress can play an important part in assuring that the partnership between humans and machines evolves as productively as possible.  

The OTA’s report is a deliberately balanced and moderate representation of the state of technical expert consensus on these philosophical questions, as they arose in the major policy issues before Congress. Space experts often represented agency as located in both the human and machine elements of space sociotechnical systems. However, unlike the Office’s explicit statement of this view, expert representations tended to relay it indirectly in descriptions of particular artefacts and users in action.

Space specialists often conveyed machine agency more subtly by representing devices as functional, rather than processual. These renderings emphasized the effects that the artefact produced, rather than its interaction with its human creators, operators, and users. A given artefact, such as a satellite or a GPS receiver, was a unitary and finished entity. In the words of Bruno Latour, these representations produced the object as a “black box:” a closed, singular, distantly assembled entity whose internal workings and production history were obscured.  

Seams, literal and figurative, between components of an artefact were rendered invisible in a

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868 Ibid., 3. Emphasis in the original.
discourse that produced the item as a whole. Specialists represented systems as complete, functional entities.

These renderings of artefacts also held out of view the human choice and effort encapsulated in the object. With engineering and manufacturing inputs dissimulated, a machine’s origins in human design and labour were erased. The process of human creation ended at the factory. Once deployed, technical systems became givens. These representations produced technologies as endowed with built-in capacities. Artefacts were functional and effective. Instead of snapshots of sociotechnical systems in action, specialist representations focused on devices themselves.

While space experts saw technologies as inherently effective and consequential, they did not believe that space systems were robust or resilient. On the contrary, they consistently emphasized the vulnerability of space assets. Distant, fragile, loaded with sensitive instruments, and circulating in predictable orbits, satellites were easy to target and difficult to defend. The vulnerabilities that this situation created for users reliant on space assets preoccupied experts, their concerns once again underscoring the constitution of agents by their tools.

Representing technologies in this way implied a supporting conception of the humans who partnered with them in sociotechnical configurations. For the space expert, the human user was a passive recipient of technologies that empowered and enabled them. While scholars of technology preferred to represent users as participants in the continuous creation and re-creation of technical artefacts in practice, professional space experts saw users as derivatives of their technical systems. The roles of maker and operator often yielded to the role of user.

Space specialists conveyed their conception of human actors as constituted by their technologies in turns of phrase. For example, space experts described technologies as enabling human actors and outcomes. The 1985 National Commission on Space summarised the
preceding fifty years of research and development in space as having generated “enabling technologies” in communications satellites.\textsuperscript{870} The Aerospace Commission wrote that propulsion and power were the “key technologies to enable” human access to space.\textsuperscript{871} The 1990 Augustine Commission similarly described “new materials, electronics, engines, and the like” as the key “enablers” that make missions possible.\textsuperscript{872} These constructions conferred agency upon devices and artefacts they associated with space development. More generally, the struggle between human and machine agency was a recurring theme in space expert representations of their sociotechnical systems.\textsuperscript{873}

1.1.2. Society and the individual

Space experts’ representations also conveyed a concept of human collectives, or of how individuals related to society. This tacit anthropology was structural and systemic: individuals were derivatives of their larger social structures. Adopting a macroscopic perspective, space experts often represented human collectives as an integral wholes. The groupings that figured recurrently in space specialist discourses were nations, industries, and humankind. These functioned as systems. Individuals, firms, and interest groups were subsumed under aggregate and abstract social units that functioned as wholes. The social was closer to a system of moving parts than to a collection of motivated individuals.

Individuals in these accounts were products of their time and circumstances, not figures who controlled their fates or the course of space development. Instead of creating and changing


\textsuperscript{872} Advisory Committee on the Future of the U.S. Space Program, \textit{Report of the Advisory Committee on the Future of the U.S. Space Program} (Washington, DC, December 17, 1990), 5.

\textsuperscript{873} A detailed empirical discussion of this issue and of how space experts described it is found in Mindell, \textit{Digital Apollo}. 
their structures, human actors passively bore their effects. Humans derived of their circumstances. Larger impersonal forces dictated outcomes. Even those specialist accounts that foregrounded individuals or other actors tended to represent them as enabled and constituted by their technologies, rather creators and users of them.

This tendency appeared in specialist portrayals of even the most important of humans in their sociotechnical systems: astronauts. Specialist portrayals of astronauts were ambivalent, expressing a combination of admiration and contempt, casting astronauts as both inspirations and instruments. Non-specialist representations celebrated the heroes of spaceflight. Works such as Tom Wolfe’s *The Right Stuff* presented strong-willed, capable, and idiosyncratic personalities whose choices and behaviours shaped the larger systems of spaceflight in which they operated. But these aspirational, non-specialist depictions contrasted with expert representations. In private, technical space experts vacillated. They regarded astronauts, especially pilots, as impressive in a sense, but also as limited. In experts’ private observations, astronauts were weak actors. For example, astronauts were incapable managers (of an international meeting of the heads of major space agencies, “The Administrator couldn’t be there because a high school in Iowa was having a science fair that day”). Astronauts were political tools (“they picked him because a four-time shuttle astronaut has that standing within the community to push this through”). And astronauts were idealistic naïfs (“of course astronauts will say anything about international cooperation, they don’t understand national security”). In short, space specialists who stayed on the ground often saw astronauts as useful, but not inherently capable.

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874 E.g. News media representations of these figures are discussed in Allen, *Live From the Moon*, 75–98.
875 Wolfe, *The Right Stuff*.
876 Loosely paraphrased informal, off-the-record conversations with experienced professionals in the U.S. space policy community.
Smithsonian Air and Space Museum historian Roger Launius found that astronauts tended to be portrayed by technical historians and specialists as embodiments of an idealised masculinity and rationality.\textsuperscript{877} So caricatured were these depictions that they verged on mission-driven automatons or passive appendages to large technical systems controlled by engineers on the ground.\textsuperscript{878} Representations of astronauts in policy discourses and technical practices similarly rendered the astronaut as a position, rather than a protagonist. National programs trained astronauts to be interchangeable members of a corps seamlessly integrated into a large technical system, rather than pioneers, leaders, or even decisionmakers.\textsuperscript{879} Astronauts existed by virtue of their function in a mission, in which they partnered with rockets, capsules, and antenna. Humans were products of their technical systems.

### 1.2. The space specialist’s sociology of technology

In addition to their common anthropology, space specialists expressed a tacit sociology in their representational practices. This sociology was consistent with their anthropological understanding of agency as residing within both technical systems and humans. The specialist’s sociology was made up of basic assumptions about the relationship between society and technology. As experts depicted sociotechnical systems, they described how societal and technological conditions interacted. Their tacit sociology comprised two parts: a view of technical change and a view of technology’s influence upon society.

\textsuperscript{877} A discussion of representations of Apollo astronauts of this type, including in popular culture, is found in Roger D. Launius, “Perceptions of Apollo: Myth, Nostalgia, Memory or All of the Above?,” \textit{Space Policy} 21, no. 2 (May 2005): 130–137.

\textsuperscript{878} Ibid., 137.

\textsuperscript{879} An extended discussion of this subject is found in Mindell, \textit{Digital Apollo}.
1.2.1. *Sources of technical change*

When space experts represented the evolution of sociotechnical systems, such as rockets and telescopes, they also expressed an implicit understanding of technical change and what caused it. Specialists tended to represent the evolution of technology as unidirectional, cumulative, and irreversible. Experts recognized that technical change had many sources, but believed that at least one of them was a momentum internal to technology itself. Technological change was propelled by its own logic, which sometimes eluded humans. Societal factors could marginally “condition” this process, by accelerating its pace or affecting the specifics of where and how technical changes emerged, but the direction and content of technological progress were exogenous to society. Experts represented these ideas in discourses about technology in general and in discourses about specific technical systems.

Discourses of the first type, about technology in general, rendered technology in abstract terms as a diffuse factor evolving according a logic apart from humans. Space specialists drew on contemporary philosophers of technology to develop their ideas. For example, Dr. James Vedda of the Aerospace Corporation, a leading FFRDC for space, and NASA, was influenced by science fiction writer Vernor Vinge and futurist Ray Kurzweil. Vedda cited these figures who saw technological change as self-propelled by cumulative, self-reinforcing advances to conclude that “knowledge and technological advances are increasing exponentially.”\(^{880}\) Herman Kahn, an analyst at Rand and a co-founder of the future studies center the Hudson Institute, and the Princeton University physicist Gerard K. O’Neil also shared a view of “space development as a logical and all-but-inevitable step in societal evolution.”\(^{881}\)

\(^{880}\) James A. Vedda, *Choice, Not Fate: Shaping a Sustainable Future in the Space Age* (LaVergne, TN: Xlibris, 2009), 173.

These ideas informed broader understandings of space technology’s progress in relation to policy and programmatic choices in the United States. For example, Vedda pondered “whether the space program was the result of natural human evolution or a Cold War fluke.”\textsuperscript{882}

The more I study and work in this area, the more I am convinced that the drive to explore and develop space is not merely a Cold War anomaly, not a fad that we’ll eventually abandon, and not just the province of rich countries representing a minority of the planet’s population. Our species is at the earliest stages of a type of transition that has recurred throughout our history, each time changing us forever by pushing back physical limits and putting new sources of materials and energy within our reach.\textsuperscript{883}

John H. Marburger, III, Science Advisor to President George W. Bush and Director of OSTP during that administration, also regarded space development as inevitable.

The Moon is the most massive near-Earth object – massive enough to have a useful surface gravity, but substantially out of Earth's gravity well and therefore of great interest to deep space operations. I think it is inevitable that the Moon will eventually become a space station and a source of mass for space applications.\textsuperscript{884}

In Vedda and Marburger’s visions, particular human intentions toward and choices over technical change receded into the background. At the fore was the progress of space technology driving the species’ staged evolution, each leap forward in technology transforming its way of life.

Space experts also represented particular technical systems as evolving according to an inherent, functional momentum. An example is found in the report of the National Commission on Space. The commission proposed and recommended a transportation system for carrying humans and cargo into space, first to Earth’s orbits and then on to further destinations, including

\textsuperscript{882} Vedda, Choice, Not Fate: Shaping a Sustainable Future in the Space Age, 185.
\textsuperscript{883} Ibid., 191.
\textsuperscript{884} John Marburger, “Keynote Address” (presented at the 46th Robert H. Goddard Memorial Symposium, Greenbelt, MD, March 6, 2008).
the Moon. In the commission’s vision of the “phased space transportation system,” technology begets technology.

It starts with simple components, but evolves over time into a system of spaceports, bases, and connecting transportation systems that will open the space frontier for large-scale exploration, science, and the initiation of economic development. Resources will be utilized where they are found, to minimize the need for resources transported from Earth. This inner Solar System network will ensure continuing American leadership in space in the next century.885

Like all representations of sociotechnical systems, the commission’s also served a political function. This characterisation produced the system as virtually effortless, costless, and guaranteed. In removing humans from the depiction, the commission also removed technical risk and expense from consideration. Once initiated by decisionmakers, the space transportation system plan would all but fulfill itself. It would also pay for itself.

A sense of the inevitability of technological progress in space pervaded these discourses. As early as 1952, space visionary Werner Von Braun stated the near certainty of humans building a space station, similar to Skylab, Mir, or the ISS, as a step in the journey outward into space: “Development of the space station is an inevitable as the rising of the Sun; man has already poked his nose into space and he is not likely to pull it back.”886

These representations of technology in general and of certain space systems in particular as evolving out of an inherent momentum conveyed and reinforced the tacit understanding of the society-technology relationship that space specialists shared. In discursively producing the non-human elements of these compositions as possessing a capacity for autonomous change, they effectively conferred a greater agency upon them than upon the human constituents.

885 National Commission on Space, Pioneering the Space Frontier, 15.
886 (Von Braun cited in Marsha Freeman’s chapter on skylab in Challenges of Human Space Exploration, 2000, p.2).
1.2.2. The society-technology relationship

As experts represented their sector, they also articulated space systems to their social context. In drawing these connections, they conveyed a vision of how technology and society relate to each other. Taking as given that some element of the technical was separate from the social, experts often described technical change as causing social change. Technology advanced according to its own logic while the social environment around it responded to its impact. Specialist representations represented space systems as unilaterally shaping society. In a sense, experts also depicted a more complex society-technology relationship, often expressing ambivalence about the direction of the influence between them. Some specialists described the relationship between society and technology as interactive or interdependent. In spite of these nuances, many space expert accounts of particular societal outcomes traced them to a technological circumstance.

Specialists expressed an understanding of the ‘technology factor’ in life as thick and substantial.\(^{887}\) Changing technological conditions were exogenous sources of specific social phenomena, such as economic growth, the organisation of the industrial base in the space sector, and policy choices. While technological change progressed autonomously, its influence upon the social and political was unidirectional and deterministic.\(^{888}\)

Representations of sociotechnical systems in this mode reproduced the specialist community’s conception of technologies as possessing agency. Vedda’s work illustrated this view. Describing the twenty-first century, he conveyed his view of the society-technology relationship.

Part III: Chapter 10

In an age of weapons of mass destruction, global transportation networks, and dependence on interconnected electronic information systems, the technology factor has become more central than ever before in human history, and its tempo keeps increasing.  

Vedda also applied this general insight to specific technical systems. For example, he located the advent of communications satellites in a longer process of technological development that reshaped societies.

Each time in human history that better communication techniques were developed they quickly gained wide acceptance, not only improving existing services but also creating new ones. Orbiting satellites are another step in that continuing evolution characterized by huge leaps in capability and substantial reductions in user costs.

In the strongest expressions of this sociology, technological development not only brought societal change, it also allowed humans to literally transcend their condition on Earth. As the specialists on the National Commission on Space observed, “Now space technology has freed humankind to move outward from Earth as a species destined to expand to other worlds.”

The chair of the Stafford Synthesis Group similarly wrote that exploration of the Moon and Mars would “propel us toward a future of peace, strength, and prosperity.”

Not all the specialist discourses were so explicit about the influence of technology, but the underlying promise of social change following technical change was often present. Many discourses conveying this technological determinism addressed more concrete and immediate social phenomena. A report of experts appointed to the 2002 Walker Commission on the U.S. aerospace industry to study space policy illustrates these representations. The commission identified as a national objective the achievement of “breakthroughs in propulsion and space

889 Vedda, Choice, Not Fate: Shaping a Sustainable Future in the Space Age, 54.
890 Ibid., 103.
891 National Commission on Space, Pioneering the Space Frontier, 6.
power,” defining these technologies as critical for a range of space capabilities, including spaceflight beyond LEO. Space technology was not only functionally self-propelling, it also generated demands on the society that spawned it. As the commission wrote:

The ability to access space and travel through the solar system in weeks or months instead of years would help create the imperative to do so. Propulsion and power are the key technologies to enable this capability. Future progress in these areas will result in new opportunities on Earth and open the solar system to robotic and human exploration – and eventual colonization. The nation would benefit from a joint effort by NASA and DoD to reduce significantly the cost and time required to access and travel through space.

These representations included articulations of sociotechnical systems to national interests.

The Commission concludes that the nation will have to be a space-faring nation to be the global leader in the 21st century – our freedom, mobility, and quality of life will depend on it. America must explore and exploit space to assure national and planetary security, economic benefit and scientific discovery. At the same time, the United States must overcome the obstacles that jeopardize its ability to sustain leadership in space.

Influential Chinese space experts reproduced these same ideas. Yin Xicheng, from GAD’s main research unit, wrote that the “influence of space exploration on the progress of society and humanity’s future extends beyond the scope of science and technology (太空探索对社会进步和人类未来的 影响却远远超越科学技术的 范围).” He also explained that space exploration transformed people’s culture and values. Yin extended these ideas by seeing space exploration as the only path forward for the species: “developing and exploiting outer space is

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894 Ibid.
895 Ibid.
896 p. 62, Yin Xicheng
897 p. 62, Yin Xicheng
humankind’s only road to sustainable development (开发太空是人类社会可持续发展的必由之路).”

Influential space security expert Dai Xu made a similar prediction in 2007:

Because Earth faces climate warming, disease, war, natural disasters, and other challenges, humanity’s future outlet lies in developing outer space. Within 20 years humanity might have a foothold on the Moon, within 40 years it may build permanent bases on Mars. If these predictions turn out to have scientific merit, then humanity will again want to exceed itself – history shows that the colonisation of areas beyond the frontier has always attended the rise of Great Powers. (因为地球面临气候变化、疾病、战争、灾难等挑战，人类将来的出路在于开发太空。人类20年内可能在月球立足，40年内在火星建成永久基地。如果这一预言有着某种科学性，那么我们又要回过头看了—历史表明向边界之外的未知世界迁移, 总是伴随着大国的崛起。)

Specialist rhetoric and analysis of space programs and policies represented assemblages of humans and non-humans. The descriptions of these assemblages conveyed an implicit sociology, in which efficacy and causality originated in the non-human elements and affected the human ones. Expert discourses reproduced a conception of machines as endowed with agency.

1.3. The space specialist’s theory of international politics

When space specialists represented sociotechnical systems, they also conveyed a common theory of international politics and vision for foreign policy. When space experts described policies for their sector, they articulated space technologies to national interests in trade, security, and standing in the international system. These representations of policies and of sociotechnical systems varied in their substance, but tended to take the same form, structured by common ideas about international politics. These ideas about international politics constituted an informal theory that both explained international politics and prescribed policies. Space expert

explanations for international phenomena located their deep causes in diffuse technological conditions or in particular technical systems. Space specialists reproduced an understanding of agency as inhering in both humans and their technologies.

The first element of this theory was a vision of the international system. When they looked beyond their country’s borders, space experts saw an hierarchical system of national industrial bases, each one’s position dictated by their mastery of critical technologies. Space experts represented technology as an essential ingredient of national power. Possessing the capacity to domestically produce sophisticated devices was integral to international leadership and standing. Because national power and the strength of industry were tightly interdependent, industrial bases remained organised and confined by national boundaries. Specialists maintained this vision of the international system even as civil and commercial space rapidly became more globalized and integrated.900

The second element of this theory was an understanding of the role of technology in international relations. For the space expert, the distribution of power in the international system was a function of the distribution of technical capacity. The pivotal technologies that dictated the rise and fall of nation-states included defense systems, such as conventional and strategic weapons, but others also mattered. Technologies that afforded a country’s industrial base a role in shaping important domains of activity, from waterways, to the internet, to space, were other determinants of national power. Economic outcomes, such as a country’s balance of trade, and political outcomes, such as victories in wars between states, were functions of the distribution of technical capacity across the international system.

The third element of this theory was an understanding of devices as agents in international politics. Sometimes experts represented this agency as located in a diffuse technological circumstance. Other times they represented this agency as residing within particular artefacts. For instance, space experts represented the introduction of certain technologies into the international system as creating runaway dynamics eluding control by governments and militaries. Some space specialist regarded the advent of space weapons as an irreversible event that transformed the international system, effectively producing disarmament as impossible: “we cannot go back to a time before nuclear and space weapons.”\(^901\) Space expert Wang Song, for example, expressed a variant of this view when he theorised that advances in space technology would inevitably shape military and political affairs:

> Of all of humankind's new scientific and technical developments, most have caused an aspect of military or political value to emerge, as with the starry sky that humankind has from time immemorial looked up toward and which, upon humankind setting foot into, will inevitably fill with the smoke of gunpowder. (人类所有新发展的科技大部因其军事/政治价值面起，作为人类自亘古以来一直仰望的星空，一旦涉足，必然满硝烟四起。)\(^902\)

In this same vein, many believed that the international proliferation of dual-use space technologies was impossible to prevent. For them, technologies diffused automatically from their place of origin. One U.S. official described in these terms the advent of commercial in-space satellite servicing capabilities, space-based platforms for robotics capable of modifying other spacecraft. The first commercial servicing mission would be “opening Pandora’s box – once it’s

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\(^901\) Interview with physicist, space security expert, and professor of international relations at Fudan University, Shen Dingli, Shanghai, China, 2010.

out, you can’t put it back in.”  

Observed by other space actors, these technologies would be imitated and applied to military space missions in “just a matter of time, not if.”

Space experts also described advances in space systems as creating imperatives for their government to respond, forcing a decisionmaker’s hand or at least collapsing the range of options available to them. In an example of this perspective, observing U.S. test flights of X-37 series space planes, a space security expert concluded that “China has no choice but to respond, cannot not respond.”

Xu Nengwu of NUDT, a center of policy expertise on technology issues, similarly wrote that technological progress redefined interests, compelling states to pursue space activities:

> Following the development of contemporary science and technology, especially aerospace science and technology, the world's major countries compete for their own national interest in entering the expansion of space; this instigated the international community's active attention to space diplomatic efforts. 随着现代科学技术特别是航空航天技术的发展，世界各主要国家竞相进入太空拓展自身的国家利益，由此引发了国际社会对太空安全外交努力的积极关注.

Once again, this account accorded agency to technical elements at the expense of human ones.

As space experts represented the sociotechnical systems in their sector, they conveyed their common anthropology, sociology, and theory of international politics. Together, these distinct theories, carried in individual acts of expression, formed a coherent culture shared throughout this specialist community. Sectoral experts in different countries expressed this culture in representations of space systems, programs, and policies in their own national contexts.

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903 Interview with senior State Department official responsible for space security diplomacy, Interviewee 06-18-00, Washington, DC, 2011.
904 Interview with senior State Department official responsible for space security diplomacy, Interviewee 06-18-00, Washington, DC, 2011.
905 Interview with titled academician and senior colonel specializing in space security in the AMS of the People’s Liberation Army, Interviewee 02-19-24, Beijing, China, 2009.
They expressed a background anthropology, in which technologies constituted and empowered their human users. Experts also conveyed technologically deterministic sociology. Finally, specialists an implicit theory of international politics, in which technology decided interstate struggles for security and dominance. This set of philosophical commitments, expressed in representational practices, was a product of currents of thought and practice that converged among space experts during the early decades of the space age.

2. Sources of the space specialist culture

Space experts’ representational practices reflected their community’s encounter with currents of thought from fields of activity outside their contemporary civil-commercial sector. Their representations expressed understandings of the human-technology relationship that existed in other specialised communities, including some that predated state-sponsored spaceflight. Currents of thought from these fields were adopted into the professional space community, particularly in the United States, where many elements of the space specialist culture coalesced and took hold before spreading outward. As space specialists appropriated knowledges from adjacent fields into their discourses, they also imported the tacit conceptions of human-technology relations embedded in them. These sources provided the structural and deterministic conceptions that guided how space experts depicted their sector to policymakers.

The sources of modern space experts’ ideas about the human-technology relationship were several. The first of these sources was the work of early spaceflight visionaries in Europe in the late nineteenth century. The second source was the nuclear security theories and practices of the Cold War. The third source lay in defense intellectuals’ theories of the Revolution in Military Affairs (RMA), a movement to utilize space and information, communications, and space
technologies in warfare. The fourth source consisted in naval histories, on which space experts
drew to extrapolate from the evolution of maritime warfare to the prospect of war in space.

2.1. Early space visionaries’ agenda for humanity’s expansion into the solar system

Modern spaceflight had advocates long before it started. The earliest were scientists and
engineers based in Germany and Austria in the late nineteenth century. They formed the core of
a small network of dedicated space enthusiasts extending across the continent and Great Britain.
These early visionaries drafted the first modern agendas for activity in space, plotting roadmaps
to destinations and technology development milestones. The course they charted into the solar
system began with flights to LEO, progressed on to exploration and settlement of the Moon, and
culminated in human visits to Mars. The architects of this vision disseminated their ideas
through technical papers. In these, they not only elaborated concepts for space systems and their
applications, but also imagined how these would impact humankind. The early European
spaceflight advocates were among the first professional futurists, for whom long-term social and
technological forecasting was a specialisation.

This loose group included writers of science fiction. Part novelists, part inventors, these
writers were committed to rendering futures that remained within the limits of known technical
feasibility. Among them was Arthur C. Clarke, whose stories anticipated later real-world devices,
such as communications and data-relay satellites.\(^{907}\) Having devised these systems, Clarke and
some of these writers predicted how they would transform the economy, culture, and the basic
human condition. Space technology would make new ways of life possible.

Orion, 2011).
From within these circles of amateur and academic European spaceflight experts emerged Werner Von Braun, often called the father of modern spaceflight. An early and influential conceptual architect and designer of space systems, Von Braun began working on large-scale rockets as an officer leading Nazi Germany’s V2 program. Sensing his regime’s demise near, he defected to U.S. troops before the war’s end. Once in the United States, Von Braun assisted the Army in the country’s first government-backed spaceflight program, establishing the first community of active, formally organized American rocket engineers of its kind. To this young community of space specialists, Von Braun brought not only technical expertise and experience, but also a larger vision for space development. He proposed a long-term program for staged space exploration that took humans to the Moon and onward to Mars. The ‘Von Braun paradigm’ guided the Apollo program in the 1960s and continued to orient U.S. space policy into the second Bush administration.

Sixty years after Von Braun expressed his vision, the space specialist continued to evaluate contending agendas for space development against it.

The futurists, science fiction writers, and Von Braun shared a program and a philosophy. Their vision of space development reflected a common underlying philosophy. These figures produced sociotechnical systems in space as evolving along a predictable course, their progress linear and self-enabling. The early space visionaries also constructed space technologies as reshaping societies. The futurists defined a destiny for humankind, elevating advanced technology to an end in and of itself. In these plans, space capability was a calling and space devices were indices of civilisational progress. Exploring and exploiting space would propel

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humankind to a new stage, they claimed. Escaping Earth’s gravity well, humanity would transcend one existential condition and enter another. Experts in both China and the United States were familiar with and expressed these ideas in the 1990s and 2000s.

2.2. Nuclear security theories and practices of the Cold War

A second source of ideas about the human-technology relationship to influence space specialists lay in nuclear security discourses and practices. Throughout the Cold War, space systems were incorporated into the strategies and practices of nuclear security. Space specialists participated in nuclear deterrence. In the process, they absorbed the tacit philosophy of human-machine relations embedded in nuclear security logics. Space experts involved in this work became conduits for the entry of these ideas into the space specialist community.

Cold War strategists in both super powers built space systems into the architecture of mutually assured destruction. Spacecraft both delivered and detected nuclear strikes. Ballistic missiles travelled through space to bring payloads to their targets. Early-warning satellites circling in geosynchronous orbit monitored for missile launches. GPS satellites evolved to detect nuclear explosions. Satellites provided verification and enforcement mechanisms for international nuclear security agreements. Space assets were as integral to deterrence as nuclear payloads.

(Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007), 513–537.


Many space specialists believed that it was in fact space systems, rather than strategic restraint or the balance of power, that prevented a nuclear exchange between the superpowers. Vedda argued that the success of deterrence depended on satellites.

The bulk of credit for preventing World War III from disrupting this environment is generally given to the “balance of terror” in offensive weapons between the United States and the Soviet Union. But this nuclear arsenal could not have allowed us to achieve this without the support of satellites for surveillance, reconnaissance, and targeting. The hair trigger of nuclear weapons was never pulled because each side could use satellites to see what the other had deployed, observe their behaviour, and provide early warning of attack.  

Captain John Shaw of the U.S. Navy echoed in the U.S. Air Force’s *Air and Space Power Journal*: “the initiatives and outcome of the latter half of the 20th century’s bipolar Cold War were determined overwhelmingly by space power.”

The logic of mutually assured destruction required that decisionmakers predictably retaliate at the first or near-first sign of a missile launch from enemy territory. Satellites were trip wires that initiated a highly, though never completely, automated sequence of retaliation. Eyes and ears in the sky defined and contained the time for and scope of choices about retaliation available to decisionmakers. Upon receiving warning of an incoming missile, decisionmakers delaying a nuclear counter-strike risked allowing the incoming missile to degrade their own nuclear forces. The detection of a foreign missile launch by a satellite created an imperative to respond immediately. Space systems were engineered into a rapid decision cycle that, in the event of attack, was to predictably end with a devastating retaliatory strike. For this reason, the early warning satellites in orbits 36,000 km above the Earth were considered elements of their

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916 Vedda, *Choice, Not Fate: Shaping a Sustainable Future in the Space Age*, 11.
country’s strategic forces, such that in prevalent interpretations an attack on these assets constituted an effective nuclear first strike. While satellites enabled their human operators to strike and retaliate, they were also designed to constrain judgment, discretion, and choice. In the sociotechnical systems of mutually assured destruction, agency was distributed across machines in space and humans on the ground.

The practices, discourses, and logics of deterrence assumed a distinct understanding of the human-technology relationship. As space experts represented agency coursing through both the human and non-human elements of these architectures, they accorded an inherent capacity and privileged role to the non-humans. The logic of mutually assured destruction redistributed agency from humans to machines. Machines did not completely override human intentions and machines themselves resulted from earlier design choices, but, once deployed, devices arrogated some agency from their human operators in practice. This philosophy of technology underpinned space specialist thought about later strategic architectures, including ballistic missile defense and, in particular, proposals for the deployment of boost-phase missile interception systems in the 1980s and 1990s.

While deterrence strategists expressed their understanding of human-machine relations in representations of concrete technical systems, other nuclear security experts reproduced this same understanding in social scientific accounts. Scholarship on nuclear security reproduced a vision

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of technical systems as possessing an inherent potential.\textsuperscript{921} Scholars expressed these ideas in macro-structural representations of the international system. No less an authority than Kenneth Waltz himself wrote that the introduction of nuclear weapons fundamentally transformed the nature of international security competition and war itself.\textsuperscript{922} Former Secretary of State James Schlesinger joined him in this analysis.\textsuperscript{923} Underlying these views was the assumption that technical change brought changes in international politics.

Other international security experts developed theories of arms races and security dilemmas between nuclear powers. In these models, human actors were captives of strategic situations in which technological developments constrained and compelled their actions. Arms races occurred despite the intentions of participants because the acquisition of a technology by one power created an impossible temptation to match and exceed it in the other, a dynamic that quickly spiralled out of both parties’ control.\textsuperscript{924} Security dilemmas happened when a rival’s acquisition of a new defense system presented an actor with an impossible choice between two options, each of which reduced their security. In both models, a change in technological circumstance compelled a response in the human actors, in spite of their intentions and interests.

A common thread ran through these theories and models. They assumed a conception of technical systems as constraints on humans’ freedom of action and ability to make choices. These representations of human-machine relations accorded agency to both, but skewed the distribution of this agency in favour of machines at critical moments. The intellectual constructs

\begin{footnotesize}
\begin{enumerate}
\item Kenneth N Waltz, “Nuclear Myths and Political Realities,” \textit{American Political Science Review} 84, no. 3 (1990): 731–746.
\item Barry Buzan, \textit{An Introduction to Strategic Studies: Military Technology and International Relations} (Palgrave Macmillan, 1987).
\end{enumerate}
\end{footnotesize}
of nuclear security produced changes to technical systems as causes of outcomes and humans as passive bearers of their effects.

Scholarship and strategic thought about nuclear security permeated the space specialist community. Theories and models diffused throughout nuclear security circles, which overlapped with the space expert community. Just as nuclear weapons systems looped in space assets, nuclear security knowledges extended to and encompassed space security as a subject matter. A body of scholarship on space security that reproduced and extrapolated from nuclear security concepts illustrated that these ideas were widely diffused within and familiar to the space specialist community. For example, a leading space policy research institution, the U.S. Air Force Academy’s Eisenhower Institute for Space Studies, devoted an entire issue of its journal to “space deterrence” between the United States and China. Successive U.S. national space policies and national security space strategies also made deterrence a foundation of national defense in space, and space experts acknowledged that space security ideas derived from nuclear security theory. When space specialists assimilated nuclear security knowledges and practices, they also absorbed the deterministic sociology of technology embedded within them.

Space experts were enrolled into nuclear security systems along with space assets. Configurations of strategists and satellites created the logics and systems of nuclear deterrence. Partnerships of minutemen and missiles carried out it out. As designers and operators recruited spacecraft into the architecture of nuclear deterrence, they also defined spacecraft as

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928 Blair and Chen, “China’s Space Ambitions: Editor’s Notes: The Space Security Dilemma.”
artefacts in context.\textsuperscript{929} These same understandings circulated and diffused within China’s nuclear
and space security communities. Leading space security experts were primarily nuclear security
specialists. The nuclear and space security networks overlapped and individuals in both were
exposed to U.S. international relations scholarship and ideas. Chinese space specialists expressed
the same preoccupation with deterrence and the role of space assets in nuclear security as their
U.S. counterparts.

\subsection*{2.3. Theories of the Revolution in Military Affairs}

Another current of thought to influence the global community of space specialists was
associated with the Revolution in Military Affairs (RMA), a movement led by defense
intellectuals that reached its apex in the United States in the 1990s. The Revolution in Military
Affairs referred to the transformation of warfare by modern information and communications
technologies. The concept became the basis of theories, policies, and doctrines within the U.S.
military.\textsuperscript{930} As experts represented the sociotechnical systems of the new warfare, they
articulated them to space assets. When the movement’s ideas were adopted by space experts in
the United States and abroad, so was its underlying conception of human-machine relations.

RMA thinkers argued that new cyberspace and space technologies were reconfiguring
militaries to revolutionize how they fought wars. Information and communication had always
been important to the outcomes of wars, but the advent of new technologies made information
dominance decisive, they claimed.\textsuperscript{931} As the Air Force Space Command’s former Chief of

\textsuperscript{929} Michel Callon and John Law, “On Interests and Their Transformation: Enrolment and Counter-Enrolment,”
Domestication of the Scallops and the Fishermen of St. Brieuc Bay,” \textit{The Sociological Review Monograph} 32
\textsuperscript{930} James Der Derian, \textit{Virtuous War: Mapping The Military-Industrial-Media-Entertainment Network} (Boulder, CO:
\textsuperscript{931} An extended discussion of how these ideas circulate in the U.S. defense-industrial complex is found in Ibid.
Strategic Planning, Doctrine, and Policy, Robert L. Butterworth stated, the world “saw the power of space to transform warfare in the 1991 Gulf War.”

RMA thought made a profound impact on the U.S. defense establishment. Proponents ranged from four-star generals to professional academics in the educational institutions of the military, such as the Air Force Academy and the Naval Postgraduate School. Their ideas influenced policy, doctrines, training, and acquisitions across the services.

These defense intellectuals analysed how, in the 1980s, the U.S. military accelerated its incorporation of then-emerging information and communications technologies, augmented by satellite constellations, into its systems and forces. These technologies created connections across services, across platforms, and between commanders and their troops in the field. Streams of data flowed through these configurations, forming the backbone of network-centric warfare. In parallel, C4ISR capabilities evolved to generate more usable data to circulate. Data and networks came together to put more information within reach of more military users. Together, these changes transformed U.S. warfare, observed the RMA analysts.

The institutions of the military co-evolved with the new technologies. Policy and strategy changes both reinforced and reacted to the technological transformation. The Revolution in Military Affairs grew from a concept to a doctrine, an operational and tactical logic, and a guide to acquisitions by the Department of Defense. Network-centric warfare mesmerized the U.S. defense and intelligence worlds, across the policy, acquisitions, and operations communities.

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933 Derian, Virtuous War.
934 Ibid.
Space assets were critical nodes in the networks of the new warfare. Constellations of military satellites and leased commercial satellite bandwidth transmitted data between theater and local command centers and networked distantly deployed soldiers and marines. GPS satellites provided PNT signals that precisely guided munitions to their targets, time-stamped dispatches, and synchronized systems. “Technology has extended space progressively deeper into warfare,” wrote Butterworth.

Embedded within RMA discourses and encapsulated in its technical systems was a theory of technology. In their representations of network-centric warfare, RMA theorists conveyed a conception of human-machine relations, according a privileged status to the machines. Technical systems constituted human actors. Technological advances caused social outcomes. The discourses and practices of network-centric warfare distributed agency across human and non-human elements. RMA discourses and models depicted sociotechnical systems in structural, terms, representing entire networks. Humans were elements of holistic systems, deriving from their position in them. Devices and data enabled and constituted the human participant in network-centric warfare. These representations produced soldiers in the battlefield as cyborg warriors, animated and augmented by their on-body satellite downlinks and uplinks. Network-centric systems also created an entirely new class of warfighter outside the combat zone: the remote pilot of unmanned aerial vehicles performing reconnaissance or drones delivering munitions. Disembodied and virtual, human operators reduced to functional nodes in the larger systems doing the action in war.

938 Derian, Virtuous War.
When RMA theorists looked beyond the network to the larger social and political setting of conflict, they again saw the potential of technology unleashed. Cyber and space technologies transformed the nature of warfare, making information the decisive factor in struggles between nation-states. As space systems and cyber systems partnered to revolutionise the American way of war, they demanded not only new operations and tactics in theater, but also changes to the larger structures that supplied and sustained the new capacities. Because network-centric warfare compelled a reorganisation of the forces and dictated acquisitions of new equipment, it also reoriented strategy and policy and ultimately redefined defense interests. In the configurations envisioned and advocated by these theorists, technology generated its own momentum and pulled human systems along. RMA proponents not only recognised, but also reinforced this process.

The concept of human-technology relations embedded in RMA discourses influenced space specialists in the United States and China. As space systems were enrolled in the practice of the new warfare, the space specialist community was recruited into the Revolution in Military Affairs. Space experts internalised the theories and technical knowledges of network-centric warfare. Through this process, they also imported the philosophical commitments underpinning the Revolution in Military Affairs, reproducing them in their own analyses.

Chinese defense and space security experts, closely studying their U.S. counterparts during the 1990s and 2000s, also absorbed and reproduced these ideas. In a direct reaction to U.S. network-centric warfare thought, Chinese military space strategists became intensely preoccupied with the concept of ‘informatisation (信息化),’ the aim and process of harnessing the power of digital information technologies to improve the PLA’s ability to fulfil its missions.

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Informatisation was network-centric warfare with Chinese characteristics, an assimilation of the foreign technical concepts and the philosophy of technology organizing them. Under Presidents Jiang Zemin and Hu Jintao, the objective of informatisation guided policy, strategy, and doctrine across the services. Informatisation was also a priority for the military’s technology organs, where defense space expertise was concentrated. These units decided research, development, and acquisition priorities. These organs pursued the informatisation of the forces by equipping them with new systems, including communications, navigation, and electronic intelligence satellites.

Space expert Dai Xu’s writing illustrated this preoccupation with informatisation and how Chinese experts followed the work of foreign defense analysts. In a defense journal article, Dai observed that “[i]t is universally acknowledged that the core of the revolution in military affairs is informatisation, (举世公认的世界新军事革命的核心是信息化),” before going on to describe the role of C4ISR in the U.S. military operations.  

Dai also assessed how analysts in foreign governments and militaries studied and treated the phenomenon.

The whole world is talking about informatised war issues, but most countries and militaries' attention is still focused on the transformation and constitution informatised systems on traditional-battlefield conventional weapons platforms and systems. In this image the sight of the forest is lost in the chaos of the trees: global military development follows its own pattern, having already quietly surpassed traditional spaces of war, entered a deep and murky new frontier [new territory]. 全世界都在谈论信息化战争的问题， 但 大 部分国家和军队的注意力 仍 集 中在 传 统 作 战 空 间 常规式器平台和系统 的信息化技术的改造和构建上。就在这只见树木不见森林的一片混沌叭世界军事按照的发展规律, 已悄悄 穿 越 了传 统 的 作 战 空 间 ，进入一个深不可测的全新领域。 

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941 Ibid., 8.
As Chinese space experts imported and appropriated U.S. RMA concepts, they also assimilated the philosophy of technology embedded in this brand of strategic thought. Articulating these ideas to their country’s needs in space, they insinuated assumptions about human-technology relations into discourses circulating throughout the Chinese space specialist community.

2.4. Naval histories and the expansion of conflict across domains

A third source of space specialist ideas about technology lay in a tradition of defense intellectual accounts of warfare dating back to the early industrial age. An influential current in this tradition examined the progression of warfare and military power across physical domains and environments. The narrative that most captivated these scholars traced the changing modes of warfare across historical time and its spread through the domains of land, sea, air, space, and cyberspace.\(^{942}\) This telling of history culminated in an inevitable space war. In accounts of this type, the advent of new technologies made control of a given domain decisive in warfare. Technological change joined other historical forces to shape the struggle for power between states. These historians wove together adaptations in defense technology, grand strategy, trade, and geography to tell the rise and fall of Great Powers.\(^{943}\)

The leading scholar in this current was turn-of-the-century historian and U.S. Navy Captain Alfred Thayer Mahan, regarded as the most influential naval strategist in U.S. history.\(^{944}\)


In his histories of Great Britain’s navy, Mahan concluded that the empire’s sea power, its control of movement across the seas, was the most important factor behind its political and military hegemony for over two centuries. In time, Mahan’s impact extended beyond the Navy to the Air Force, where space experts adopted his ideas. Civil and commercial space experts and even President John F. Kennedy in a historic speech also reprised Mahan’s ideas, referring to space as the “new ocean” facing explorers, scientists, and merchants.945

Air Force space experts extrapolated forward from Mahan’s contention that sea power decided wars. They observed that, for most of the twentieth century, air power was decisive.946 At the end of the twentieth century, in “the next logical step,” space power determined which nation-states dominated the international system.947 The expansion of terrestrial conflict into space was an extension of a long-term historical process in which changes in the technical systems of warfare moved the locus of conflict from one domain to another. For some space strategists, the space domain was intertwined with the cyber domain.

Space experts argued that the sea lanes of the industrial age were the orbits of the information age: the travel of information in commerce and defense was as critical to U.S. strategic superiority as sea trade and naval power were to Britain’s.948 They adapted Mahan’s insights into British sea power to create a vision of “space power” in the twentieth century.949

Mahan’s work supplied space experts with important concepts, but, like any translation, their adoption of his ideas introduced significant adaptations. The space experts took from Mahan a theory of history that they developed into a teleological vision of the evolution of warfare. They also adapted Mahan’s vision of agents and structures in international politics,

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947 Ibid., 2.
949 Johnson, Pace, and Gabbard, Space: Emerging Options for National Power, 5–17.
emphasizing technological circumstances as determinants of struggles between countries. Strategic choices and individual character were central themes in the Mahan’s accounts, but these factors contended with larger and more abstract forces.\textsuperscript{950} The forces, both divine and earthly, compelling a power’s expansion across land and sea exceeded the will and capacity of any individual or group. Mahan saw behind the rise and fall of empires the hand of God, a manifest destiny unfolding not because, but in spite, of feeble human intentions.\textsuperscript{951} The original Mahan saw inherent potential in technology, but was no technological determinist.\textsuperscript{952} Neither humans nor their ships were prime movers in these histories.

A century later, space experts saw in Mahan’s accounts the play of historical forces propelling the unrelenting advance of war into new domains, but gave technology itself a more prominent role among them. Space strategists looking for a theory of space power read in Mahan’s accounts a destiny foretold, presaging war in space and the weaponisation of space.\textsuperscript{953} These thinkers redefined the concept of power as more closely associated with technology. Mahan explained sea power as capacity of a nation-state to control movement on the sea, claiming that this control is the most potent factor in its prosperity and in the course of history.\textsuperscript{954} Space experts of the late twentieth century expressed “space control” as the possession of capable technical systems.\textsuperscript{955}

\textsuperscript{951} Crowl, “Alfred Thayer Mahan: The Naval Historian.”
\textsuperscript{953} Dolman, \textit{Astropolitik}; Dolman, “Geostrategy in the Space Age”; Sterling Michael Pavelec, “The Inevitability of the Weaponization of Space: Technological Constructivism Versus Determinism,” \textit{Astropolitics} 10, no. 1 (2012): 39, 41, 55; see also Peoples, “Assuming the Inevitable?”.
\textsuperscript{954} Mahan, \textit{The Influence of Sea Power Upon History, 1660-1783}, 15–16.
These ideas also permeated the Chinese space specialist community, whose members reproduced the American experts’ projection of warfare stretching into space. Chinese space specialists represented international politics in space as a logical and inevitable outgrowth of struggles in other domains. Fudan University’s Xin Qiang, for example, directly referred to the Mahanist school when he wrote that the “development of science and technology” brought the expansion of warfare across domains, which in turn transformed how actors think about regional politics.956

The development of science and technology causes humankind's activities in space, a result of expansion from land, to the oceans, and the atmosphere, each time, the expansion of the domain of activity brought a transformation of conceptions of regional politics. Sea power theory, land power theory, air power theory emerged because of such favourable situations. Currently, space science and technology's swift development causes outer space to become a new dimension of domain, in the military, economic, and social spheres, the value of outer space is increasingly manifest. The struggle in and for space control will become an important factor influencing national power. To rule outer space will imply to rule on Earth. (科技发展使人类活动空间由陆地扩展到海洋, 大气层, 每次活动区域的扩展都 引起地缘政治观念的变革. 海权论, 陆权论, 空权论应运而生. 当代航天科技的迅猛发展, 使 外空成为又一新的维度空间, 外空在军事, 经济 社会领域的价值逐渐彰显. 对外空的争夺和控制将成为影响国家权力的重要因素. 太空的领导权就意味着地球上的领导权.)957

Because of this, he predicted, following President John F. Kennedy, that “The struggle in and for space control will become an important factor influencing national power. To rule outer space will imply to rule on Earth” (对外空的争夺和控制将成为影响国家权力的重要因素. 太空的领导权就意味着地球上的领导权).”958

957 Ibid.
958 Ibid.
Particular images also conveyed these ideas. Chinese space specialists often referred to space as “the strategic highland.”⑨59 Dai Xu, wrote that space was “war’s ultimate high ground (太空，战争最后的高地)” adding that “Just as the eagle occupies the pinnacle of the food chain, so too does space occupy the pinnacle of the food chain in war (就像鹰是所有食物链 中最高端一样, 太空也处在战争 “食物链” 中的最高端)。”⑨60 Shen Dingli, a physicist and space security expert at Fudan University, predicted that a “space race is inevitable,” between China and the United States, although he believed the two could “still moderate the relationship.”⑨61 A former analyst in the PLA’s AMS described China’s need to prepare a retaliatory response (抱回反应) to a U.S. attack, as the “outer space powers try to dominate the new battlefield.”⑨62 An academician in the same institution agreed: “influential people believe that the development of [military] space technology is inevitable,” such that governments “cannot trust treaties.”⑨63 Representational practices drawing on the Mahanist tradition inscribed interstate competition in space in a staged, linear progression. These representations discursively produced space war as a historical inevitability, rendering efforts to thwart it as futile. Competition in space resulted from structural dynamics that eluded human control. Institutions and agreements devised to limit competition were doomed to fail. Intentions and choices were insufficient to constrain or contain runaway technologies.

Teleological histories of warfare supplied concepts that space experts in both China and the United States used to depict sociotechnical systems in space. They extrapolated from these readings of the past to their own vision of a future, in which space technologies reshaped the

⑨59 Interview with space policy analyst Wu Chunsi, Shanghai Academy of Social Sciences, Shanghai, China, 2010.  
⑨61 Interview with physicist, space security expert, and professor, Shen Dingli, Fudan, University, Shanghai, China, 2010.  
⑨62 Interview with space security expert, formerly of the PLA’s AMS, Interviewee 20-10-17, Beijing, China, 2010.  
⑨63 Interview with Senior Colonel and academician in PLA’s AMS, Interviewee 002-19-24, Beijing, China, 2010.
interstate system and redistributed power across its units. Through these representational practices, specialists both expressed and reinforced their structural and deterministic assumptions about society and technology.

By 1989, U.S. and Chinese space specialists had assimilated representational practices from these several sources. The technological determinism and structural sociology conveyed in these experts’ representations of their sector were traceable to the work of early European visionaries of modern spaceflight, who organised in the late nineteenth and first half of the twentieth century. Space experts’ representations of technical systems as intrinsically potent and as constraining human agency reproduced ideas implicit in the nuclear security theories and practices of the Cold War. Space specialists’ representations of technical change as transforming the nature of interstate struggles for power drew on U.S. defense intellectual thought about the Revolution in Military Affairs of the 1980s and 1990s. Finally, space experts’ teleological predictions of war in space reproduced the representational practices of earlier military historians, who explained the evolution of interstate conflict across domains in the tradition of Alfred Mahan.

As space specialists grew fluent in the vocabularies of these fields, from nineteenth-century science fiction to naval history, they also absorbed their implicit understandings of society, technology, and history. By the Cold War’s end, these currents of thought coalesced to form an internally consistent set of theories shared and expressed throughout the transnational specialist community. This specialist culture first consolidated in the United States, in time spreading outward to other spacefaring countries. Representational practices travelled with other specialised knowledges as they diffused throughout the transnational space community.

Space experts’ representations of sociotechnical systems expressed their community’s culture. Through their depictions, specialists conveyed a view of the individual human actor as passively bearing the effects of technology, as enabled by and reliant upon devices, and as shaped
by structural circumstances. Specialist representations reflected a technological determinism. Experts represented the international environment as competitive and hostile. They described states as autonomous units and depicted institutions for space as insufficient to limit international competition or conflict in space.

3. Recurring representations of space environments and systems

Space experts expressed their background assumptions about the human-technology relationship in representations of specific aspects of their sector throughout the 1990s and 2000s. As specialists represented sociotechnical configurations, they articulated space systems to societal needs and collective aspirations. Specialist depictions assembled humans and machines, situating them in a physical domain and in time. Each of these representations connected the hardware of space systems to the software of policy priorities and national interests. The arrangements that they composed pulled together astronauts and mission controllers, rockets and satellites, national interests and mission objectives. Of these depictions, some proved particularly mesmerizing. Space experts returned to these representations time and time again. Diverse space experts reproduced certain widely shared and enduring images across different settings.

These representational practices revealed two competing visions of space development: exploration and exploitation. In the first of these, space activities consisted in exploring new destinations beyond Earth for their own sake. In the second, space activities consisted in exploiting the domain for benefits to country and humanity back on Earth. Most statements about space defined it as a place to be explored, exploited, or both. Although in principle these two visions were compatible, in practice they competed for attention and resources. For instance, in every annual budget process, NASA’s large robotic missions to explore deep space threatened
to eat into its Earth observation programs, which exploited the space medium to monitor climate
change and deforestation.  

The “exploration” vision was distinctive. Taking an outbound perspective on space, its
proponents advocated an expansionist and positive agenda for space development. The
“ultimate goal” of exploration was “to chart a path for human expansion into the solar system,”
wrote the second Augustine Committee on human spaceflight policy. Leaving the cradle of
Earth was humanity’s destiny, a desirable and all but inevitable outcome. A committee of
experts appointed to review U.S. human spaceflight plans in 2009 summarised the central issue
for exploration proponents:

Will we leave the close proximity of low-Earth orbit, where astronauts have
circled since 1972, and explore the solar system, charting a path for the
eventual expansion of human civilization into space?

Although this vision of space activity had an evident spatial aspect, its rhetorical force lay
in its temporal dimension. Exploration proponents told history as a teleological process of
humanity’s conquest of new places. Spaceflight was a direct extension in time of earlier efforts
by humans to travel the oceans and explore new continents. This process culminated in
occupation of the Heavens. Systems in space represented the final stage in technology’s
subordination of new domains. In programmatic terms, this view emphasised crewed spaceflight
and a human presence in space, but did not exclude roles for robotic precursors.

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964 Lambright, “Administrative Entrepreneurship and Space Technology”; Henry Lambright, “NASA, Ozone, and
Space Satellite Technology.”
559–560; Michaud, Reaching for the High Frontier.
966 Review of U.S. Human Spaceflight Plans Committee: Seeking a Human Spaceflight Program Worthy of a Great
967 An influential statement of this view familiar to the space specialist community is found at Carl Sagan, Pale Blue
968 Review of U.S. Human Spaceflight Plans Committee: Seeking a Human Spaceflight Program Worthy of a Great
Nation, 9.
In contrast, the “exploitation” vision of space development emphasised the exploitation of space for benefits to life on Earth. In discourses of this type, experts produced space systems as the upward extensions of terrestrial infrastructures. Space assets, signals, and data were integral to the large technical systems that constituted public utilities, national security capabilities, the internet, and the global economy. These critical systems were distant, removed from sight, and so reliable that their users took them for granted. Satellite constellations receded out of individuals’ awareness like oil pipelines and electrical grids.

The exploitation vision of space supported a view of the space environment not as a place external to Earth, but as a medium that terrestrial activities utilized. The vacuum beyond Earth’s atmosphere was an efficient conduit for telecommunications signals. An orbit was a perch for intelligence satellites. Space was a zone on the trajectory of ballistic missiles. Satellites defined the outer limits of the “technosphere,” an envelope around Earth extending to the orbital belt where communications satellites circled.

“Like the plumbing” for the world, “space systems are now global utilities that provide critical modern infrastructure for all the nations and people on Earth,” said Peter Martinez, Chair of a working group under the UNCOPUOS. As an alternative to exploration visions, former Chair of UNCOPUOS and astronaut Dmitri Prunariu described activity in space “as an advanced industrial skill that any country should pursue to foster development.” The presidentially appointed 2002 Aerospace Commission, known after its chair as the Walker Group, illustrated this perspective as it called for developing “a Next Generation Communication, Navigation,

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969 Vedda, Choice, Not Fate: Shaping a Sustainable Future in the Space Age, 101.
970 “Space Exploration: The End of the Space Age,” The Economist, 60/30 2011.
971 Peter Martinez, “Address to the Space Generation Congress” (presented at the Space Generation Congress, Cape Town, South Africa, September 2011).
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Surveillance and Reconnaissance Capability,” calling it a necessary “core infrastructure.”

China’s space specialists emphasized this perspective in the country’s 2000 and 2006 white papers on space. In these documents, they described the development of the space sector as an integral component of a larger agenda of scientific and technological modernisation for development.

These representations shared a common focus on the development of the space sector as instrumental to social and economic priorities on Earth. However, in spite of their focus on the value of space technology as a means to other ends, proponents of the exploitation perspective often also succumbed to exploration tropes, depicting space activity as an end in and of itself.

In addition to the exploration and exploitation visions, others on the fringes of the space specialist community proposed alternative representations of space and space activities, although their impact on policy tended to be limited. For example, academics and peace researchers in think tanks conceived of space as a sanctuary, deserving of protection and exempt from terrestrial politics. Other movements developed a vision of space as uncharted territory toward an anti-statist position. They proposed that private entrepreneurs, unfettered by ineffective governments, should be those to explore and exploit space. Both the exploration and exploitation visions were expressed by participants across the U.S. space community. Space experts shifted between these two modes as suited their purposes.

The exploration and exploitation visions organised and structured policy priorities and preferences. Yet, in spite of their differences in substance and focus, these two modes of

975 Michaud, *Reaching for the High Frontier*.
representation shared underlying assumptions. The exploration and exploitation visions agreed at a philosophical level, assuming a common understanding of the relationship of the technical to the social. As these two visions structured contestation over the orientation and priorities of national space activities, they reinforced these shared underlying beliefs. Disagreement at the substantive level diverted scrutiny away from more fundamental commonalities, sinking these further into the community’s bedrock of unstated common sense. Space experts challenged each other on everything but their understanding of the relationship between humans and human-built systems.

Whether experts connected space systems to humanity’s aspiration to explore or the imperative to exploit, they drew on a common repertoire of images and narratives. Specialists in China and the United States frequently represented at least four such constructions. The first of these was their construction of the space domain as a frontier to be explored and exploited. The second was the construction of space development as analogous to the European experience of colonisation. The third was the construction of facilities and personnel that built space hardware as a unified base.

3.1. The frontier image and humanity’s expansion into the solar system

Before space could become a place for exploration or exploitation, it required interpretation. Outer space could be no more directly apprehended by humans than any other location, even those closer places experienced everyday on Earth. The infinite vacuum of space, with its scattered planets and stars, was rendered intelligible before it was imagined as a setting for action. Among specialists, different ways of making sense of the vastness, potential, and hostility of space contended over time. But one image proved to have an unyielding grip on the space expert’s imagination: the image of space, with all its perils and promise, as a frontier.
The frontier was a boundary to be pushed and a new field to be exploited. Applied to outer space through image or metaphor, the frontier meaning located outer space in a category of physical spaces and produced it as a kind of environment for action. Constructions of space as a frontier were ubiquitous within the specialist community and pervaded popular culture. Space was the final frontier, the high frontier, the next frontier, and the ultimate frontier. Films and books reproduced the frontier image. Formal institutions adopted the frontier image. An organisation representing elements of the space industry called itself the Space Frontier Foundation. Policy statements reproduced the image of space as a frontier.

Depictions of space as a frontier were so prevalent that historical studies examined the use of the frontier image as a practice. Space historian Dwayne Day of the Space Studies Board at the National Academy of Sciences described the representational practice as inherently contingent.

Just as people at the end of the 19th century looked at Mars and thought they saw a flourishing, exotic civilization, modern space enthusiasts and activists look at Mars and see a bold, challenging new frontier waiting to be explored, conquered and exploited. But not everyone agrees with this image; others look at Mars as a barren wasteland, or as a scientific wonder, and may fail to see anything that they would consider a frontier. A frontier does not exist as a physical thing, but rather as a vision in someone’s mind.

While studies of the frontier image noted its prevalence and significance, they usually overlooked whether and how the frontier image was implicated in space policymaking. The frontier image was more than aspirational and inspirational. It also constituted space as a domain for and object of state action. Through this process, the frontier image produced not only outer space, but also space policy.

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978 Michaud, Reaching for the High Frontier.
980 Ibid.
The frontier image produced outer space as an extension, upward in physical space and forward in historical time, of earlier expansions of Western civilisation. In defining space as a place, the frontier image also smuggled in a larger narrative of humanity’s spread. Like Mahanist naval histories, this story told the unfolding in time of human exploration and settlement as a succession of cumulative phases in a steady and irreversible expansion. The frontier image produced the exploration and exploitation of space as inevitable and imperative.

The frontier image also sustained a civilisational and technological imperative to explore and exploit space. “The settlement of North America and other continents,” wrote the drafters of the report by the 1985 National Commission on Space, “was a prelude to humanity’s greater challenge: the space frontier.”

“From the voyages of Columbus to the Oregon Trail to the journey to the Moon itself: history process that we have never lost by pressing the limits of our frontiers,” President H.W. Bush told an audience of space specialists. “Space is clearly our most challenging frontier,” wrote retired Lieutenant General, U.S. Air Force, Thomas Stafford, chair of the Synthesis Group on America’s Space Exploration Initiative, in the foreword to its 1991 report describing the irresistible pull of space exploration. The 1985 National Commission on Space called for “opening new worlds on the space Frontier, with vast resources that can free humanity’s aspirations from the limitations of our small planet of birth.”

President George W. Bush told an audience of space specialists that “This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart.”

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981 National Commission on Space, Pioneering the Space Frontier, 7.
The frontier image became a rhetorical device for space professionals advocating and contesting policies. They used analogies to historical frontiers to argue for their preferred means. Advocates invoked the frontier image to produce their desired policies as self-evident and natural. For example, calling for a strong government role in space, the 1985 National Commission on Space analagised:

As formerly on the western frontier, now similarly on the space frontier, Government should support exploration and science, advance critical technologies, and provide the transportation systems and administration required to open broad access to new lands.\(^986\)

In contrast, the Space Frontier Foundation used the same image to construct government as an obstacle to space exploration and development, which it argued should be led by private entrepreneurs.\(^987\)

Despite divergent policy preferences, space specialists agreed on a common analogy to the frontier and on the theory of human-technology relations underpinning it. Producing space as the next frontier produced human’s technical mastery over new domains as increasing and advancing with the passage of time. The space frontier image tapped into an understanding of technological change as linear and cumulative.

John H. Marburger, III, Science Advisor to President George W. Bush and Director of OSTP during that administration, summarised this teleology in his remarks to the human spaceflight policy community in 2009.

*Our programmatic vision for human space flight is to bring the successive spheres of every space frontier within our reach, to diminish the daunting cost and risk of every expedition into this new territory.*\(^988\)

\(^987\) Tumlinson, “The Rise of the New ‘Frontier’ Movement.”
Like other popular turns of phrase used by U.S. space experts, the frontier image permeated China’s space specialist community. Chinese experts referred to space as the “high frontier (高边疆)”989 and as “Earth’s ultimate frontier (地球最后的边疆).”990 When space specialists used these images, they did more than state what type of place outer space was. They also communicated what type of action was to be done there. Representations of space as a frontier called forth policies for the development of the sector and the expansion of activity in the domain. To locate sociotechnical systems at the space frontier was to intervene in debates over the ends and means of space policy. It was also to advocate for more space activity. The space frontier image was both productive and prescriptive.

As the space frontier image produced a place for action, it functioned as more than a static spatial construct. It was a dynamic concept, conveying change over time. The space frontier was the setting for a chapter in the story of humankind’s unfurling across physical domains and into the future. Set in motion, the space frontier image carried a narrative of civilisational expansion. One expression of this narrative produced space development as analogous to European colonisation.

3.2. European colonisation and humanity’s expansion beyond Earth

The frontier image supported a narrative that compared space development to the European colonisation of the New World, or at least to the space specialist’s understanding of it.

Using this analogy, space experts inscribed space development into a history of human expansion across territories and domains on Earth. Space specialists compared human expansion into space to two historical colonial experiences they imagined. The first was the European encounter with and settlement of the New World. The second was the westward migration of European settlers across the continental United States. Space experts represented human occupation of outer space as both a parallel to these processes and as a linear extension of them in historical time.

For many space experts, the end goal of exploration and human spaceflight was literal colonisation. President George H.W. Bush described his vision of such a future upon the twentieth anniversary of the Apollo 11 moon landing in 1989.

And space is the inescapable challenge to all the advanced nations of Earth. And there’s little question that, in the 21st century, humans will again leave their home planet for voyages of discovery and exploration. What was once improbable is now inevitable. The time has come to look beyond brief encounters. We much commit ourselves anew to a sustained program of manned exploration of the solar system and, yes, the permanent settlement of space. We must commit ourselves to a future where Americans and citizens of all nationals will live and work in space.991

In his message opening NASA’s 2004 statement of *The Vision for Space Exploration* policy, the agency’s Administrator Sean O’Keefe wrote:

When Christopher Columbus made his voyages across the Atlantic in the 15th and 16th centuries, his ships carried the inscription “Following the light of the sun, we left the Old World.” I look forward to joining you as we follow the light of the planets and the stars into the new worlds of the 21st century.992

When officials at the highest levels of government drew a parallel between space development and European colonisation, they were not making a colourful comparison, but producing one phenomenon as a direct and logical extension in time of the other.

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991 “Remarks on the 20th Anniversary of the Apollo 11 Moon Landing (20 July 1989).”
992 *The Vision for Space Exploration*, 3.
These associations of space development to European colonisation served a function. Space specialists used these constructs to communicate the benefits of space exploration and exploitation to the societies that initiate them. They argued that the development of space would benefit their society in the same way that settlement and colonisation had benefitted Europe. Locating space development in this longer history produced it as desirable and all but inevitable.

In the concluding paragraph of a section of its report called the “Declaration for Space,” the 1985 National Commission on Space provided such a rationale for the government’s support of its agenda for civil space. Having estimated the short-term returns on investment in the program, the Commission discussed the long term:

[…] we believe that the longer-term benefits from the settling of new worlds and the economic development of the inner Solar System will prove even more rewarding to humanity. These returns are difficult to quantify. What was the true value of developing and settling North and South America, Australia, and New Zealand? Today more people speak English, Spanish, and Portuguese in the New World than in Europe, and they have built economies surpassing those of Europe. But the contributions to humanity from Columbus’ “New World” are surely far beyond its material returns, impressive as they are. We believe that in removing terrestrial limits to human aspirations, the execution of our proposed space agenda for 21st-century American will prove of incalculable value to planet Earth and to the future of our species.

In 2004, NASA policy specialists used the same language proposed a new program and budget for human exploration.

Like the explorers of the past and the pioneers of flight in the last century, we cannot today identify all that we will gain from space exploration; we are confident, nonetheless, that the eventual return will be great. Like their efforts, the success of future U.S. space exploration will unfold over generations.

The imagery of colonial expansion was not the purview of human spaceflight enthusiasts alone. The space science community also found analogies to the colonial experience inspiring.

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994 The Vision for Space Exploration, 5.
The Space Studies Board of the National Academy of Sciences described the “Impetus to Explore” guiding NASA’s 2004 space policy vision in the same terms, opening with a vignette.

In the winter of 1804-1805, a small band of Americans, two French-Canadian voyageurs, and a Shoshone woman and her baby faced the bitter cold in a camp on the upper Missouri River in what is now the state of North Dakota. They were on the way to the Pacific Ocean—sent on a journey of exploration by President Thomas Jefferson. The explorers survived the winter and pushed on to spectacular success, returning in 1806 with information that transformed the nation’s view of itself.

Although settlers had drifted across the Allegheny Mountains and down the Ohio River Valley after the Revolutionary War, the Lewis and Clark expedition was the first American scientific exploration of the Far West. The bounty of geographic and biological knowledge gathered by the Lewis and Clark expedition of 200 years ago initiated American migrations westward that have shaped the United States for two centuries, a transformative process that is continuing to this day.  

Space experts also used analogies to historical colonisation to advocate for spending on specific space systems. Their articulation of these space systems to the national interest took the form of a comparison to earlier large technical systems that benefitted their sponsoring colonial state. For example, the National Commission on Space predicted the service to the nation that the space transfer vehicle, a system the commission proposed for transportation between low Earth orbit and the Moon, would bring:

When that second link in our space transport system is completed, the event will compare in significance to the driving of the Golden Spike in Utah more than a century ago that marked the completion of the transcontinental railroad.  

In addition to justifying the expense of systems for space travel, advocates used analogies to European colonialism to legitimize accepting the risk to human life inherent in space activities.

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996 National Commission on Space, Pioneering the Space Frontier, ca. 20.
The first Augustine Commission relativized the likelihood of catastrophe in spaceflight by comparing the exploration of space to earlier forms of risky, but rewarding, travel.

Risk has been a companion to all great human adventures. Today, astronauts routinely circumnavigate the Earth in 90 minutes. In 1519, Ferdinand Magellan’s quest to circumnavigate the globe began with five vessels and a crew of approximately 280. Only one ship and 34 crewmen returned, three years later. Magellan himself did not survive the voyage. In more contemporary circumstances, test pilots in the 1950s had a fatality rate of about one in four as they pushed in barriers of supersonic flight.

In a very real sense, the space program is analogous to the exploration and settlement of the New World. In this view, risk and sacrifice are seen to be constant features of the American experience. There is a national heritage of risk taking hand down from early explorers, immigrants, settlers, and adventurers. It is this element of our national character that is the wellspring of the U.S. space program.997

In their analogies to European colonisation, experts reinforced the same underlying philosophy of how the forces of history and technology partnered in humanity’s expansion. Establishing a continuity between past and future experiences of colonisation rendered future space activities as natural and self-evident outcomes. Specialists produced human expansion into the solar system as a probable, if not inevitable, extension of a colonial past. They used colonial analogies to illustrate the benefits to the nation and humankind of enrolling exoplanetary spaces into terrestrial technical systems. In the process, experts produced the building of sociotechnical systems in space as a national and civilisational calling.

3.3. Commercial and defense space manufacture as unified

Another image to recur in the discourses of space policy experts was of the national space industry as a “base.” Usage of this term was not stable, but usually the “space industrial base”

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referred to the private-sector concerns that produced space hardware for either government or large commercial customers.

The space industrial base comprised facilities, equipment, personnel, and their expertise, configured into a tiered hierarchy of firms. Every major U.S. space policy document from the 1980s onward addressed the health of this industrial base. The National Commission on Space emphasized the importance of building and protecting a national “technology base” for the space sector. The first Augustine Commission similarly called for supporting the “space technology base.” The 2000, 2006, and 2010 national space policies outlined means to strengthening the sector’s “industrial base.” Over eighteen major studies issued by government agencies and prominent think-tanks during this period addressed the state of the space industrial “base.”

The representation of this sociotechnical system as the space industrial “base” produced it as a whole. The tiered structure of firms constituted an integrated ecosystem, together forming a national capacity whose protection became an interest in its own right. An effect of this representation was to obscure the diversity and division among players in the national industry, dissimulating their contending interests. Most importantly, however, the representation of this system as a unitary base dissolved any distinction between its civil, commercial, and defense elements at the levels of firms, personnel, knowledges, and products. As Marion Blakey, head of the AIA, told the 2010 meeting of the Air Force Association: “The entire aerospace industry – civil and military – is joined at the hip. When one piece is weakened, the whole suffers.” Producing the industry as an undifferentiated unit produced space sociotechnical systems as irreducibly dual, indistinguishably civil and military.

1000 Marion Blakey, “Presentation to the Air Force Association Conference” (presented at the Air Force Association Conference, National Harbor, MD, September 2010).
The language of industrial or technology “bases” was prevalent in Chinese science and technology policymaking circles. Formal government initiatives targeted the development of an integrated civil-commercial and military scientific, technical, and industrial system. Sectoral policy discourses routinely produced the complex of facilities, equipment, and personnel producing hardware as constituting a foundation. The representation of the space industrial base as incorporating civil-commercial and defense elements was consistent with other representations of space systems and the space domain. Wu Chunsi, a space policy specialist at SIIS, defined the space sector as “special” because it at once engaged “commercial, security, military, and national prestige – multiple interests.”\footnote{Interview with space policy analyst at SIIS, Wu Chunsi, Shanghai, China, 2010.} A space security expert at the Renmin University explained that obstacles to China-U.S. cooperation lie in the fact that “every space technology with military applications is related to” commercial technology.\footnote{Interview with space security and China-U.S. relations expert at Renmin University, Interviewee 19-25-08, Beijing, China, 2010.} An expert at the CSSAR under CAS described civil-commercial and defense space technologies as “very close” and “related” (“技术很进，相关的”).\footnote{Interview with program manager at the Center for Space Science and Applications Research under CAS, Interviewee 23-10-00, Beijing, China, 2010.} Space law expert Wu Fang emphasized the problems that the utilisation of dual-use space technology [新进出现的军民共用的趋势] posed to international space law.\footnote{Wu Fang (吴芳), “Challenges to Outer Space Law from Military Space Operations (外空军事行动对外空法带来的挑战),” Hebei Law Science (河北法学) 25, no. 1 (2007): 129–132.} Characterisations of specific systems also reproduced the unity of civil-commercial and defense space expressed in the notion of a base. For example, a space policy expert at the AMS described China’s lunar program as “dual-use,” even though its “fundamental purpose is civil” (本身的目的是民用的).\footnote{Interviewee with Senior Colonel and academician in PLA AMS, Interviewee 02-19-24, Beijing, China, 2010.} \footnote{Wang Chunyong (王春永), “‘Space Defense’: National Security Strategy in the Space Age (“天防”: 太空时代的国家安全战略),” Journal of PLA Foreign Languages University (解放军外国语学院学报) 22, no. 1 (1999): 106.}
The “base” image provided a structural and holistic vision of social and technical systems, dissimulating diversity at the level of organisations, personnel, devices, and applications in civil, commercial, and defense space. In performing this representational practice, specialists produced the various elements of the space industry as constituting an irreducible whole, a single and undifferentiated object of regulation.

To represent space systems and activities in various contexts, experts in both China and the United States used the image of the frontier, the analogy to European colonisation, the and the depiction of a holistic industrial base. These representations expressed a common sense of how humans were configured to their machines, locating the agency transforming sociotechnical assemblages in the machines themselves. Experts also conveyed a shared understanding of the human condition as evolving in response to the unrelenting and autonomous progress of technology. They introduced these constructions and the tacit theories underlying them to policymakers’ debates and deliberations of space policies and programs in their countries.

Through these representations, experts constituted the space sector as a target of policy. Evidence of their role is found in policy discourses that recall and reproduce specialists’ representational practices. When experts depicted technical changes as proceeding according to a supervening structural logic, they also constituted technical processes as escaping human control. Eluding human mastery, technical change threatened and unsettled. When specialists defined their technologies as active and laden with potential, they also produced the risks associated with them as unbounded and diffuse. Space experts’ representational practices contrasted with those of aeronautic specialists, who depicted technical processes as effects of human action and subject to human manipulation. Through their representations, space experts produced technical changes in their sector as impossible to reliably or predictably regulate, contain, or direct to serve national interests. They generated agreement within their community that export control and
arms control institutions were insufficient to contain and manage the diffusion of sensitive space technologies and the escalation of international hostilities in space.

**Conclusion**

Space experts in China and the United States shared a unique specialist culture. This culture comprised technical knowledge and philosophical commitments, detectible in their patterned representations of sociotechnical systems. The specialist culture drew on sources of thought about technology and society from fields of activity related or adjacent to the contemporary civil-commercial space sector. The sources of this community’s shared culture included the work of early space visionaries before the advent of state-sponsored spaceflight, the nuclear security theories and practices of the Cold War, defense intellectuals’ theories of the Revolution in Military Affairs, and military histories that explained the evolution of interstate conflict across physical domains. After the Cold War, space specialists assimilated philosophical assumptions and appropriated representational practices from these outside fields of expertise. They reproduced them in their own representations of the sociotechnical systems of spaceflight.

Space experts reproduced and reinforced these theories of technology and society in their discourses about space, including their constructions of the space environment and space systems. These included their depictions of outer space as a frontier, of humanity’s expansion into space as analogous to the European experience of colonisation, and of the space industrial base as seamless integrating civil-commercial and military-defense production. Specialists circulated these representations throughout their community and among policymakers designing and deciding programs and policies for the sector. In both China and the United States, experts’ cultural production of the space sector in representational practices guided and oriented policymaking. These representations not only described and explained the sector to policymakers,
but also implicitly prescribed certain policies and programs. Experts’ representations called forth specific measures. They produced some forms of state action in the sector as more intuitively sensible and defensible than others in these ways. Having defined the ends of government in the space sector, specialists tacitly presented decisionmakers with the means by which these could be achieved, defining the range of policy options before them.
The constitution of bilateral order in space

Introduction

The limitations on and abrupt end of trade and civil cooperation between China and the United States in the space sector between 1989 and 2009 resulted from policies adopted by both governments, acting on similar understandings of the sector. Mounting suspicion and tension between the two countries during this time both owed to and reinforced policies that both governments adopted on the basis of these common views. In China and the United States, space experts’ analyses shaped how policymakers understood the space sector and domain. In the United States, these experts fostered agreement among policymakers that the sector required policies to strengthen the national space industrial base, to limit transnational trade and industrial integration unless necessary, and to curb the cross-border movement of space articles. In China, space experts created agreement among policymakers that their country required policies to autonomously develop core space capabilities and that international cooperation could complement, but not substitute for, this national pursuit.

Space policies and programs in both countries fostered mutual mistrust, suspicion, and self-reliance, in the process also limiting bilateral trade and cooperation. In the United States, policymakers imposed strict controls on exports of space items. Reluctant to allow bilateral trade, the U.S. government permitted it only when national circumstances demanded the resort to Chinese launches. Fearing that technology transfers would threaten U.S. security and suspicious of foreign motives, U.S. policymakers abruptly ended trade at the first sign of export control violations. They also resisted civil space cooperation with China, which they saw as carrying risks while promising scant benefit.
In parallel, the Chinese government implemented a strategy to autonomously develop core national space capabilities across civil, commercial, and defense space. Advances in these areas raised concerns among U.S. space and defense experts. Chinese policymakers welcomed international cooperation when it supplemented, but did not substitute for, the development of national capabilities. After the unexpected end of bilateral trade and China’s sudden exclusion from world markets by U.S. export controls in 1999, the Chinese government grew even more committed to policies fostering self-reliance in space, including large national space engineering projects. At the same time, Chinese space organisations pursued international partnerships in select areas with Europe, Russia, and developing countries.

Together, these policies and programs formed an evolving bilateral order that limited and then prohibited bilateral trade and cooperation. It fostered tension and mutual suspicion. By 2009, the two countries’ space firms had effectively no contact; they neither bought nor sold each other’s products. In civil space, the two countries’ programs evolved independently of each other, following distinct paths. In national security space, relations between the two countries grew increasingly tense after 1999 as their respective military space programs advanced. Observers on both sides began to warn of an escalating security competition in space. By the end of this period, the deterioration in bilateral relations across civil, commercial, and defense space seemed all but irreversible. The possibility of resuming even limited trade or initiating even small-scale civil cooperation grew remote.

When U.S. and Chinese policymakers and decisionmakers adopted policies and programs, they acted on specific understandings of the space sector. Specialists contributed to the bilateral outcome in space by supplying policymakers with understandings and representations of the nature and demands of the sector. Their descriptions and explanations of the sector, rendered in
their distinct representational practices, implicitly prescribed policies that hindered bilateral trade and cooperation and fostered bilateral suspicion and tension.

This chapter examines how space helped entrench and maintain a bilateral order limiting and then blocking trade, industrial integration, and technical cooperation in space, while fostering security tensions and suspicion between the two countries over their respective technology development programs. The first part of this chapter discusses the roles of specialists in sectoral policymaking in China and the United States. The second part examines how experts produced the global space sector as a configuration of several competing space industrial bases, compartmentalised by national borders. These representations implicitly prescribed controls on the transnational movement of space items and the development of national space capabilities. The third part of this chapter examines how Chinese space specialists defined U.S. export controls as a hostile form of “containment” policy targeting China. With this construction, they helped sustain agreement on the need to develop autonomous capabilities and increased suspicion of U.S. motives in space. The fourth part examines how experts in both countries represented space systems as conferring both great advantages and great vulnerabilities upon the U.S. military, in each case producing the other country’s defense programs as threatening. In the United States, these representational practices maintained policymakers’ and decisionmakers’ agreement on the need for strict export controls. The fifth part of this chapter examines how experts in both countries represented a bilateral confrontation in space as imminent or inevitable, fixing an understanding among policymakers in each country that programs to develop greater space capabilities were necessary. Within the U.S. space community, these representations also sustained support for strict export controls. The conclusion to this chapter reviews how a tacit consensus on these basic features of the space sector guided policymaking.
1. The space specialist community and space policy

While the institutions of government were different in China and the United States, both systems allowed for substantial input from space specialists to sectoral policy. In both countries, policymakers who designed sectoral policies and decisionmakers with the authority to adopt or fund policies regularly consulted space experts. Through their consultations, specialists conveyed their community’s basic philosophical commitments to policymakers in both countries.

1.1. Space specialists and policymaking in China

During the two decades that followed the end of the Cold War, space specialists were found across several institutions. These individuals formed a pool of sectoral expertise for policymakers and leaders to consult. Elite experts within this community also had privileged access to top leaders. Policymakers drew on their insights when they made, evaluated, and revised policy for the space sector. Experts contributed to sectoral policymaking through several channels. They briefed, wrote reports, and presented at conferences for policymakers preparing five-year plans and long-term strategies for the sector, such as Project 921 and the projects outlined in the *Medium- and Long-Term Plan*.

Over the course of this period, space experts contributed to policymaking as individuals and as an increasingly organised community. Central leaders taking a direct interest in space activities often listened to select senior experts. Individual space scientists and engineers had left their mark on space programs since the founding of the People’s Republic. Throughout administrations, these figures held the ear of China’s highest leaders, their status allowing them to propose and advocate for specific policies and programs. Examples of such influential experts included the father of China’s space program, Qian Xuesen, who, reporting directly to Mao
Zedong and Zhou Enlai, defined and directed China’s “Two bombs, one satellite (两弹一星)” program.\textsuperscript{1007} Several of Qian’s students also became influential policy advisers. Among them, missile control scientist Song Jian designed and persuaded Deng Xiaoping to implement the One-Child Policy.\textsuperscript{1008} Another of Qian’s students, space engineer Huang Zhicheng, spent a career in the PLA’s GAD, overseeing and advocating for space technology development programs and researching space policy issues. Senior space scientist Liu Zhenxing was the main architect and proponent of China’s Double Star program, an international project started in 2003.\textsuperscript{1009} The elder scientist Ouyang Ziyuan is credited with devising and advocating the lunar exploration program to President Hu Jintao and other top leaders, who included it in the \textit{Medium- and Long-Term Plan}.\textsuperscript{1010} Space scientists proposed and advocated large-scale space projects that policymakers included in strategies and programs.\textsuperscript{1011}

Under Deng and his successors, the influence of scientific and technical experts on space policy evolved and grew. While elite experts continued to make personal appeals to leaders, institutionalised specialist communities became more important shapers of policy than under Mao. As scientific and technical institutions reconstituted and developed in the 1980s, communities of specialists emerged and organised.\textsuperscript{1012} Policymaking in general became more professionalised and specialised. Coalescing communities of space scientists and engineers went

\textsuperscript{1007} Iris Chang, \textit{Thread Of The Silkworm} (New York, NY: Basic Books, 1996). In addition to his space policy role, Qian is also remembered as author of the projections of crop-yield increases on which Mao Zedong based the Great Leap Forward agricultural modernisation campaign.


\textsuperscript{1009} Interview with CAS academician in the Center for Space Science and Applications Research Professor Liu Zhenxing, Beijing, 2010; Zhang Yan (张艳), “Using Wisdom to Initiate an Undertaking, Using Painstaking Care to Enrich Human Life - An Interview with the Chinese Academy of Sciences Space Science and Applications Research Center’s Professor Meng Xin (用智慧开创事业 用心血充实人生—中国科学院空间科学与应用研究中心孟新教授专访),” \textit{Chinese Scientist (科学中国人)} no. 5 (2008).

\textsuperscript{1010} Besha, “Policy Making in China's Space Program.”

\textsuperscript{1011} Li Chengzhi, “The Chinese GNSS - System Development and Policy Analysis.”

\textsuperscript{1012} Cong Cao, \textit{China’s Scientific Elite} (New York, NY: RoutledgeCurzon, 2004); Cao, “Red or Expert.”
from ad hoc interveners to regular providers of input into policymaking. Under the Jiang and Hu administrations, space specialists participated in formulating policy and designing programs.

Space experts working in institutions within China’s government, military, and defense-industrial nexus provided policy analyses and expertise. Although the CNSA itself was not an influential organ during this time, its administrator was jointly appointed to a leadership position within Costind, the most important government organ coordinating policy formulation and implementation across the defense industry and the military. The CNSA administrator for most of the period after 1999, Dr. Sun Laiyan, was a frequent writer and media commentator on policy issues. Before 2008, the CNSA had a small research staff examining international civil space policy and programmatic issues. The PLA’s GAD, which subsumed the CMSEO, also had a policy research staff. Experts in this institution studied international trends in space programs and policies, sharing their analyses with decisionmakers. Academic institutions within the military had specialists analysing space policy issues. Officers and researchers within the AMS of the PLA and the National Defense University contributed their insights to policy deliberations in space security. MOST, the Ministry of Commerce, and the later Ministry of Industry and Information Technology had divisions dedicated to space technology development programs, manufacture, applications, and commercialisation. Researchers and policy experts in these diverse units analysed the sector and made policy recommendations.

The largest reservoir of technical space expertise during these two decades was the space industry. The defense industrial groups Casc and Casic were among the most influential actors in the sector. Responsible for the implementation and execution of major programs and policies in practice, they captured the near totality of state spending on space. In China’s leadership system for large state-owned enterprises and government, the president of Casc occupied a

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1013 Interview with former CNSA official, Interviewee 25-24-19, Beijing, China, 2010.
corresponding position in government and sat on bodies within Costind. The holder of this office for most of the period after 1999, Ma Xingrui, and other senior leaders within industry wrote articles and gave presentations about policy and programmatic issues to policymakers and other audiences. They drew on the industrial group’s growing in-house capacity for policy analysis. Near the end of this period, Casc established a policy research unit that played a formal advisory role to the central government. Casc also hired consultants to study specific policy issues relevant to its business, such as U.S. export control reforms.¹⁰¹⁴

Sectoral experts were also found in several large and expanding think-tanks whose function was advising policymakers. The most influential of these were national-level institutions. Research organs of this type included CICIR, CIIS, and the Institute for American Studies of CASS. The regional SIIS also conducted space policy research projects. In these facilities, international security, political economy, and area specialists conducted studies related to foreign space industries and programs and to the global space sector. In addition to experts in these areas, nuclear security and disarmament experts often studied space security as a secondary topic. For example, former diplomats and intelligence analysts with disarmament and space security backgrounds worked within a quasi-independent non-governmental organisation called the China Arms Control and Disarmament Association, which also organised conferences and produced reports for policymakers.

Academic and other experts participated in policymaking in formal and informal roles. An active community of space law experts, several of them based at the China University of Politics and Law, coalesced to produce legal, regulatory, and policy analyses. A community of these experts drafted national space legislation for the National People’s Congress and other legal

¹⁰¹⁴ Interviewee with senior Casc manager responsible for international cooperation, Interviewee 24-20-00, Beijing, China, 2010.
and regulatory instruments implementing China’s international commitments. Technical experts at universities such as Beihang and the Harbin Institute of Technology contributed programmatic and policy studies on issues such as orbital debris. Experts at Tsinghua University in Beijing, Fudan University in Shanghai, NUDT, and the Chinese Academy of Engineering Physics in Mianyang studied space security, arms control, and disarmament issues, often with a focus on missiles and anti-ballistic missile systems. These figures contributed to policy debates in the sector, writing analyses, reports, and articles on sectoral issues.

These specialists’ authoritative analyses and findings provided a basis for policymaking in the sector. From their products, policymakers learned about the space sector in China and abroad, made choices about high-level goals for national space development, and designed and adopted policies to meet them. Through their representations of sociotechnical systems in their sector, specialists conveyed to policymakers their tacit philosophical assumptions about humans and technology. Committees of specialists produced studies, reports, articles, and presentations for policymakers at various levels. ¹⁰¹⁵ Through these channels, experts not only described and explained the sector, but also produced it as a site of state action and an object of policy. In this process, specialists defined the range of policies feasible and desirable in and for their sector. Guided by their insights, policymakers decided on specific policies and programs.

1.2. Space specialists and policymaking in the United States

In the United States, space specialists also contributed their expertise to policymaking. Specialists in government agencies, industry, academia, and civil society provided input into the

¹⁰¹⁵ Interview with former CNSA official, Interviewee 25-24-19, Beijing, China, 2010.
formulation of space policies and programs and into decisions about whether to adopt and to fund them. Experts participated in policymaking through several formal and informal channels.

Within the executive branch of government, space specialists across several organisations contributed their expertise to policy formulation. Technical and policy experts within NASA and the Department of Defense studied space policy issues and circulated their findings among policymakers and decisionmakers. Divisions responsible for policy development and program formulation within these agencies contacted outside experts to participate in or conduct studies of space policy issues. A research staff and space experts within the White House OSTP consulted outside sectoral specialists. The director of space policy on the National Security Council, who coordinated the drafting of each administration’s national space policy and other specific space policy documents, was a space expert and consulted sectoral specialists across government, industry, and academia. The FAA’s Office of Commercial Space Transportation, responsible for regulating space launch sites and activities, established a policy research office and research partnerships with specialists in several universities.

Government space experts who contributed to policymaking came from a range of organs. Several FFRDCs employed specialists who conducted studies of technical, programmatic, and policy issues. These centers included the Rand Corporation and the Aerospace Corporation. Experts from these organisations shared their findings with congressional representatives and sectoral participants throughout government agencies. Space specialists within the OTA, a unit that reported to the Congress, undertook detailed policy studies. Researchers within the CRS consulted space specialists and incorporated their input into research reports produced for Congress.

Experts from industry were also represented among those who had a voice on space policy issues, either as individuals or through trade associations. Individual specialists testified
before congressional committees and met with the administration’s policy coordinator. They submitted written statements. Industry experts were also in contact with congressional staffers, who helped shape the views of individual representatives and sometimes committees. Individual government agencies organised industry meetings and working groups to consult. For example, officials from the FAA’s Office of Commercial Space Transportation met with and received reports from an industry working group focused on commercial space transportation that comprised representatives of major space companies.

Associations representing the space industry also channelled the policy preferences and perspectives of industry participants to policymakers. Representatives of groups such as the AIA, the Space Foundation, the Satellite Industry Association, and the Space Frontier Foundation communicated these views. They produced reports, position papers, speeches, presentations, testimony, and met with individual elected officials in Congress and their staffers as lobbyists or to give briefings. The goal of these specialists’ efforts was to communicate industry perspectives to policymakers.

Specialists in academia and civil society shared their views with policymakers in the administration, government agencies, and the Congress. Individual experts wrote reports, testified before Congress, and briefed officials formulating policy. Professional societies channelled the views of academic, industry, and government experts to policymakers. For example, the AIAA organised conferences attended by specialists and policymakers from these distinct types of institutions. Civil society groups also organised events and published reports that drew policymakers’ attention. The National Space Society, the Union of Concerned Scientists, and the Secure World Foundation were among the major civil society groups that advocated for specific policies and communicated specialist knowledge to policymakers. The
Mars Society and the L5 society also organised space professionals to advocate for space exploration.

The most authoritative and influential expert contributions to the making of space policy took the form of reports by presidentially appointed panels and the by the NRC. Every presidential administration of those two decades established ad hoc expert panels to examine issues in space policy, such as exploration and human spaceflight. Some of these groups were created in response to particular events, such as the Columbia Accident Investigation Board, which studied a catastrophic space shuttle mission. Other panels were established to prepare for the formulation of major policies and programs. The individuals appointed to these bodies were senior specialists with experience in industry, government, the military, or academia.

Reports of such eminent panels were influential. Administrations often followed their policy recommendations even if they were politically inconvenient. For example, the second Bush administration ended the popular shuttle program after the Columbia Accident Investigation Board concluded that NASA’s continued operation of the experimental vehicle was unsafe. Despite strong opposition, President Barack Obama terminated his predecessor’s Constellation program after the second Augustine Commission found it impossible to execute.

The NRC also assembled panels of experts to study space policies. The NRC often conducted its studies at the request of leaders in executive departments of agencies, such as NASA, to assist in the formulation of policies and programs. These studies examined the state of U.S. industry, technology, policies, and programs in the sector, generating recommendations to policymakers. Policymakers regarded these widely circulated reports as authoritative and based concrete choices on them. For example, the research priorities identified in the NRC’s *Decadal Survey of Space Science* guided NASA’s selection of space science missions in the 2000s.
Consultations with and reports by space experts were the main means through which policymakers learned about the space sector. As individuals or in panels, experts produced studies, reports, briefings, and presentations for policymakers. Through these media, experts rendered the space sector and space technologies intelligible to policymakers.

Space experts in both China and the United States played indispensable roles in the making of policies and programs. Although they acted within different institutions and through different channels, experts in both countries regularly provided policymakers with their authoritative representations of the space sector. Most often, policymakers in China and the United States did not experience the space sector in a direct and personal way, but indirectly through experts who described and explained it to them. As specialists interpreted the sociotechnical systems of spaceflight for policymakers, they also constituted the sector as a target of policy measures and programs. Expert consultations and materials were sources upon which policymakers relied to formulate and select means for the state to act in the sector.

1. Producing the space environment as an arena of interstate competition

Space experts in China and the United States produced the space environment as a hostile and competitive environment to policymakers in both countries, in the process prescribing competitive policies. In China during those two decades, specialists represented space technology as necessary to their country’s economic development, social progress, and international security.

As they represented the space sector, specialists in both countries conveyed their technological determinism and a theory of international politics. In this theory, technology’s advance had pushed international politics outward into the new theater of outer space. Space technologies had become sources of a country’s power and indicators of its position in the
international system. Specialists articulated the space environment and technical space systems to national interests and policy goals, rendering these links natural and self-evident through their repeated performance of these representational practices.

China’s specialists solidified agreement on these understandings of space systems as they expressed two rationales for developing the space sector. First, they represented space technologies as capable of transforming their country and necessary for domestic economic and social development. Second, drawing on their community’s theory of international politics, they represented space technologies as transforming the international system and the nature of state power. As they reasoned, China could not afford to be excluded from this important domain. The effect of these representations was to create and maintain agreement that space development was integral to national security and survival. Based on their understanding of the sector, these experts constructed autonomous space development as necessary, while also advocating the selective pursuit of opportunities for international cooperation.

1.1. Space technology transforms society

Specialists represented the development of the space sector as integral to China’s holistic development and modernisation. Space technology had the potential to transform society, the economy, and culture, they emphasised in depictions of devices in diverse contexts. Underlying this representational mode was the assumption that technology unilaterally transformed the social world around it. During the 1990s and 2000s, experts reproduced and adapted socialist discourses about technology promulgated under leader Deng Xiaoping and his successors.

In space experts’ representations of sociotechnical systems, machines were agents of change. Engineers and scientists discursively produced space hardware as bringing societal improvements. Chinese space specialists had a tradition of representing space technology as
conducive to national transformation. Since Qian Xuesen, known as the father of China’s space program, began the “two bombs, one satellite (两弹一星)” technology development program in the 1950s, space experts provided informal economic and sociological analyses in support of public spending on space activities. Representing space systems as catalysts of economic development and guarantors of national security, they justified the allocation of scarce resources to costly and risky space technology development programs.\textsuperscript{1016}

By the 1990s, China’s space experts had developed a vocabulary to characterise the space sector. Specialists represented space systems as serving the economy, education, and defense.\textsuperscript{1017} These produced space technology as essential to their country’s transition to a knowledge-based economy. Developing a space sector would allow China to cast off the oppressive and exploitative export-oriented low-end manufacturing on which its economy relied, they claimed. An advanced space program, like an advanced aeronautic program, would show the world that “China doesn’t just make shoes.” Within China’s borders, a foundation of scientific, technical, and industrial capacity in the space sector would raise the level of education and technical expertise in the population at large.\textsuperscript{1018} Space technology would serve the people in concrete applications. These encompassed disaster, mitigation, telemedicine, agricultural monitoring, and waterway management. Space technology would also raise the level of industrial and technical capacity. Performing ambitious space missions with indigenously developed hardware would develop systems engineering and advanced manufacturing capacities.


Particular verb-subject constructions conveyed this tacit sociology of technology. Space technology ‘spurred on (促进)’ China’s development and strengthening. Launch vehicles and satellites would ‘propel (推进)’ China’s economic growth and defense modernisation. The advancing space sector would ‘pull along (带动)’ other elements of society, ‘launching (开展)’ and ‘pushing forward (推动)’ progress in other industrial sectors.\textsuperscript{1019} It would ‘raise (提高)’ not only living standards, but also the level of culture and values.\textsuperscript{1020} Space technology development would bring the country’s holistic transformation.

In speech and writing, leading space specialists in the military, industry, and government continued to represent space development in this way throughout the two decades.\textsuperscript{1021} In 1999, Huang Zhicheng, then in the PLA GAD Systems Engineering Research Institute, emphasized that the space sector was “an important component of the country’s holistic development strategy (国家整体发展战略的重要组成部分).”\textsuperscript{1022} In a nod to Jiang’s theory of the “Three Represents,” according to which the Party represents the country’s advanced productive forces, Huang elaborated.

The development of spaceflight will inevitably push forward the development of our country's social productive force and produce transformations in an increasing way. Facing environmental, population, and natural disaster challenges, space development will greatly serve pushing forward the transformation of our country's economic growth mode and sustainable national economic development. 航天的发展必将推动我国社会生产力的发展和生产增长方式的转变。面对环境、人口和灾害的挑

\textsuperscript{1019} Ibid.
\textsuperscript{1021} Chang Xianqi (常显奇), \textit{Military Astronautics (军事航天学)}, Second Edition (Beijing, China: National Defense Industries Press, 2004), iii.
In this passage, Huang located agency in advancing spaceflight technology. In the configuration he envisioned, the technical pushed forward, produced, and transformed, while the social bore its effects and adjusted to it.

Other space experts expressed a technological determinism explicitly inspired by orthodox Marxisms. Their practices conveyed the teleology and materialism of this tradition, producing space systems as historical forces and structures. Writing in the influential *Global Times* in 2006, prominent space expert Dai Xu situated space systems as chief among other technological engines of history:

> Space is the sum total of contemporary high technology. Marxism regards science and technology as "history's powerful lever" and "the most significant revolutionary force." China's past backwardness was most evident in technology. For future rising powers, catching up or even surpassing advanced countries in science and technology is the first mission.

Casc president Ma Xingrui conveyed a similar understanding when he described the sociotechnical systems of space manufacturing. Implicitly advocating for state support to this industry in China’s major space industry journal, *Aerospace China*, he represented space technology as transforming society. His 18-character slogan encapsulated this logic: “发展航天制造，服务国民经济，促进社会进步 (Develop space manufacturing, serve the national economy, promote social progress).”

For Ma, the development of the space sector carried holistic social change. He represented this process by reasoning from concrete technologies and

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1023 Ibid., 2.
1025 Ma Xingrui (马兴瑞), “Develop Space Manufacturing, Serve the National Economy, Spur on Social Progress (发展航空制造，服务国民经济，促进社会进步),” 3.
specific programs out to diffuse, systemic social benefits. For fifty years, Ma wrote, China’s space industry “continuously and vigorously developed (不断蓬勃 发展).” As a result, he continued,

Not only did [our country’s space industry] create the "Two bombs, one satellite," human spaceflight, and the Moon orbiter probe, signifying brilliant success, casting three milestones into our country's history of undertaking space development; it also brought mastery of a great many core technologies with our own autonomous intellectual property rights, cultivated a distinctive spirit of the space golden age, the spirit of the "Two bombs, one satellite" program and the human spaceflight spirit, perfected specialisation, created a complete set of functional capabilities, completed facilities, and a space industrial system with unique characteristics. It established "a place for one's mat" [for our country] in the world's high-tech fields, powerfully strengthened our country's national defense, science and technology power, economic power and national cohesion, safeguarded national security, drove scientific and technical progress, stimulated economic development, pushed forward social progress and made important contributions toward inspiring national spirit.

The Communist Party leading group within Casc (中国航天科技集团公司党组) characterised space technology as bringing broader societal improvements in a similar way. Space technology applications “have pulled along related industries and social economic development (带动了相关产业和社会经济发展),” the group wrote in *Aerospace China.*

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1026 Ibid.
1027 Ma Xingrui (马兴瑞), “Develop Space Manufacturing, Serve the National Economy, Spur on Social Progress (发展航天制造，服务国民经济，促进社会进步).”
As CNSA administrator and Costind vice-minister, Sun Laiyan also defined technological change as an engine of economic and social progress. In *Aerospace China*, Sun called space technology a “productive force (生产 力)” in national development, reprising Deng Xiaoping’s dictum that “science and technology is the primary productive force (我说科学技术是第一生产力!)”. Writing about space exploration policy, he emphasised that exploration activities would advance the country’s economic, social, and overall science and technology development.

In yet another article, Sun conveyed these same ideas as he described the contribution of the space sector to the country’s eleventh Five-Year Plan (2006–2010) and the *Medium- and Long-Term Plan*.

The future development of space [...] will serve national economic construction, national security, and social progress, drive the nation's scientific development [Hu Jintao’s “scientific concept” of development], support the formulation and implementation of major national policies and strategies, that is, it will be oriented toward the "serve, drive, support" idea.

Other experts also represented the advance of space technology as necessary to national development. For example, space scientist Chen Quanyu expressed this philosophy of science and technology in his discussion of the Space Science Development Plan under the eleventh...
Five-Year Plan. Focusing on science, he characterised the space sector as spurring societal advancement: “The development of space science research and exploration activities is a major driver of building an innovative nation (开展空间科学研究和探测活动是建立创新型国家的重要推动力).”

Space policy writer Liao Chunfa described space technology as “as a twentieth-century promoter of humanity's social progress, among twenty technology items that have influenced human life (航天技术曾被列为 20 世纪促进人类社会进步、影响人类生活的20 项先进技术之一 ).”

Some space experts focused on particular technical systems as possessing an inherent capacity to transform human systems. These representations reproduced an anthropology that endowed artefacts with agency. For example, experts predicted that the Beidou constellation would bring economic development and social progress. Luan Enjie, a senior manager in the CLEP, described deep space probes as bringing a “drive to scientific and technological development (深空探测对科技发展的带动).” Space engineer Wang Ruiliang described China’s advances in space exploration hardware engineering, focused on building vehicles and communications systems for surveying the Moon and Mars, as “pulling” along development in other areas, including information and communications technologies, medicine, material and

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1036 Lan Bo (蓝波), “China’s ‘Beidou’ Breaks Western Space Monopoly (中国‘北斗’打破西方太空垄断),” Communist Party Member (共产党员), 2007; Wu Mo (吴沫), “The Obvious Characteristics of Beidou for Earthquake Disaster Relief (抗震救灾显北斗特点),” Aerospace China (中国航天), December 2008; Liu Jiyuan (刘纪原), Bai Bai’er (白拜尔), and Liu Jingsheng (刘景生), Space Technology and Modern Society (航天技术与现代社会), 24–26.
cultural life, and national defense.\textsuperscript{1038} Chen Shanguang, director of the Chinese Astronaut Research and Training Center, wrote that “the rapid development of space technology caused humankind’s space activities with increasing frequency (空间技术的飞速发展使人类的太空活动日益频繁).”\textsuperscript{1039}

Whether describing technology in general or specific technical systems, China’s space experts produced their advancement as driving social development, progress, and modernisation. Technical progress would fulfill national aspirations. These constructions served their personal and professional interests in producing space activities as necessary and beneficial.\textsuperscript{1040} However, these dominant representations were not simply instrumental. Nor were they the only means to argue for space development. The effect of these representational practices was to reinforce the imperative of space development. Performing these practices, experts produced the advancing technology of space systems itself as generating a societal need for it. To produce space development as a national interest, space specialists articulated space systems to societal demands in representations that reflected their basic philosophy of human-technology relations.

1.2. Space technology transforms international politics

In addition to representing domestic issues, specialists explained the space environment and the global space sector to political leaders. When Chinese experts described global developments in the sector, they expressed their specialist community’s theory of international politics. While expert discourses about domestic development tended to draw on socialist


\textsuperscript{1039} Chen Shanguang (陈善广), ed., Fundamentals of Space Law (空间法概要) (Beijing, China: China Astronautics Publishing House, 2007).

\textsuperscript{1040} Interview with retired officer in the People’s Liberation Army who managed major space engineering programs under the GAD, Interviewee 08-26-03, Beijing, 2010
influences, their discourses about the space domain and sector beyond China’s borders often reproduced those of U.S. space and defense experts.

Chinese space specialists’ representational practices conveyed their theory of international politics in two ways. First, space experts represented the space domain as an increasingly important site of international politics. Many space experts characterised competition for mastery of the space domain as deciding outcomes on Earth. Second, experts’ representations of space systems reflected their common understanding of space technology as integral to national power. Circulated and repeated, these naturalised constructions produced space as a site from which China could not afford to be excluded.

1.2.1. The space domain is competitive and hostile

Space experts in both China and the United States produced the space domain as the next setting for interstate competition. They foretold futures in which space activities were essential to national success and survival. Through these representational practices, Chinese specialists produced policies supporting space development as necessary. In their analyses, they described the growing influence of space technology on two spheres of international politics. The first of these was the international political economy. The second was the international security sphere.

Experts situated space systems in the international political economy, where international industrial competition centered on mastering advanced technologies. Specialists described space capabilities as transforming the international system. They represented technological revolutions – introductions of disruptive technologies – as transforming economic competition between nation-states. Their constructions reflected a sociology that endowed technology with the capacity to act upon social structures.
Casc President Zhang Qingwei in 2007 wrote that major powers valued space technology because it promised to transform societies and humankind. Since the start of the twenty-first century, the world's major spacefaring countries have one after another adjusted and formulated new space development strategies, goals, and programs. Future space activities are regarded as an integral part of comprehensive [holistic] national development strategies. In the future, near-space development and utilisation will continue to be a focal point of space activities, in addition to entering a new stage of larger-scale exploitation and service to society. Human spaceflight will expand into deep space, exploration of the Moon and Mars will once again make them hotspots for deep space probes. Space activities' great influence on cultural and social progress will further increase, emerging as a new dimension of flourishing development.

Space policy writer Zhang Zhiwei wrote that the space sector was a unique site of growing industrial competition among great powers. “The particularity and importance of the space industry (太空产业的特殊性和重要性),” he wrote, “stems from that every great power attaches importance to it, as well as that it has become an industry that great powers compete to develop (使其从诞生之日起便为各个大国所重视,并成为大国竞相发展的产业).”

CNSA Administrator and Costind leader Sun Laiyan described the sector in similar terms. Space technology was a “new domain (新疆域)” and “new frontier (新领域)” of humanity’s exploration, use, and knowledge. Every government made the space industry “a focal point of

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1042 Zhang Zhiwei (张志伟), “Inquiring into the Issues Related to Developing Our Country’s Space Industry (发展我国太空产业有关问题探讨),”
1043 Sun Laiyan (孙来燕), “The Brilliant Achievements and Development Strategy of China’s Space Sector (中国航天的辉煌成就和发展战略).”
their country’s development of strategic industries (各国重点发展的战略产业).”

In another article, Sun wrote that the sector had become “a strategic industry for every country’s key development (各国重点发展的战略产业).”

For these reasons, Sun explained, “[e]xploration, exploitation, and utilisation of space became the future development strategy of the world's main countries (探索, 开发和利用空间正成为世界主要国家未来发展的战略取向).”

Dai Xu wrote that China had a mission to catch up or even surpass the advanced countries in science and technology. Comparing the space industry to automobile and aircraft manufacture, in which China’s performance was weaker, he wrote that his country needed to autonomously “achieve breakthroughs in high-end science and technology fields (率先在高端科技领域实现重大的技术突破)” in order to “rapidly close the gap with advanced countries (以迅速缩短和先进国家的差距).”

Similarly, Zhang Zhiwei emphasised that China’s space industry faced a critical moment to leapfrog ahead and catch up to established powers. “To prioritise the importance of and vigorously develop our country's space industry (高度重视并大力发展我国的太空产业),” he wrote, “is to race to seize the decisive occasion for future economic and scientific and technical development (抢占未来经济科技发展的先机).” Other space experts explained that “[a]mong the important functions of space technology (航天技术的重要作用之一)” was that it could “make developing countries leap over the traditional stages of development in many
industries, accelerating social modernisation (就它能使发展中国家许多领域技术超越传统的发展阶段，加快社会现代化)。”

1050 These representations came together to produce the space sector as a site of industrial competition between nation-states, prescribing policies that supported the autonomous development of China’s space sector.

Throughout these two decades, experts in both countries also represented the space domain as a site of security competition and power politics between major states.1051 They defined the space environment as a new arena that great powers vied to control through force and the physical presence of their systems. Specialists also characterised space technology as transforming the nature of security relations between states, acting as a new source of state power, and reshaping deterrence.1052 These practices produced the space environment as exceptional, as determining security outcomes on Earth, and as a domain in which great powers needed to establish their presence. Specialists defined the space domain as the next frontier of warfare and space weapons as an inevitable stage in the development of warfare. Chinese and U.S. experts relied on common discursive practices to represent the role of space systems in contemporary warfare and the significance of the space domain to international security. As specialists explained space systems to policymakers, they articulated space technology to national interests.

1050 Liu Jiyuan (刘纪原), Bai Bai’er (白拜尔), and Liu Jingsheng (刘景生), *Space Technology and Modern Society (航天技术与现代社会)*, 19.

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The cause of the battlefield’s expansion into space was the progress of technology itself. As China’s leading space engineers explained, "The emergence and development of space technology are the factor that caused the military antagonisms of human beings' society to pour over into outer space." Governments could not reverse or change this process, but merely adapt to it.

Space experts represented the space environment as the next frontier of great power competition, as the next battleground, and as the ultimate strategic high ground.

Chinese space experts reprised constructions of the space domain as “commanding heights” and the next frontier of warfare. The GAD’s Huang Zhicheng used the image of high ground to describe the rise of technology as shaping international politics.

The commanding heights in contemporary wars are less geographical than they are technological. Presently, the high technologies that a country is developing occupy a more and more important position. The country that has captured the technological commanding heights has grasped the power to take the strategic initiative. In this sense, an important objective of the United States's utmost effort to develop space weapons systems is to seize control of the technological commanding heights, to enjoy the advantage of a technological edge. 现代战争的制高点与其说是地理上的，不如说是技术上的。当前，高技术在国家发展中占有越来越重要的地位。哪个国家占领了技术制高点，就掌握了战略主动权。从这个意义上说，美国不遗余力地发展太空武器系统，一个重要目的就是抢占技术制高点，享有技术差的优势。

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1053 Liu Jiyuan (刘纪元), Bai Bai’er (白拜尔), and Liu Jingsheng (刘景生), Space Technology and Modern Society (航天技术与现代社会), 18.
1054 Peebles, High Frontier; Dai Xu (戴旭), “Space: War’s Ultimate High Ground (太空: 战争的最后高地)”;
1055 Liu Jiyuan (刘纪元), Bai Bai’er (白拜尔), and Liu Jingsheng (刘景生), Space Technology and Modern Society (航天技术与现代社会), 19.
Wei and Rong used similar representations. The advance of U.S. space technology, they wrote, fundamentally transformed the international system and distribution of power. The future belonged to those powers that deployed space weapons first.

In the process of outer space militarisation, the United States possesses an absolute advantage, its goal is to strive for outer space hegemony. Considering that space is Earth's final frontier, taking the initiative to deploy outer space weapons could give the United States a strategic advantage in outer space. [...] the first step to U.S. control of outer space. Outer space militarisation and in particular outer space weaponisation once in the actual combat deployment stage will change the current structure of the international strategic balance. 在外空军事化的进程中，美国具有绝对优势，其目的是争夺外空霸权。从把外空作为地球最后的边疆来看，率先部署外空武器将可能使美国获得在外空的战略优势。[...]美国控制外空的第一步。外空军事化特别是外空武器化一旦进入实战部署阶段，将改变国际战略平衡的现有格局。1057

Wang Chunyong of the PLA Foreign Languages University discussed space experts’ practice of representing the domain as a frontier. She explicitly pointed to Mahan’s influence on space security thought in China, reiterating herself that warfare progressed toward an all but inevitable war in the final domain of space.

‘Space defense’ strategic thought grew out of the ‘strategic frontier’ thinking that our country's intellectuals proposed in the mid 1980s, and was stimulated by Mahan's ‘sea power theory.’ The so-called ‘strategic frontier,’ also called the soft frontier, regards geographic frontiers (hard frontiers) [...] (关于 ‘天防’战略的思索萌生于我国学者 80 年代中期所提出的‘战略边疆’思想，并受到马汉的‘海权论’的启发。所谓‘战略边,’ 也 称软边疆, 是相对于地理边疆 (硬边疆) [...]。)1058

Like U.S. space specialists, Wang saw warfare expanding to new domains over the course of history. Each time, great powers vied to establish their control over portions of the new domain.

The history of war repeatedly demonstrates that every time war evolved, it included the expansion of war-making to new domains; the emergence of

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In the practice of experts inspired by Mahan, Wang narrated the “expansion of the battlefield” from land to sea. “After the Wright Brothers invented the aircraft in 1903,” warfare expanded to air. The launch of the “first man-made satellite in 1957” and the “new technological revolution” brought the “birth of fourth-domain war.” This expansion compelled states’ behaviour, making some actions inevitable. Wang wrote that this extension of the battlefield made every country in the world struggle for ‘space power’ with a view to the major objectives of future war; every country’s (especially developing countries’) security faced a new threat; the conduct of ‘space defense’ strategy to constrain space war and to defend one’s own interest, among other means, will come inevitable choices. Both Chinese and U.S. experts used the concept of space power throughout this period. In her article, Wang went on to contrast Mahan’s history of warfare with traditional Chinese concepts of defense, in the process defining space development as necessary to her contemporary China.

1059 Ibid., 107.
1060 Ibid.
1061 Ibid.
1062 Ibid.
1063 Ibid.
Future wars will comprehensively unfold over the five domains of "land, sea, air, space, and cyberspace," consequently traditional defense systems based on "[the idea of a four-sided defense, associated with the four ancient Chinese kingdoms to the West, East, North, and South of contemporary China, drawn from Sima Qian’s *Yearly Chronicle of the Feudal Lords*]" is already insufficient to defend the nation; national defense construction must be carried out across the five domains of "land, sea, air, space, and cyberspace" and must form a mutually linked, mutually fused, mutually supporting national defense system. 未来战争将在“陆海空天电”五维空间内全面展开，因而类似于以传统的所谓“晋阻山河，齐负东海，楚介江淮，秦因雍州之固”为基础的防务体系已不足以保卫国家，国防建设必须在“陆海空天电”五维空间中进行，并构筑一个环环相扣，相互融合，相互支持的国防体系。1065

Wang envisioned a systemic transformation of national defense, integrating hardware and institutions across every physical environment into a single overarching structure. Built into this view of defense systems was a logic of technological inevitability, expanding national defense needs outward into domain after domain to the final frontier. Chinese specialists, like their U.S. counterparts, expressed a shared underlying sociology of technology and theory of international politics in these depictions. Their accounts not only described and explained the sector, but also prescribed policies that prepared China for a coming space war. This inevitability on the horizon, the development of national space capabilities and counter-space systems grew necessary and pressing in their depictions.

Reproducing U.S. specialist accounts, Chinese experts explained that space technology was integral to states’ pursuit of “information dominance.” In their working theories of international politics, this ascendant factor decided international power struggles. As Chinese specialists assessed the contribution of space systems to military power, they assumed revolutionary changes in technology that transformed warfare, adopting the tacit technological

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Part III: Chapter 11

determinism of their U.S. counterparts. These representational habits circulated throughout the
Chinese space specialist community.

Government experts responsible for space programs accepted and adopted these
representational practices, reproducing them in their own analyses. Huang Zhicheng of the
PLA’s GAD described technological revolutions as transforming the space sector. “Because of
the push of the information revolution (由于信息革命的推动),” he wrote, “worldwide space
technology, especially satellite technology, is pregnant with major technology breakthroughs (世界航天技
术特别是卫星技术孕育着重大的技术突破).” In U.S. strategic thought, Huang
explained, “the capacity to control information is not only important for war-making, but also
that, in this fast-changing world, this type of capacity will become an important factor in
international relations (控制信息的能力不仅对作战是重要的，而且在瞬息万变的世界上，这
种能力将成为国际关系中的一个重要因素).” Against this backdrop, Huang described how
technology reshaped international politics, citing U.S. RMA theorists.

Surveying the status of worldwide space development, it is not hard to see
that space-based communication networks will become important
components of the national information highway that every country is in the
process of building and the global information highway. Undoubtedly,
building an information highway will enormously accelerate our country's
development of national economic and national defense construction.
Presently, the information revolution wave is in the process of sweeping
across the globe, the struggle for the power to control information is already
growing in intensity, vying for the power to control outer space
communication channels has already become an important component of
the great powers' national strategies. The U.S. military claims ‘a country
that can outstandingly command the information revolution will inevitably
be stronger than any other country.’ ‘Many people believe that in the new
information age upon us, obtaining and controlling information will be the
decisive feature of possessing military strength.’ The United States has
already realised that, in an age when significant changes have already

1066 Huang Zhicheng (黄志澄), “Thought of Space Strategy for Our Country in Early 21st Century (对 21 世纪初我
国航天发展战略的思考),” 1.
1067 Ibid., 1–2.
occurred to nuclear deterrence and conventional deterrence, information
dominance can strengthen the organic link between foreign policy and
military power. In fact, it has already become a new type of deterrent force.

Huang warned that advanced space-enabled communications network would allow the
United States to “contain other powers in diplomacy (在外交中遏制其它大国)”\(^\text{1069}\) U.S. space
assets served the “construction of a global information highway” providing information
dominance.\(^\text{1070}\) Producing space assets as part of a sociotechnical system supporting U.S.
hegemony and threatening China, Huang established the development of space capabilities as a
pressing national need.

Space-based communication networks and a ground-based information
highway can realise seamless compatibility to become an important
technological foundation for today's information revolution. Europe and
Japan have already started to formulate policies for this site of struggle for
the power to control information. Facing an information offensive, our
country urgently needs to formulate a space development program from the
perspective of our country's holistic development strategy. 全球信息公路的关键是建设
全球天地一体化的通信网. 天基通信网与地面信息高速公路可以实现无缝兼容，成为当前信息革命的主要技术基础. 对
这场争夺信息控制权的斗争, 欧洲和日本也已开始制定对策. 面对这场
信息攻势, 我国急需从国家整体发展战略的高度来制定我国的航天发展规划.\(^\text{1071}\)

\(^{1068}\) Ibid., 1.
\(^{1069}\) Ibid., 1–2.
\(^{1070}\) Ibid., 2.
\(^{1071}\) Ibid.
In Huang’s depiction, major powers vied for control of the space domain. The nation-states that competed in this arena were not linked and connected to each other, but distinct, separate, and compartmentalised entities. These states built redundant national capabilities, each competing to construct its own space systems. Rather than a single seamless global communication network, the space environment contained rivalrous national constellations.

Performing these representations, specialists produced the space sector as an object of policymaking. They constructed this object as requiring specific forms of state action, their descriptions calling forth policy measures. Experts agreed that technology’s unrelenting advance expanded warfare to new domains, defining the space environment as the next setting for international struggle. They characterised space activities as necessary to national security and even survival in a competitive international system. The effect of their analyses was to justify state support to defense space technology development programs and the testing of new defense space systems.

### 2.2.2. Space technology decides the rise and fall of nation-states

Experts produced space technologies as elements of national power. In the theory of international politics underlying these representations, space systems were indexes of and sources of national strength that no great power could afford to neglect. Throughout the two decades, Chinese experts agreed that the “space industry and related space resources and science and technology (与太空产业相关的太空资源和太空科技)” have an “important influence on a

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1072 Ibid.
1073 Liu Jiyuan (刘纪原), Bai Bai’er (白拜尔), and Liu Jingsheng (刘景生), *Space Technology and Modern Society (航天技术与现代社会)*, 18.
country’s national security (对一国的国家安全构成重大影响),” as Zhang Zhiwei observed.1074 According to other experts, space systems “strengthened the mutagenicity of national defense power (航天技术[……]导致国家防务力量的突变性增强),” transforming the very nature of state power. 1075

After 2002, space specialists connected space technology to the concept of “comprehensive national power,” emphasised under the Hu administration as a goal of socialist construction. A systemic and holistic concept, “comprehensive national power” referred to the sum of political, military, economic, demographic, and cultural resources that a country brought to its relations with others and that defined its position in the international system. CNSA Administrator and Costind leader Sun Laiyan and other experts described space activities as “an important sign of a country's comprehensive national power (航天事业是一个国家综合国力的重要标志)” and “possessing great power status (具有大国地位的一个重要标志).” 1076 They articulated space systems to top leaders’ priorities and the military’s strategic guidelines.

In an article of this period, Sun elaborated on the societal functions of space assets that contributed to comprehensive national power. Space technology would

Spur on humankind's cultural and social development, benefit all humankind; satisfy economic construction, national security, scientific and technical development, social progress and other aspects of increasingly growing demand, protect national interests, strengthen comprehensive national power 促进人类文明和社会发展, 造福全人类; 满足经济建设、

1074 Zhang Zhiwei (张志伟), “Inquiring into the Issues Related to Developing Our Country’s Space Industry (发展我国太空产业有关问题探讨).”
1075 Liu Jiyuan (刘纪原), Bai Bai’er (白拜尔), and Liu Jingsheng (刘景生), Space Technology and Modern Society (航天技术与现代社会), 18.
The space sector enhanced every aspect of China’s power as an international actor.

The Communist Party leading group within Casc also represented space technology as making China into a great power, writing in 2009 that

Space technology succeeded at going global [entering world markets], expanded the Chinese space sector's influence, established our country's status as a great power in space.

Shi Jiangyue and He Shi drew on U.S. sources in a similar representation.

 [...] the U.S. air force space command strategic master plan said, "the capability to master space dominance is the most important, preserving the advantage is an indispensable condition of winning modern wars [...].美国空军太空司令部的战略总体规划指出,“掌握太空优势的能力是至关紧要的,维持太空优势是现代战争取得胜利必不可少的先决条件.”

These depictions entrenched a view of space systems as indispensable to China’s security.

Having defined the space domain as critical to China’s interests, space experts explained that their country must establish itself as a player that could not be excluded from space. China needed to guarantee itself a “seat at the table” or “a place for one’s mat (席之地)” in space, they wrote. For example, Major General Chang Xiangqi of the PLA GAD’s Institute of Command and Technology stressed this imperative on the first page of the foreword to his influential book, *Military Astronautics*, officially designated a central work of military research

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1080 Ma Xingrui (马兴瑞), “Develop Space Manufacturing, Serve the National Economy, Spur on Social Progress (发展航空制造, 服务国民经济, 促进社会进步); Sun Laiyan (孙来燕), “The Development Strategy and Key Areas of China’s Space Sector (中国航天的发展战略和重点领域),” 13; Kulacki and Lewis, *A Place for One’s Mat*. 

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for all the services under the tenth Five-Year Plan. Ensuring and expanding a physical Chinese presence in space, first in the form of satellites and then humans, was the surest means to avoiding exclusion from the domain. As a major participant in the global space sector, China would join major international processes that would bear upon how government and commercial actors could use space in the future, such as international negotiations about space security.

Chinese experts produced U.S. space systems as tools of hegemony and instruments of intimidation. In order to secure its interests in space and resist hegemony, China had to develop space capabilities of its own. Without these, negotiations or other means of checking U.S. conduct in space would be futile. Wang Song expressed this view:

To oppose and contain "space militarisation" without formidable strength and corresponding capabilities will be merely a weakling's unrealistic fantasy. Weapons are in the clutches of those with a subjective initiative, if one wants to hold the big stick-wielding adversary while increasing security and achieving equality, one must first possess a big stick. This is also an important principle of "standing up" to others, in which the Chinese people take pride since the era of their own Mao Zedong. 没有强大的实力和相应的能力, 反对和遏制 "太空军事化" 将 只能是 弱者不切实际 的 空想. 武器是掌握 在具有主观能动性的人手中的, 要想在握有大棒的对手面前获得安全和平等, 自己必须先拥有大棒, 这也 是 中华民族自毛泽东时代以来, 真正 扬眉吐气 站立起来 的一项重要原则.

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1081 Chang Xianqi (常显奇), Military Astronautics (军事航天学), iii.
1082 Interview with retired officer in the People’s Liberation Army who worked on major Chinese space engineering projects under the GAD, Interviewee 08-26-03, Beijing, 2010; Interview with former space intelligence analyst and technical advisor to policymakers based in the China Arms Control and Disarmament Association, Interviewee 12-8, Beijing, 2010.
1083 Interview with retired officer in the People’s Liberation Army who worked on major Chinese space engineering projects under the GAD, Interviewee 08-26-03, Beijing, 2010; Interview with titled academician and professor in the AMS of the PLA, Interviewee 2-19-24, Beijing, 2010.
In this same vein, the GAD’s Huang Zhicheng advocated, “doing the utmost to close the technology gap between China and the advanced countries (尽可能缩短与世界先进水平的差距)” in space.\textsuperscript{1085}

U.S. defense space analysts followed these writings by defense intellectuals in China. In their own analyses, they cited Chinese these writers to argue that Chinese military doctrine had been evolving toward a greater role for military space assets, a development that required a U.S. response.\textsuperscript{1086} The PLA was trying to catch up to the United States in space by developing its own version of networked warfare and the Revolution in Military Affairs.\textsuperscript{1087} Long concerned about China’s defense modernisation, U.S. analysts grew more aware of how space assets would contribute to this process.

2.4. The cultural production of competitive and autonomous policies as necessary

In their depictions of space capabilities, Chinese specialists defined the space sector as a configuration of competing space industrial bases, compartmentalised by national borders. This environment required governments to adopt policies that served the domestic development of space capabilities, rather than policies fostering the integration of their country’s industrial base into a global space industry. In China, experts established the need for policies and programs that developed indigenous space technologies and prevented Chinese space users from relying on


foreign partners. In the United States, experts represented cross-border flows of space technology items as threatening, implicitly prescribing strict export controls.

3. Producing U.S. export controls as space containment

China’s space experts represented the 1999 tightening of U.S. export controls on space items as part of a U.S. strategy to suppress China’s peaceful rise. These representations were grounded in the community’s tacit sociology and theory of international politics. From the supposition that space technology was integral to economic development and security, space specialists reasoned that measures to deny their country space technology and deny its launch industry access to world markets were designed to stifle their country’s economic development and slow its advancement. Chinese space specialists saw U.S. export controls as curtailing China’s legitimate pursuits and sovereign prerogatives in space.

According to Chinese space experts, the Strom Thurmond measures were not just a denial of trade opportunities, but one facet of a larger U.S. strategy to block their country’s economic and political rise. Chinese space specialists, including then-president of Casc Zhang Qingwei, referred to the export control regime as a “space containment policy (航天遏制政策)” that the U.S. government waged against China.¹⁰⁸⁸ Insisting that the access to and utilisation of space were integral to any advanced nation’s economy and defense, Chinese experts represented the export controls as intolerable and unjust constraints on China. These constituted a hostile policy targeting China, they wrote. More than a U.S. government reaction to export control violations or a trade policy, the space embargo was an offensive measure striking at China’s core development and security interests.

¹⁰⁸⁸ Zhang Qingwei (张庆伟), “Exploring Diversified International Cooperations for China’s Space Industry (积极探索多元化航天国际合作之路).”
These experts characterised technological “containment” as a two-pronged strategy to block China’s rise. First, it would constrain China’s economic rise by excluding it from markets for strategic high-technology goods. Second, this approach also aimed to slow and stifle China’s defense modernisation, preventing the country from pursuing its legitimate security goals. Their country victim of a hegemonic power’s designs, the only way to survive was to continue autonomously developing comprehensive space capabilities, they argued.

China’s space community regarded the Cox investigation as a thinly veiled “pretext” to impose a technological embargo on China. Impressions of the Cox report varied among space professionals, but almost all were sceptical of the motivations behind it. Chinese space scientists and engineers regarded the Cox investigation and the ensuing regime as fundamentally unjust, dishonest, and wrong. Some Chinese space experts claimed that the Cox committee, much like most of the U.S. Congress, was “anti-China,” under-educated, and technically illiterate. Out of ideological conviction and incompetence, the Congress used the Cox report as an “excuse” to push through legislation to stifle China’s industry, explained senior managers at Casc and Great Wall. Technical claims in the report were false, they pointed out. The report mischaracterised the relationship between commercial and defense space technologies. It

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1089 See Ibid., 1; also Interview with retired officer in the People’s Liberation Army who worked in the Chinese human spaceflight program under the GAD, Interviewee 08-26-03, Beijing, 2010; Interview with titled academician and professor in the AMS of the PLA, Interviewee 2-19-24, Beijing, 2010. See also 2000 and 2006 White Papers on space.

1090 Interview with export control specialist at the China Institute for Contemporary International Relations, a think-tank subordinated to China’s Ministry of State Security, Interviewee 7-24-2, Beijing, 2010.

1091 Interview with export control specialist at the China Institute for Contemporary International Relations, a think-tank, Interviewee 7-24-2, Beijing, 2010.

1092 Interview with professor of space engineering at Beihang (Beijing University of Aeronautics and Astronautics) familiar with the U.S. export control regime, Interviewee 3-19-25, Beijing, 2010.

1093 Interview with senior official formerly responsible for international cooperation at CNSA, Interviewee 26-25, Beijing, 2010; Interview with Gao Ruofei, Vice-President, Great Wall, Beijing, 2010; Interview with senior management-level employee responsible for international cooperation and familiar with the company’s U.S. operations through subsidiary Great Wall, Interviewee 24-20, Beijing, 2010.
represented the launch business, a “routine transportation sector,” as a defense industry. Specialists at Casc described the export controls as ill-conceived measures to protect the U.S. launch industry from foreign competition, disguised as a law to protect national security.

Many other space specialists, including in particular those outside of industry, claimed that U.S. motives were more sinister. Space experts affiliated with the AMS of the PLA regarded the restrictive export controls as expressing unbridled U.S. hegemony in its trade, security, and technological dimensions. Fencing in space technologies was a means to shoring up power and keeping challengers at bay. Export controls had China’s launch industry in a chokehold. By stymying the development of its launch industry and denying it civil-commercial satellites, U.S. laws constrained China’s access to and use of space. Scientists and engineers in universities joined the defense intellectuals in this analysis.

Feeding into these arguments about U.S. hostility toward China in space was a growing conviction among Chinese space specialists and security experts that the United States regarded China as a threat it needed to subdue. These ideas drew on theories of international relations which predicted that a major war would ensue when a new power rose in the international system to challenge an established hegemon. Chinese intellectuals referred to the view in U.S. security and defense circles that China’s rise posed a threat to the United States as ‘China threat

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1094 Interview with Gao Ruofei, Vice-President, Great Wall, Beijing, 2010.
1095 See discussion in Harvey, China’s Space Program: From Conception to Manned Spaceflight.
1096 Interview with titled academician and professor in the AMS of the China People’s Liberation Army, Interviewee 2-19-24, Beijing, 2010; Interview with space security expert formerly of the AMS of the PLA and later with the think tank China Arms Control and Disarmament Association, Interviewee 20-10-17, Beijing, 2010.
1097 Interview with titled academician and professor in the AMS of the China People’s Liberation Army, Interviewee 2-19-24, Beijing, 2010; Interview with space security expert formerly of the AMS of the PLA and later with the think tank China Arms Control and Disarmament Association, Interviewee 20-10-17, Beijing, 2010.
1098 Interview with professor of space engineering and space security expert at Beihang, Interviewee 3-10-2, Beijing, 2010; interview with physicist and professor of international studies at Tsinghua University, Interviewee 12-2, Beijing, 2009.
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theory.” With China threat theory in view, Chinese space experts began to explain that their country’s increasingly visible space capabilities alarmed U.S. defense analysts.

China’s civil space achievements, including its first human spaceflight missions, “gave rise to anxiety among certain foreign China threat theorists (引起国外某些敲诈 “中国威胁论”者的焦虑).” For instance, space specialist Liao Chunfa saw evidence of this situation in U.S. congressional hearings. Pointing to a hearing on NASA’s fiscal year 2007 budget, Liao found that “the main focus of the questions the members asked the NASA administrator was not on the budget, but on whether it can vie to be the first to land a human on the Moon by 2017 (议员们向NASA局长提问的重点不是预算，而是中国是否会抢先在2017年实现载人登月)” and that “deep concern about China dominated the entire hearing (对中国的关切主宰了整个听证会).”

China threat theorists dominated the U.S. defense community, Chinese space specialists argued. For instance, with each passing year, in the annual report they submitted to Congress on Chinese military power, analysts in the U.S. Department of Defense gave greater prominence to the growth of China’s space capabilities. These experts defined space systems as a linchpin of the country’s accelerating military modernisation.

1101 Ibid.
3.2. Producing autonomous development as necessary

During those two decades, Chinese and U.S. experts represented the development of autonomously assured national space capabilities as necessary. U.S. experts maintained that preserving U.S. technological leadership in space was an imperative.\textsuperscript{1102} Chinese space experts represented indigenous space capabilities as integral to their country’s economic development. China’s military security depended on securing itself a place in space.\textsuperscript{1103} Specialists emphasised the risk of being excluded from the space domain by a more powerful United States.\textsuperscript{1104} For these analysts, the only reliable means to prevent this outcome was to develop space capabilities that would ensure China’s access to space and establish it as a power that could not be denied use of this environment.\textsuperscript{1105} China’s civil space activities were part of a strategy to achieve this goal.

China’s space experts expressed an ambivalent attitude toward international cooperation throughout this period. On the one hand, they recognised that their national programs had benefitted from Soviet and Russian assistance in the 1950s and early 1990s.\textsuperscript{1106} Learning from foreign partners offered China’s space community the opportunity to leap-frog over early space technologies and hurdles. Moreover, many Chinese experts recognised that, in the post-Cold

\begin{itemize}
  \item Interview with retired officer in the People’s Liberation Army who worked in the Chinese human spaceflight program under the GAD, Interviewee 08-26-03, Beijing, 2010; Interview with titled academician and professor in the AMS of the PLA, Interviewee 2-19-24, Beijing, 2010; Interview with physics professor and space security expert at Fudan University, Interviewee 19-4-12, Shanghai, 2010.
  \item Kulacki and Lewis, \textit{A Place for One’s Mat}.
  \item Interview with titled academician and professor in the AMS of the PLA, Interviewee 2-19-24, Beijing, 2010.
  \item Interview with retired officer in the People’s Liberation Army who worked in the Chinese human spaceflight program under the GAD, Interviewee 08-26-03, Beijing, 2010.
\end{itemize}
War era, large-scale technical space projects would be multinational. They hoped their country would become a participant in these efforts.

On the other hand, space experts saw the risks and vulnerabilities brought by tying China’s space development to other countries. Some experts remembered Soviet and Russian assistance as limited, begrudging, and intermittent. Foreign partners, they argued, could not be relied upon to develop China’s space sector. In the aftermath of the Cox investigation and China’s abrupt exclusion from the global commercial space business, many Chinese specialists concluded that the external environment they faced was hostile and unpredictable. China’s expert community was sceptical of cooperation projects that would substitute or interfere with the development of domestic capabilities on the critical path.

China’s space policy reflected this ambivalence. Civil and commercial programs were in principle and practice open to international cooperation, including with the United States. At the same time, however, policy and programmatic choices emphasized autonomously building capacity in the sector. In practice, the result for most of these two decades was a hybrid approach: China’s space policies emphasised acquiring capabilities through a combination of indigenous technology development, imports, and international collaborations. Chinese organisations sought international partnerships in particular areas. International contributions could augment, but not substitute for, the indigenous development of cornerstone technologies.

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1107 Interview with retired officer in the People’s Liberation Army who worked in the Chinese human spaceflight program under the GAD, Interviewee 08-26-03, Beijing, 2010.
1108 Interview with retired officer in the People’s Liberation Army who worked in the Chinese human spaceflight program under the GAD, Interviewee 08-26-03, Beijing, 2010; Interview with titled academician and professor in the AMS of the PLA, Interviewee 2-19-24, Beijing, 2010.
The main thrust of space development was in large-scale national engineering projects with no foreign partners.\(^{1110}\)

As the head of the agency in charge of China’s international space cooperation, CNSA Administrator Sun Laiyan expressed this ambivalence in a 2006 article. Sun advocated both international cooperation and autonomous development. He argued that international cooperation was among several trends in the space sector, to which China must adjust. “Proactively developing international dialogue and cooperation, dedicating abundant resources (积极开展国际交流与合作, 充分调动各方资源),” would “serve national interests (为国家利益服务),” he wrote.\(^{1111}\) For example, in space exploration, China should try to “expand cooperation and link rails with international space exploration activities (坚持开放与合作，与国际空间探测活动相接轨).”\(^{1112}\)

However, Sun argued that in strategic areas of space technology, China should develop indigenous capabilities. Writing of global navigation satellite systems in 2007, Sun wrote that China needed to get “a place for one’s mat (占有国际卫星导航领域一席之地)” by building independent national systems to reduce reliance on the U.S. GPS and the Russian Glonass.\(^{1113}\) In general, policymakers resisted large-scale projects that tied Chinese systems to foreign entities.

\(^{1110}\) Interview with retired officer in the People’s Liberation Army who worked in the Chinese human spaceflight program under the GAD, Interviewee 08-26-03, Beijing, 2010; Interview with titled academician and professor in the AMS of the PLA, Interviewee 2-19-24, Beijing, 2010. See also 2000 and 2006 White Papers on space.

\(^{1111}\) Sun Laiyan (孙来燕), “The Brilliant Achievements and Development Strategy of China’s Space Sector (中国航天的辉煌成就和发展战略),”

\(^{1112}\) Sun Laiyan (孙来燕), “Principles of the Development of China’s Space Exploration (我国空间探测发展的原则),” 3.

\(^{1113}\) Sun Laiyan (孙来燕), “The Development Strategy and Key Areas of China’s Space Sector (中国航天的发展战略和重点领域),” 13.
Dr. Meng Xin, a senior space scientist in the CSSAR under CAS, also described the limits of international cooperation in an interview. He advocated seizing the opportunities posed by international collaborations, but relying primarily on national programs to develop space science.

Professor Meng: Following our country's rapid economic growth and fast development of space technology, foreign counterpart organisations and scientists are very interested in initiating scientific and technical academic dialogue with China, our country has also held several international space science and technology dialogue events, such as hosting international space science conferences. But, overall, our foreign dialogue has been mainly on scientific research aspects, rather than on space technology areas, where the foreign side has a strict blockade against our country. Having gone through many dialogues and cooperation in recent years, we can clearly perceive that foreigners are willing to share some space science items with us, but are absolutely not willing to share space science technology. Therefore, Chairman Mao's guidance that we "maintain independence and hold the initiative" is a policy guideline that scientific technology and engineering technology personnel must insist on. 孟教授: 随着我国经济的高速增长和空间技术的快速发展，国外相关机构和科学家对与中国进行空间科学技术方面的学术交流兴趣很高，我国也举办了不少的国际空间科学技术学术交流活动，如举办国际空间科学大会等。但从总体上看，国外与我们的交流主要在科学研究层面，而在空间技术领域，外方则对我国严格封锁。通过近年的许多交流和合作，我们可以清楚地感觉到，外国人愿意与我们共享一些空间科学项目，但决不愿意与我们共享空间科学技术。所以，毛主席教导我们的“独立自主，自力更生，”是从事科学技术和工程技术研究的人员必须要坚持的方针。1114

By 2009, space experts articulated different policy options and strategies reflecting the reconciled goals of fostering indigenous innovation and engaging in international cooperation. 1114

The Communist Party leading small group within Casc (中国航天科技集团公司党组) proposed how these two objectives could be simultaneously pursued. The group wrote that China must begin by “insisting on making indigenous innovation a basic point of strategy (必须始终坚持以自主创新为战略基点),” and from there “strengthen international dialogue and cooperation (加

1114 Zhang Yan (张艳), “Using Wisdom to Initiate an Undertaking, Using Painstaking Care to Enrich Human Life - An Interview with the Chinese Academy of Sciences Space Science and Applications Research Center’s Professor Meng Xin (用智慧开创事业 用心血充实人生—中国科学院空间科学与应用研究中心孟新教授专访),” 4–5.
强国际交流 与合作)” and “firmly grasp the initiative in high-technology space industry development (牢牢把握发展航天高技术产业的主动权).”

This strategy entailed two aspects. On the one hand, the group explained, developing a strategic space industry required “having a footing in indigenous innovation, maintaining one's independence and initiative (方面必须立足于自主创新, 通过独立自主),” and “self-reliance (自力更生).” Yet this emphasis did not preclude international collaboration. On the other hand, the group went on to write, “we must fully absorb worldwide science and technology's newest achievements (必须充分吸收世界科学技术最新成果)” and “fully draw lessons from developed countries' advanced experience of space industry development (充分借鉴发达国家发展航天事业的先进经验).” The experts then illustrated how the space industry implemented this two-fold strategy in concrete projects. For example, it used autonomously developed carrier rockets to launch U.S.- and European-made satellites, it jointly developed satellites with Brazil, and with ESA’s Cluster program “together realised humankind’s first six-point observation of Earth space (首次实现了人类对地球空间的六点观测).”

These combined approaches – “walking the road of indigenous innovation (走自主创新的道路)” while “unceasingly strengthening international dialogue and cooperation (并不断加强国际交流和合作)” – would allow China to “continuously realise leapfrogging in the world’s high-technology fields (在世界高科技领域有所作为并不断实现新的跨越),” they wrote.

1116 Ibid., 8–9.
1117 Ibid.
1118 Ibid., 9.
1119 Ibid.
Through these representations, space experts established the autonomous development of space capabilities as necessary while also producing trade and cooperation with foreign partners as instrumentally serving this goal. Space experts derived and expressed these policy conclusions from characterisations of space development as a national imperative and of the external environment as hostile and competitive, but affording technical learning opportunities.

Over time, these representations became commonplace, receding into the background of taken-for-granted understandings shared within the transnational space community. These representational practices reinforced agreement among Chinese policymakers on the necessity of pursuing the development of major national space capabilities. Given the hostility of the external environment, China’s space development could not rely on any other country or foreign power. In addition, these representations established the understanding among Chinese space professionals that advancing U.S. space programs were driven by hegemonic and hostile ambitions. They threatened China’s core interests and demanded a response.
4. Producing U.S. space systems as both potent and vulnerable

Throughout those two decades, Chinese and U.S. space experts represented the function of space systems in contemporary warfare and the significance of the space domain to national defense in similar ways. Both Chinese and U.S. space experts represented space technology as revolutionising modern war and as indispensable to capable militaries. In so doing, they conveyed that technological change shaped societal outcomes and that machines constituted and enabled their human operators. As they examined space technology in war, these experts also emphasised the U.S. military’s reliance on space assets and the vulnerability it created. Experts in both countries asserted that this vulnerability presented opportunities for a rival less reliant on the space domain, such as China, to exploit.

4.1. Growing U.S. reliance on space systems

Chinese and U.S. experts treated U.S. military engagements after the Cold War as case studies in modern warfare, each providing evidence of technological revolution. Analyses of this type circulated between the Chinese and U.S. expert communities. Chinese experts cited U.S. data and analyses to represent the function of satellites in networked warfare and the reliance of the U.S. military on space systems. U.S. analysts also cited Chinese experts discussing these trends to argue that China’s space strategists had identified vulnerabilities in U.S. defenses.


To U.S. experts, space technology was an indispensable element of U.S. military power. Space systems were part of the infrastructure of the “American way of war.” To Chinese space experts, a string of post-Cold War conflicts demonstrated why the United States was determined to preserve its space hegemony and to deny the full benefits of access to and exploitation of space to its rivals. As defense analyst Barry D. Watts summarized in a 2001 report for the Center for Strategic and Budgetary Assessments, an independent U.S. think tank,

American requirements for global power projection suggest the United States is also more dependent on space systems than other countries, and future opponents may be able to offset many of the advantages the American military derives from space without a major space program.

In a 2001 report for the Commission to Assess United States National Security Space Management and Organization, staff member Tom Wilson wrote “the United States' (U.S.) increasing economic and military dependence on space creates a vulnerability that is an attractive target for our foreign adversaries.” Explaining the significance to the U.S. military, he added

If adversaries are able to employ offensive counter-space operations — operations which are intended to deceive, disrupt, deny, degrade, or destroy U.S. space systems — the force multiplication effect they provide would be reduced or eliminated. This could lead to more expensive victories or even to defeat.

Experts in both China and the United States observed that the 1991 Gulf War was the first in which space assets played a major role. Influential Chinese strategists, such as the GAD’s

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1126 Ibid.
Major General Chang Xianqi, interpreted these events for policymakers and decisionmakers as turning points in the history of warfare. These specialists then cited the U.S. invasions of Afghanistan in 2001 and Iraq in 2003 to show the battlefield payoff of incorporating space assets into the armed forces. Chinese writers cited U.S. experts to describe the U.S. military’s growing reliance on satellites. Shi Jiangyue and He Shi illustrated through their use of U.S. sources how U.S. representational practices circulated within the Chinese space specialist community. The authors cited U.S. documents and reproduced the habit of defining space as the new domain of warfare to argue that space assets were vital to winning wars.

In the past, the Pentagon has in several internal reports said that outer space is the new military domain. The Pentagon believes that the Persian Gulf War of the 1990s was "the first space war," in which it tested entirely new technologies in battle, and started to implement a force-building concept of "holding omnidirectional [comprehensive] superiority." In the 2003 invasion of Iraq, of all the weapons the U.S. military's used in its first round of attacks, 70% employed military satellites for control and guidance. The war on terror presently in progress also uses space assets to implement comprehensive coordination.

Space law expert Wu Fang also stressed how the U.S. military relied on satellites.

1127 E.g. Ning Ling (宁凌), Wang Chun (王春), and Rong Hui (荣晖), Confrontation in Space (太空对抗) (Beijing, China: Military Affairs Literature Publishing House, 2006), 26–46; Chang Xianqi (常显奇), Military Astronautics (军事航天学), 248–252.
1128 Ning Ling (宁凌), Wang Chun (王春), and Rong Hui (荣晖), Confrontation in Space (太空对抗), 49–84; Chang Xianqi (常显奇), Military Astronautics (军事航天学), 259–265.
1130 Shi Jiangyue (石江月) and He Shi (何适), “The Opening Round of ‘China-U.S. Space War’ in 2016? (2016 打响‘中美太空站’?).”
Outer space military operations are unavoidable in today's war, a point best demonstrated by the "Operation Iraqi Freedom" period of the 2003 Iraq war. During the truly most intense period, human-made satellites controlled 60% if the allied forces communications, including among these 100% of secure communications. Attackers relying on communications satellite links, unmanned aerial vehicles, confirmed and attacked Iraqi targets extremely effectively. Space assets can perform precision strikes even in the most complex of war-fighting environments and within cities. (外层空间军事行动在现代战争中是不可缺少的，这一点在2003年开始的伊拉克战争中的“自由伊拉克” (Operation Iraqi Freedom)行动期间得到了最好的证明。在真正最激烈时，人造卫星控制着联合部队60%的通讯，包括其中100%的 安全通讯。依靠通讯卫星联系的“掠夺者”无人驾驶飞机在 确认与攻击伊拉克的目标上十分有效。外空物体在最复杂 的战争环境和城市中也能实施精确的打击。)\textsuperscript{1131}

That Iraqi forces near Baghdad used GPS jammers indicated that “they realized to what degree military operations based in outer space could imperil the ground war (这就证明他们已经认识到外层空间基础上的军事行动对于陆战的威胁程度),” wrote Wu. This demonstrated “the importance of outer space applications to the present and future (从中我们不难看出外层空间利用对现在 和未来的重要性),” he added.\textsuperscript{1132}

Prominent expert Dai Xu repeated these conclusions. Reviewing U.S. wars in the Persian Gulf, Kosovo, Afghanistan and Iraq, he found that “space was a salient factor behind the victories (隐藏在胜利背后的太空因素十分突出).”\textsuperscript{1133} He described U.S. satellites as enabling

the ultimate war-making phenomenon: the characteristic of the ‘three withouts’ – without wires, without contact, and without symmetry [asymmetric]. (正是因为有了这些卫星, 美国实现了夜晚单向透明, 实现了远距离精确打击, 实现了数字铰链, 并最终使战争呈现出“ 三非特点” —非线性, 非接触, 非对称。)\textsuperscript{1134}

\textsuperscript{1131} Wu Fang (吴芳), “Challenges to Outer Space Law from Military Space Operations (外空军事行动对外空法带来的挑战),” 129.
\textsuperscript{1132} Ibid.
\textsuperscript{1133} Dai Xu (戴旭), “Space: War’s Ultimate High Ground (太空: 战争的最后高地),” 8.
\textsuperscript{1134} Ibid.
Wang Song observed the same reliance on space systems. Satellites, he wrote, “are the platforms supporting the entire core of some countries' military power (某些国家全部武装力量的核心支撑平台之一).” Shuai Ping also constructed satellites performing unique functions in warfare. He wrote that “because space systems have already become force multipliers for land, sea, air, and other militaries (由于航天系统 […]已成为海陆空各军兵种作战力量的 “倍增器”),” major space powers had “accelerated the development of various military satellite systems (加快发展各种军用卫星系统)” in the preceding decade.1136

Mesmerized by space hardware and captivated by its potential to transform societies and warfare, Chinese space experts described these systems as engines of their country’s economic development and catalysts of its defense modernisation. Looking outward to the international environment, Chinese thinkers saw space systems as conferring a strategic advantage in war upon the United States and advances in space systems as capable of disrupting the global balance of power.

4.2. Asymmetric warfare systems can exploit U.S. vulnerabilities in space

Convinced of the transformative nature of space technology, space experts in both countries represented users as growing reliant upon it. This reliance on space assets, they reasoned, brought vulnerability: a degradation of its satellites would cripple U.S. military operations in distant theaters. Space systems were the U.S. military’s Achilles’ heel.

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As space experts in China began to represent U.S. reliance and vulnerability in these terms, they also proposed new concepts based on these ideas. In this effort, they drew on a variety of sources, including ancient Chinese military thought. Adapting ideas about asymmetrical warfare, specialists proposed turning their country’s disadvantage in space into an advantage. Rather than trying to correct the asymmetry in the two countries’ space capabilities, they advocated using it as the basis of a strategy. As the advantage conferred by sophisticated space systems upon the U.S. military also bred a reliance on those fragile systems, a weaker adversary with a lesser investment in space could exploit this reliance, they wrote.

Chinese defense intellectuals proposed the concept of an “assassin’s mace” in space. For some of these thinkers, the mace was a secret weapon that, while simple, could deliver a surprise blow to an adversary by targeting that which was at once their greatest strength and greatest weakness. Often, these proposals were theoretical and abstract in nature, but Chinese space experts sometimes associated them with electromagnetic pulses and thermonuclear explosions in crowded orbits of space, suddenly disabling constellations of U.S. satellites. China’s experts saw in space an opportunity to erase the advantages U.S. forces possessed on the ground. For example, Dai Xu wrote that “historically, the seas offered rising powers an opportunity to level the playing field (海洋是历史上大国崛起的共同机遇)." Soon, he wrote, space will provide such an opportunity to the next century's rising great power's (奔向太空是新

1137 Chang Xianqi (常显奇), Military Astronautics (军事航天学); Ning Ling (宁陵), Wang Chun (王春), and Rong Hui (荣晖), Confrontation in Space (太空对抗).
1141 Interview with retired officer in the People’s Liberation Army who worked in the Chinese human spaceflight program under the GAD, Interviewee 08-26-03, Beijing, 2010; Interview with titled academician and professor in the AMS of the PLA, Interviewee 2-19-24, Beijing, 2010.
1142 Interview with retired officer in the People’s Liberation Army who worked in the Chinese human spaceflight program under the GAD, Interviewee 08-26-03, Beijing, 2010; Interview with titled academician and professor in the AMS of the PLA, Interviewee 2-19-24, Beijing, 2010.
Abstract or concrete, their representations of the assassin’s mace produced a space article as a unique device endowed with the capacity to disrupt a strategic balance or reverse the course of a conflict. The assassin’s mace, like the spy satellite or the GPS receiver, was a machine with the power to shape struggles between countries for security.

U.S. space experts became aware of these proposals within China. They then disseminated their knowledge of them to policymakers. Military and think-tank specialists, such as Andrew Scobell and Larry Wortzel of the Strategic Studies Institute at the Army War College, circulated translations and analyses of Chinese writings about asymmetric warfare in the U.S. space community through articles, reports, briefings, and congressional testimony. Chinese experts, in turn, became concerned with U.S. analyses of Chinese systems and concepts. For example, Shi Jiangyue and He Shi wrote:

Not long ago, the U.S. Pentagon's public report on China's military power, compared with previous years, had some changes, among them that it increasingly emphasized "China's threatening space capabilities." According to the report, in the PLA's current strategy, space will be the center of contemporary information war. The PLA is making a great effort to build up its own space technology, improve its space-based C4ISR capabilities. Besides the already tested and proven kinetic-kill [anti-satellite system], the PLA is also developing interference, blinding, or other capabilities for destroying satellites or supporting ground facilities. In addition, China is still vigorously developing asymmetric warfare capabilities, emphasizing developing innovative strategies and tactics, combined with others to be applied to existing technology and weapons systems, in order to close the gap between China and advanced military powers.

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1144 Seedhouse, The New Space Race, 104.
1145 Andrew Scobell and Larry Wortzel, eds., Civil-Military Change in China: Elites, Institutes, and Ideas after the 16th Party Congress (Carlisle, PA: Strategic Studies Institute, Army War College, 2004).
They explained that, in U.S. analyses, “counter-space systems” would be among the technologies that “form the core of China’s asymmetric warfare capabilities.” Chinese specialists used these ideas to justify investments in military space programs, while U.S. experts monitoring these discourses concluded that China posed a growing threat to U.S. interests in space.

**4.3. Chinese anti-satellite capabilities threaten U.S. vulnerabilities**

In January 2007, the Chinese military tested its first kinetic anti-satellite weapon. The conduct of the test itself and its reception by the U.S. space community entrenched a view of trade and cooperation with China as undesirable and threatening. U.S. experts’ interpretations of the event helped establish for policymakers that a space competition was underway or probable. In these analyses, space experts in both countries reproduced a sociology that defined space hardware as shaping warfare and deciding conflicts. A consensus emerged among U.S. experts that space trade and cooperation with China was threatening and that strict export controls should remain in place.

U.S. experts depicted the 2007 test as a signal that China intended to target vulnerable U.S. space systems in a forthcoming confrontation. They described U.S. space assets by situating them in a broader context, consisting of doctrines, functions, national interests, and targets. Locating the Chinese anti-satellite device in this context, they produced it as targeting U.S. vulnerabilities in a new and intolerable way.

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1147 Ibid.
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As U.S. experts pointed out, the set of targets to which China’s new capability could be directed in 2007 was far greater and more important than when the Cold War superpowers tested their systems decades earlier. The U.S. economy and way of life were dependent on fragile satellites that China had become capable of destroying with an effective, reliable, and cost-effective system. U.S. experts claimed that China was not merely pursuing space development in the tracks of its American and Soviet predecessors, but was intent on exploiting U.S. strategic vulnerabilities. Interpreted in this way, the test marked a rupture in bilateral relations, signalling to U.S. policymakers and decisionmakers that a hostile China intended to challenge the United States in space.

As the reality of a counter-space-capable China set in, the U.S. space security community assessed the changed environment it faced. In a string of studies, defense analysts examined the prospects for “space deterrence.” They emphasized the challenges of deterring China. China was less reliant on space than the United States. There were far fewer Chinese satellites on orbit than U.S. ones. All of them were of far lesser value to the country’s defenses. Space-based data and services were not nearly as integrated into the functioning of the military, government, and economy as they were in the United States. China was far less vulnerable to attacks on its assets. An architecture of deterrence consisting of opposing space systems was not possible. U.S. think tanks began to study the consequences of the Chinese anti-satellite weapon for specific scenarios that might oppose U.S. and Chinese forces. For the first time, some specialists

1149 For example, the first Chinese data relay satellite was launched only in 2007.
1150 Marquez, “Space Deterrence: The Prêt-à-Porter Suit for the Naked Emperor.”
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concluded that, in a confrontation with China in the Taiwan Strait, the United States could no longer be certain to achieve its political objectives. 1151

Examined in these ways by U.S. experts, the Chinese test made bilateral civil cooperation and export control reform impossible. A minority of space experts who had advocated engaging China on space issues before the test was further marginalised after the event. More convinced than ever that Chinese intentions in space were hostile, mainstream U.S. space experts emphasised the need to preserve U.S. national leadership in space. Some experts stressed reinforcing space cooperation within alliances and strengthening relationships in space with China’s regional rivals India and Japan. Their proposals, interpreted in turn by Chinese experts, provided decisionmakers in Beijing with further evidence that the United States intended to contain and encircle China. 1152 The test chilled an already tense bilateral relationship, putting reform of controls on U.S. space exports to China “off the table.” 1153

U.S. space experts’ discourses turned to solutions in the form of technological improvements. These included building redundancy into U.S. space systems, hardening space assets against interference, and achieving the capability to replace degraded satellites within hours. Others suggested new constellation designs, replacing the large satellites carrying multiple instruments used by defense organizations with distributed architectures of several smaller satellites, each on its own a less attractive a target. In short, U.S. experts proposed

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1153 Informal consultation with senior satellite industry participant familiar with U.S. export controls, Interviewee 16-03-00, Washington, DC, 2010.
patching technological vulnerabilities with greater investments in technology or, as space expert Joan Johnson-Freese put it, by “seeking funding for hardware to protect our hardware.”

4.4. The cultural production of foreign space systems as threatening

Specialists in both China and the United States reproduced and disseminated depictions of the U.S. military as reliant on vulnerable space systems. Expert representations of these fragile space systems as conferring great advantages upon the United States established the space sector as a setting for asymmetric warfare. In the United States, these representations entrenched an understanding of Chinese advances in space as targeting the U.S. military’s vulnerabilities and undermining a pillar of U.S. power. U.S. specialists produced the Chinese anti-satellite test as preparing the PLA for a confrontation with U.S. forces in space. These depictions maintained a consensus among U.S. policymakers on maintaining strict export controls to minimise the risks of space technology transfers to China. In China, these same representations reinforced policymakers’ consensus on forging ahead with major defense space programs, including efforts to both modernise the PLA with space technology and develop counter-space capabilities that could be used against a technologically superior adversary. Through their representations, experts rendered bilateral trade and cooperation even more unlikely. They aggravated suspicion and tension between the two governments.

5. Producing China-U.S. space competition as imminent

Events after 2007 aggravated bilateral relations to such an extent that experts in both countries predicted an imminent China-U.S. space competition or even a space war. In 2008, the U.S. government decided to shoot down a satellite in a procedure similar to the Chinese anti-

\[1154\] Johnson-Freese, Heavenly Ambitions, 102.
satellite weapon test. Called “Burnt Frost,” the mission’s official goal was to destroy a malfunctioning U.S. satellite, U.S. 193, whose uncontrolled descent toward Earth posed a public safety threat. Chinese experts interpreted this U.S. manoeuvre as a response to the Chinese anti-satellite test of the previous year, galvanising their conviction that U.S. hostility was growing. Chinese specialists predicted an arms race in space and a new round of international space competition, some asserting that a space war loomed. U.S. experts similarly drew on their technologically deterministic histories of warfare to argue that a war with China in space was an imminent reality. With experts in both countries convinced that space was the next battleground in their rivalry, bilateral cooperation and trade in the sector became inconceivable to the space community. Policymakers in the United States determined to maintain strict controls on space exports to China and to further restrict technical cooperation between the two countries civil space institutions.1155

5.1. The 2008 U.S. satellite intercept as a response to the Chinese anti-satellite test

Scientists and experts in the United States, China, and other countries, including Russia and India, met the official justification for the intercept of U.S. 193 with scepticism.1156 In China, space specialists expressed a mounting sense of inevitable competition after Burnt Frost. They represented the decision to shoot the satellite down in the manner of the Chinese test conducted shortly before as an unmistakeable message that the U.S. would not allow threats to its hegemonic position. In this view, the U.S. military intercepted a satellite to show China that it also had the capability to destroy other countries’ space assets. For example, a space expert in

The PLA’s AMS said that Burnt Frost was “a signal to China” that the United States would not allow a challenger to emerge.\(^\text{1157}\)

Analysing the event, space analyst Li Daguang wrote that “the curtain of space war is opening (太空战帷幕正在拉开).”\(^\text{1158}\) He went on the cite a U.S. expert to argue that

[… the threat brought against other countries' space systems by the United States is initiating a round of space arms race. China’s 2007 anti-satellite weapon test was a warning to the United States that no country can "seek hegemony in space." In response, the United States in 2008 destroyed one of its own out-of-control spy satellites, revealing to the world U.S. forces capability to strike space targets. In that satellite-destroying action, the U.S. navy launched a missile into space from an Aegis destroyer, successfully shooting down the target satellite. This attempt also suggested to Russia and China that the Aegis missile defense system has an assault capability, able to serve as part of the United States's primary offensive capability. 美国对其他国家太空设施带来的威胁正在引发新一轮太空军备竞赛。2007年中国进行的反卫星武器试验就是在警告美国,任何一个国家都不可能“称霸太空”。作为回应,美国于2008年也摧毁了一颗本国的失控间谍卫星,向世界展示了美军打击太空目标的能力。在这次打卫星行动中,美国海军从一艘“宙斯盾”舰上向太空发射了一枚导弹,成功地击落了目标卫星。这次试验也向俄罗斯和中国发出暗示——“宙斯盾”导弹防御系统有进攻能力,可以充当美国第一打击能力中的一部分.\(^\text{1159}\)

The effects of the test on bilateral relations were profound and enduring. As U.S. observers updated their assessment of China’s capabilities, they also revised their beliefs about its intentions. Chinese and U.S. interests in space were, in their view, fundamentally at odds.

5.2. Space competition between China and the United States is imminent

Over the course of the decade after 1999, Chinese space experts grew more pessimistic about their country’s security in space. At the beginning of this period, they had represented

\(^{1156}\) Johnson-Freese, Heavenly Ambitions, 110–114.
\(^{1157}\) Interview with retired officer in the People’s Liberation Army who worked in the GAD, Interviewee 08-26-03, Beijing, 2010.
\(^{1159}\) Ibid.
space as a relatively benign and pacific environment. For example, in 1999, GAD space systems engineering expert Huang Zhicheng wrote that “the tendency toward outer space competition has greatly abated (当前, 总的趋势是空间竞赛的势头已大大减弱).”\textsuperscript{1160} As late as 2004, space security expert Wang Xianfeng, still advocated China-U.S. space cooperation as a means to mitigate mistrust and the “latent potential for conflict” in space.\textsuperscript{1161} By the end of the 2000s, however, both Chinese and U.S. space specialists saw international relations in space as deteriorating. Some U.S. observers believed that a space competition with China was either imminent or already under way.

Chinese specialists argued that tensions and hostilities with the United States in space would take the form of a bilateral or multilateral competition, a space arms race, or a race to land a craft at a distant space destination. For example, space expert Liao Chunfa predicted an all-but-inevitable competition. He described a trend “toward a new round of international space competition (将对新一轮国际太空竞争).”\textsuperscript{1162}

After each country's space activities experienced a decline during the ten years following the end of the Cold War, they stepped onto a track of rapid increases anew, presaging another round of international space competition surreptitiously and turbulently surging up. The difference with the Cold War U.S.-Soviet struggle for supremacy lies in that: this time it is not a space race, but a space competition, it is a competition for comprehensive national power between great powers, specific manifestations ensure or promote great power status, strengthening science and technology, economic and military competitive power. That investing in space is investing in the future has already become consensus among and a strategic choice for major space powers. 各国航天投入在经历了冷战结束后的 10 年低迷之后，重新步入快速增长的轨道，预示着新一轮国际太空竞争热潮正在暗中涌 动。与冷战时期美苏太空争霸的不同之处在 于: 此次不

\textsuperscript{1160} Huang Zhicheng (黄志澄), “Thought of Space Strategy for Our Country in Early 21st Century (对 21 世纪初我国航天发展战略的思考),” 1.
\textsuperscript{1161} Wang Xianfeng (王显峰), “Questioning ‘China-U.S. Space Conflict Theory’ - The Equally Possible Theory of China-U.S. Space Cooperation (‘中美太空冲突论’质疑—兼论中美太空合作).”
More pointedly, Liao wrote

following the successful crewed flights of Shenzhou 5, 6, China, in a second round of international space competition, became the focus of international attention as a strong international competitor. [1163]

Shuai Ping also claimed that a new round of space competition was underway. Shuai saw U.S. technology development programs, in particular in next-generation satellite navigation systems, as reflecting its larger agenda of space control and space dominance and its mission of denying China access to the space environment. Shuai relied on the same representational practices as U.S. space theorists, producing space systems as the culmination of technological advancement in warfare over time and across domains. [1165]

[...] since the start of the twenty-first century, each major space power, especially the United States and Russia, have taken many actions, including establishing space war forces, carrying out space war simulation exercises and formulating various space control plans, projects and war-fighting rules, as well as researching and developing various anti-satellite weapons, etc., for nothing if not to prepare for future space offense and defense. [...] in the new round of international space competition, including satellite security, ensuring the freedom of entry into and exit from space, and strengthening space posture and capabilities, the emphasis is already on the U.S. head start in space development. 进入21世纪以来, 各航天大国尤其是美国和俄罗斯采取的许多举措，包括组建天军战部队，进行太空战模拟演习和制定各种空间控制规划，计划和作战条令以及研究开发各种反卫星武器等，无一不是为未来的空间攻防做准备。在新以轮国际太空竞争种，保护卫星的安全，确保出入太空的自由和增强太空态势感和能力已成为美国优先发展的重点。[1166]

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[1163] Ibid.
[1164] Ibid.
[1166] Ibid.
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In addition to those anticipating a general competition in space, other analysts in China predicted that nation-states would be forced into a worsening arms race. For example, Wei Zhixiong and Rong Wenfang described the technological momentum toward a space arms competition. They wrote that “the outer space arms race is more intense with each passing day, following the development of outer space technology, outer space militarisation is currently intensifying (外空军备竞赛日趋激烈， 随着外空技术的发展， 外空军事化正在加剧).”\(^{1167}\)

Xu Nengwu of NUDT described the challenges to stability and security in space as nearly insurmountable. He saw an inherent tension between, on the one hand, hegemonic U.S. ambitions and the momentum toward an arms race and, on the other hand, space diplomatic efforts. Diplomacy could not constrain U.S. hegemony, he wrote.\(^{1168}\)

Since always, the world's countries have had common security interests in issues of the peaceful exploitation and use of space, but in reality space security cooperation is by no means smooth, especially because it depends on the United States as the absolute all-around champion of space development, doing the utmost to strive for absolute security and absolute hegemony, incessantly scheming to realize a global strategy to seek even more support. It is precisely this difference of interests that makes space security diplomacy efforts insufficient to develop the necessary approvals and address opposition to common interests, it is because the United States in the space domain today occupies an outsize weight that space security diplomacy can become merely a formality. 尽管世界各国在太空和平开发与利用 问题上存在着共同安全利益, 但实际中的太空安全 合作却开展得并不顺利, 特别是美国凭借其在太空 发展的“全能冠军”的绝对优势, 极力谋求绝对安 全和绝对霸权, 总是处心积虑地为其全球战略实现 寻求更为有力的支撑。正是在这一利益上的歧异, 使 太空安全外交努力发展所需的“肯定”或“否定”的 共同利益都严重不足, 因为美国在太空领 域目前占有的分量决定没有它参加的太空安全的外交努力只会流于形式.\(^{1169}\)

\(^{1167}\) Wei Zhixiong (魏志雄) and Rong Wenfang (荣文仿), “Development of Outer Space Militarisation and Its Challenge to Our Country’s Security (外空军事化的发展及对我国国家安全的挑战),” 66.
\(^{1169}\) Ibid.
Finally, some Chinese specialists predicted that tensions between China and the United States in space would take the form of a race to land a vehicle at a new destination, much in the way that the United States and Soviet Union had competed to land a human on the Moon. Space security expert Lu Junyuan illustrated a growing preoccupation among Chinese scholars with achieving a second human lunar landing ahead of the United States. In this prediction, Lu reproduced the practice of representing space as the next strategic high ground, situating his anticipated future in a linear historical process.

Since the start of this new century, the world’s main powers have surged toward a new wave of space competition for a human landing on the Moon. In the geopolitical structure of space, the Moon occupies a strategic position. It is a commanding height from which to control the Earth below, it is a gateway to solar space above. [...] Great powers compete to land on the Moon. 新世纪以来，世界主要力量掀起了新一波以登月为重要目标的空间竞争。月球在太空地缘政治结构中具有特殊的战略地位，它是下控地球空间的制高点，上通太阳空间的门户[...] 大国竞相登月。1170

5.3. The cultural production of China-U.S. space competition as inevitable

As experts in both countries reproduced and diffused these representations of the sociotechnical systems in their sector to policymakers and other sectoral participants, they aggravated suspicions, tension, and hostility between the two national space communities. In the United States, these experts’ representational practices perpetuated agreement among policymakers on the need to maintain strict export controls blocking trade and cooperation, even as the costs of this policy mounted. Through their representations, experts also prescribed programs to continue developing advanced military space systems, including those with counter-space applications. In China, these expert representations entrenched an understanding of U.S.

motives in space as hostile and hegemonic among sectoral participants. Through these discursive practices, experts prescribed programs to develop China’s military space capabilities. As their representational practices escalated suspicion on both sides, they all but ensured that the two countries would not trade or cooperate in space.

**Conclusion**

Space experts in both China and the United States drew on common representational practices to produce the space sector as a site of growing tension and hostility and as an arena in which bilateral trade, industrial integration and civil cooperation were infeasible and undesirable. U.S. and Chinese experts’ descriptions produced the sector as a likely site of bilateral economic and security competition, prescribing policies for the autonomous development of national space capabilities. U.S. specialists’ descriptions of the sector implicitly prescribed maintaining barriers to the trans-boundary movement of space articles, blocking bilateral trade and cooperation.

Experts’ authoritative representations of the sector helped create agreement on four specific space policy and programmatic needs among policymakers in the United States and China. First, experts produced the global space sector as consisting of several competing national space industrial bases. In the process, they implicitly prescribed controls on the transnational movement of space items and prescribing the development of national space capabilities. Second, Chinese space specialists produced U.S. export controls as a hostile containment strategy targeting China. These representations created and sustained agreement on the need to develop autonomous capabilities and aggravated bilateral tension. Third, experts in both countries represented space systems as rendering the U.S. military vulnerable to asymmetric attacks. In the United States, these experts produced the maintenance of strict export controls on space items as necessary and Chinese advances in space technology as threatening. Fourth, experts in both
countries represented a bilateral confrontation in space as looming or inevitable, creating a consensus among policymakers in each country that policies and programs to build and enhance national space capabilities were necessary. Within the U.S. space community, these expert depictions also entrenched support for maintaining strict export controls.

In depicting the sector in these terms, space experts performed representational practices that conveyed their common understandings of the human-machine and society-technology relations. Their underlying notions of technological conditions as shaping social and political outcomes, of technical processes as eluding human control, and of space systems as intrinsically potent surfaced in these discourses. As specialists circulated and entrenched their representations of the sector among policymakers, they conveyed these philosophical convictions and implicitly prescribed policies and programs compatible with them. These policies and programs formed the hostile and competitive bilateral order in the sector, within which relations between the two countries grew tense and the likelihood of trade and cooperation remote.
Part IV:
Conclusion
Conclusion

Introduction

This final chapter begins with a review of the main argument of the dissertation and the findings about bilateral relations in air and space introduced in Parts II and III, respectively. The second part discusses the limitations of this project and possible solutions. The third part draws out the implications of the findings for international relations theory, for the empirical study of China-U.S. relations, and for methodology. The final part of this chapter proposes further avenues of research based on this project.

1. Main arguments and findings

The main argument of this dissertation is that the variation in China-U.S. relations across the air and space sectors between 1989 and 2009 owes to the sectors’ distinct specialist cultures. Transnational specialists in each sector shared a tacit background philosophy of human-technology relations, which they expressed in common practices of representation. When specialists in a sector performed these practices, they discursively produced their sector and the technologies within it as targets of policy to policymakers and decisionmakers in their country. In the process, they tacitly prescribed policies consonant with their underlying philosophy of human-technology relations. Specialists constituted their sector as a particular kind, requiring certain types of state action and unsuited to others. Specialists’ representational practices created the environment within which policymakers and decisionmakers in both countries reasoned about and adopted sectoral policies. In the air sector, these policies were conducive to bilateral trade, industrial integration, and technical cooperation. In the space sector, these policies fostered mutual suspicion, tension, and competition.
The two different outcomes in air and space cannot be understood without examining the constitution of technological artefacts in each sector and of each sector as an object of policy. Sector-specific patterns of China-U.S. interaction are traceable to distinct cultural-technical arrangements, produced in specialists’ practical constitution of technological devices and processes in each sector. Aeronautic specialists expressed their shared individualistic and agential conceptions of human nature and instrumental view of technology in their practice of representing the production and trade of aircraft technologies as commercial, relatively mundane, and manageable through regulation. Space specialists expressed common deterministic, structural, and holist assumptions about humans and technology in their habits of representing space technologies and activities as threatening, unmanageable through rules, and necessary.

Through their practices, aeronautic experts constituted the context facing sectoral policymakers and decisionmakers in each country. Within this setting, sensible policies were those that promoted aircraft trade and exports, fostered the mutually beneficial integration of the two national aircraft industries, and allowed technical cooperation. Space experts also created the sectoral context before policymakers and decisionmakers in their representational practices. They produced as sensible and intuitive policies that prevented trade and cooperation and the interpretation of the other country’s technology development programs as intrinsically menacing.

The air sector presented a mix of incentives and disincentives for bilateral integration and cooperation similar to the space sector’s. However, in contrast to space, in the air sector both governments adopted and maintained policies that allowed and supported trade, industrial integration, and cooperation. Policymakers and decisionmakers judged that the benefits of bilateral trade and cooperation outweighed their costs and risks. Trade and economic priorities guided U.S. policy toward China in the air sector. In the space sector, these interests subordinated to national security interests and technology transfer concerns. Policymakers and
decisionmakers reasoned that national security could under no circumstances yield to trade and commercial interests.

Specialists’ representational practices supplied policymakers and decisionmakers in each country with a common sense of what policies their sector required. As communities of specialists in China and the United States reproduced and circulated their tacit background philosophies in these practices, they produced and maintained agreement on this common sense. Through representational practices, specialists constituted their sectors and technologies as objects of policy, defined the ends of policy, and created agreement on what policy measures were possible and plausible in their sector. As specialists’ descriptions expressed their community’s underlying philosophy of human-technology relations, they also implicitly prescribed the policies adopted in both sectors.

2. Limitations of argument and research

This argument and the research behind it are subject to limitations. These limitations range from general theoretical and research design issues to more specific problems of observation and measurement. Some of these limitations are intrinsic to the subject matter, others could be addressed or overcome in future research efforts.

2.1. Inductive research design and generalisation

This research project was designed to answer a specific empirical question through an inductive process. A secondary objective of this project was to work toward the development of a theoretical perspective. In the course of this inductive process and an iterative cycling between inductive and deductive modes of inquiry, it became possible to formulate theoretical concepts. These concepts form a theoretical perspective on this particular research problem, but the
generalisability of this theoretical perspective is unknown. This research is best understood as having allowed the formulation of some concepts, which may be extended to other settings. These concepts included factors, such as “specialist culture” and “philosophy of human-technology relations.” This project did not yield a formal statement of relationships between factors or variables that we can expert to observe regularly. Instead, the outcome of this research is the formulation of theoretical concepts of bounded generalisability.

2.2. Conditions of possibility vs. specific mechanisms

This thesis accounts for how actors created the conditions of possibility for the distinct bilateral outcomes observed in air and space over a twenty year period. Because of the scope and nature of the explanation, this approach did not unpack and examine mechanisms or processes through which particular decisions were made or events occurred. This type of argument and theoretical perspective are not suited to explaining particular point-in-time phenomena, but rather account for general tendencies, possibilities, and, at most, likelihoods in developments over long stretches. Thus, this research does not explain the adoption of particular policies, the timing of given events, or why one of several similar policy options was chosen over others.

2.3. Comparability of the sectors

As discussed in the first chapter, the air and space sectors are not identical. They present significant differences. Some observers assert that the space sector is unique and does not admit of comparison with any other sector. In spite of these limitations and objections, I maintain that these sectoral are comparable enough for my purposes. The air sector offers the best possible frame of comparison for the space sector and vice-versa. Other conceivable candidates for comparison, such as the nuclear energy, biochemical, or information technology sectors, are far
worse fits for comparison with air and/or space. Moreover, the semi-structured comparative research design made it possible to explore whether differences between the air and space sectors, other than in their specialist cultures, accounted for the variation I sought to explain.

2.4. Assumptions about agency

Readers committed to agential ontologies may find fault with how actors in air and space are represented in Chapters 7 and 11. In these accounts, actors appear to lack agency, receding into the backgrounds rather than driving events. In a sense, this claim about the depiction of the actors is fair, since this thesis argues that the interests and motives pursued by actors are not of their own definition, but supplied by their environments and structures.

Nonetheless, there are two rebuttals to the contention that this account incorrectly overlooks agency. First, this account does not overlook agency, it just represents agency in an unfamiliar form. In fact, actors in this account do exercise agency, since they produce the stability and policy inertia that characterises periods of bilateral relations in the two sectors. As Adler and Pouliot argue, actors’ practices generate stability in international politics.\(^{1171}\) While circumstances facing governments in the two sectors changed over time, certain policies remained the same, even as they grew costly. For example, U.S. aeronautic specialists’ representational practices sustained agreement among decisionmakers on maintaining loose controls on aircraft exports even as evidence mounted that transfers of U.S. aircraft technology were strengthening China’s defense industrial base and threatened U.S. national security.

Second, this representation of actors as having “weak” agency reflects not a theoretical flaw, but rather observations of actors and their actions. These observations suggest that actors often simply were passive vectors for larger impersonal forces, such as cultures or common tacit

\(^{1171}\) Adler and Pouliot, “International Practices.”
philosophies. Specialists, policymakers, and decisionmakers frequently reproduced their sectoral community’s representational practices without significant innovation and without conveying that they had reflexively examined or deliberated their underlying assumptions. Actors may have performed their tacit background knowledges over and over again because they considered them legitimate. They may have also performed such practices because they believed that to do so was competent. Regardless of exactly why any given individual performed these representational practices, the collective reproduction of these practices by specialist communities had a constitutive effect upon policy means and ends in each sector.

2.5. The messiness of specialist cultures

Specialist cultures are in reality less neat than represented here. As discussed in Chapter 2, specialist communities are sites of contestation, disagreement, and controversy. Specialists’ basic philosophical assumptions are neither homogenous, internally consistent, nor stable. This account focuses on dominant tendencies and draws out generalisations about aeronautic and space specialist representational practices, omitting some of the variation and discrepancies at the fringes of these communities or with particular individuals. In negotiating the trade-off between empirical fidelity and lucidity of exposition, I sacrificed some of the former for the sake of the latter.

2.6. Obstacles to observation and measurement

Some of the phenomena and factors examined in this account are difficult or impossible to observe directly or measure reliably. For example, significant methodological challenges attend efforts to assess the material impact of export controls on the U.S. satellite industry’s performance. Studies by think-tanks, FFRDCs, industry associations, and government agencies
surveyed in Part III demonstrate these limitations. Moreover, conflicts of interest between analysts and the objects of their analyses compromise the reliability of some of this research.

Recognising these limits on the theoretical claims and research findings, I took measures to address them where possible and to hold them in view and acknowledge them where it was not. In spite of these challenges, this study yields several contributions to our understanding and knowledge of its topics and of international relations in general.

3. Contribution to the study of international relations

The conclusions and findings of this research carry three sets of contributions to the study of international relations in general, for the study of China-U.S. relations in particular, and for the study of the air and space sectors. These contributions are theoretical, empirical, and methodological.

3.1. Contributions to international relations theory

The theoretical constructs and findings to emerge from this study have several implications for theories of international relations. These implications have to do with explaining sectoral variation within bilateral relationships, the formation of the interests that actors pursue in given policy domains, the discursive and practical constitution of technologies, and the role that background philosophies of human-technology relations play in international orders.

3.1.1. Sectoral variation within international relationships

Influential theories of international relations, including variants of realism and liberalism, overlook or underdetermine important sectoral variation within the China-U.S. relationship. This variation exists in both the economic and security dimensions of the relationship.
Generalizations about the state of bilateral trade or security relations obscure these sectoral differences. The field’s theoretical perspectives struggle to explain relations between states that are at once strategic rivals and mutually reliant trade partners. This project draws attention to sectoral variation and presents an attempt to account for it.

The theoretical and practical stakes of overlooking sectoral variation within the bilateral relationship are high. Some of the most influential perspectives on international relations characterise the China-U.S. relationship as almost uniformly competitive or cooperative. Power transition theory, for example, predicts that the two countries are likely to challenge each other as they approach power parity. As a rising China’s aggregate power approximates that of the established and dominant United States, both sides will be tempted to initiate a confrontation. From liberal-economic or game-theory perspectives, the two actors should seek an equilibrium where each is better off than otherwise, given the other’s choices. These approaches view as optimal an outcome in which the two countries agree not to fight in order to each realise their overarching common interest in avoiding war and maximising trade.

In fact, China and the United States are neither on a unidirectional slide toward competition and war, nor on a straightforward trajectory toward trade and cooperation. Instead, they constantly engage each other at myriad sites, competing in some and cooperating in others. Pockets of tight industrial integration and interdependence coexist with pockets of intense suspicion and mutual isolation. China-U.S. relations are in this sense compartmentalised. Within specialised sectors, bilateral interactions proceed with some autonomy from developments in other areas of the relationship, an internal inertia keeping them on their own steady course. Specialist communities perform representational and other practices that maintain this stability, to a degree insulating bilateral relations in their areas from spill-overs from other parts of the bilateral relationship.
3.1.2. Interest formation

The theoretical perspective proposed in Chapter 2 aims to help explain why and how actors pursue different types of interests in ostensibly similar settings. The national interests that governments pursue in high-technology sectors are neither given nor objectively perceived from without, but rather constituted in experts and policymakers’ acts of representation and understood within a context of shared meanings. Theories that assume interests to be given or in a sense ontologically prior cannot explain why governments act to pursue or prioritise some national interests, but not others, in similar domains. As this research shows, on their putatively technical features alone, commercial air and space systems both presented important defense implications. If national security were intrinsically the most fundamental and important of interests that states pursue through policies, then aircraft and space technologies would have been subject to similarly strict U.S. export controls. Instead, experts discursively produced the air sector as a site engaging U.S. trade and commercial interests and the space sector as engaging U.S. national security interests. Consequently, U.S. policymakers in the air sector made trade promotion and export competitiveness their goals while those in the space sector aimed to protect security interests and deny China sensitive technologies at virtually all costs.

3.1.3. The constitution of technological artefacts

This project points to theoretical insights from technology studies to conceptualise how actors constitute technological artefacts in representational practices. This approach marks somewhat of a departure from standard treatments of technology in the field of international relations.

International relations theory has tended to treat technologies and technological change as exogenous to, analytically separate from, or ontologically prior to international politics.
Constructivist theory has made inroads into such widely held understandings by exposing how the technologies at stake in international politics can be put to different uses depending on actors’ norms, identities, and interests. In many of these accounts, however, technological artefacts, such as nuclear weapons, remain treated as given and ‘closed.’ Their autonomous existence as such, as the objects they are taken for granted to be and with the features and functions we typically ascribe to them, remains unquestioned. Even when politics and technology are recognized to ‘interact,’ the two remain treated as analytically separable in a way that obscures the thoroughly social and cultural nature of technological artefacts and technical work. This treatment of technology and theories based on it do not easily account for the different outcomes observed between China and the United States in the air and space sectors.

Theory and research in the field of science and technology studies rejects this problematic division. Scholarship in this field proposes instead that the social world is best represented as arrangements, or configurations, of co-constitutive human and non-human elements. These compositions are held together by ordering and representational practices, which tie together material artefacts and meaning-making activities. As John Law argues in his study of military aircraft, technological artefacts do not exist and are not knowable apart from the stories we tell about them. Long before and long after it leaves the factory, hardware is produced in discourses and practices. As this project suggests, examining the constitution of technological

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1173 Richard Price’s The Chemical Weapons Taboo is a counter-example to this trend.


1175 E.g. Law and Callon, “Engineering and Sociology in a Military Aircraft Project.”

1176 Latour, Reassembling the Social.

1177 Rouse, “What Are Cultural Studies of Scientific Knowledge?”.
artefacts across different sectors produces insights into why some high-technology sectors are sites of trade, industrial integration, and technical cooperation, but not others.

3.1.4. Tacit philosophies of the human-technology relationship

An implication of these research findings is that abstract assumptions about the relationship between humans and their tools formed part of the epistemic basis of international orders in particular high-technology sectors. These philosophical assumptions were part of the background knowledge encapsulated and expressed in actors’ representational practices, which in turn constituted the means and ends of sectoral policies adopted by governments. These philosophical assumptions were unique to particular communities of specialists. The content of these common assumptions was not deducible nor structurally supplied, but rather evolved in a historically contingent way. The assumptions were shaped by the confluence of particular currents of thought and discourse in situated intellectual communities. Where channels existed to diffuse these underlying philosophies and the practices that conveyed them, they spread to new communities.

3.2. Contributions to the empirical study of international relations, air, and space

The empirical findings of this project carry implications for scholarship about international relations and about the air and space sectors. The first of these implications has to do with sectoral similarities and differences documented in aeronautic and space specialists’ representational practices. The second implication is for how China experts and international relations specialists characterise the flow of U.S. knowledges and practices to China. The third implication pertains to prevailing characterisations of China’s defense innovation effort.
3.2.1. The trumping of national culture by sectoral culture

This research indicates that the views of scientists’ and engineers’ with input into policymaking were more strongly shaped by their membership in a sectoral community than by their nationality. This research points to the existence of two distinct communities of sectoral specialists, whose membership transcended national boundaries. At the level of basic philosophical assumptions and habits of speech, a Chinese space engineer had more in common with a U.S. space engineer than with their compatriot working in aeronautics. This observation runs counter to a conventional wisdom that assumes Chinese and U.S. individuals, including policymakers, hold different worldviews and perspectives about technology, trade, and the international environment. Instead, these national differences are tempered by significant variation across high-technology sectors and specialist communities.

3.2.2. Chinese adaptations of U.S. policy discourses

This research indicates that Chinese specialists’ representational practices of the 1990s and 2000s were in large measure derived from U.S. specialists’ discourses of the same period. However, the Chinese adoption of these foreign representational habits was more than a passive reception of them. Chinese specialists appropriated and reworked U.S. experts’ representations to suit their own context and agendas.

For example, as Chinese military space experts reproduced U.S. discourses about the Revolution in Military Affairs, they married them to Jiang Zemin’s concept of technology as a productive societal force. The result of these adaptations was a distinct hybrid, a mode of expression sharing elements of a transnational specialist culture but particular to China’s military space community. In another layer of interpretive process, these particular hybrid representations of space technology from China later (re)circulated among U.S. space experts and defense
intellectuals. Translations of Chinese texts and analyses of evolving Chinese space policy and doctrinal ideas about military space introduced U.S. space specialists to Chinese adaptations of U.S. ideas. This cultural feedback loop mattered because U.S. experts tended to find confirmation of their fears and anxieties about China’s technology modernisation effort in the Chinese texts that expounded on them, further aggravating bilateral suspicion and tension.\textsuperscript{1178}

This process and its diverse manifestations carry implications for academic and applied research in China, the United States, and other countries. Researchers aware of these issues can bring a more knowledgeable perspective to their interpretation of Chinese and U.S. sources. In particular, analysts’ awareness of these issues can enhance defense research and analysis on these topics conducted by or for government agencies in China and the United States.

3.2.3. China’s technology development strategies

General representations of China’s effort at and means to acquiring advanced defense technologies obscure variation across high-technology sectors and across products within those sectors. Analyses that attempt to characterise a comprehensive defense innovation system are limited by the specificity of sectors and products. Chinese policymakers faced not only distinct technical demands and different levels of initial capacity in each area, but also unequal degrees of access to foreign technologies across sectors. The result has been a Chinese effort at defense modernization that is less coherent and methodical than it is flexible and opportunistic.

\textsuperscript{1178} This observation corroborates other researchers’ accounts of this phenomenon. E.g. Kulacki, “Lost in Translation”; Kulacki and Johnson-Freese, “Significant Errors in Testimony on China’s Space Program”; Kulacki, \textit{Anti-Satellite (ASAT) Technology in Chinese Open-Source Publications}; Kulacki and Lewis, “Understanding China’s Anti-satellite Test.”
3.3. Implications for research methods in the study international relations

This research project suggests methodological insights applicable to the study of China-U.S. relations and of other relationships in international politics. The implications of this work pertain to comparative research design and to data collection methods developed in cultural studies of technology.

3.3.1. Semi-structured sectoral comparison

The research design for this project suggests that semi-structured comparisons of China-U.S. relations in different domains are a helpful means to examining under-theorised and overlooked aspects of the relationship. The co-occurrence of tight industrial integration and worsening security competition within the China-U.S. relationship poses a challenge to international relations theorists. A promising way of developing theoretical purchase on how such opposing tendencies persist lies in comparing contrasting sectors, issue-areas, or domains within the relationship.

3.3.2. The untapped potential of methods from technology studies

This project suggests that data collection and other research methods developed in science and technology studies can help shed light on how actors make technology policy. In particular, concepts from this field can guide how international relations specialists examine, observe, and document actors’ constitution of technological artefacts and specialised sectors in practices. In this project, the concepts of human-machine interaction and sociotechnical arrangements also informed how I observed and analysed specialist discourses about aeronautic and space technologies. Researchers have so far underexploited methods from science and technology studies in their study of technology policy and technocratic rule in China, although many have
used these tools to study U.S. and European technology policies and programs. I argue that these tools are indispensable to accounting for aspects of China’s relations with the United States.

The theoretical, empirical, and methodological insights to emerge from this project point to the overarching conclusion that deductive approaches to the study of China-U.S. relations and air and space policy are limited. Theoretical perspectives that posit trans-historical and context-independent regularities in international politics offer only weak purchase on the research problem examined in this study. The phenomena I sought to examine and explain are best understood in a perspective that gives play to their historicity, particularity, and context. Approaches suited to these objects of inquiry are based on inductive, empirically-driven research designs and conducted with a view to developing theoretical constructs of bounded generalisability.

4. Avenues for further study

The theoretical and empirical results of this research suggest several questions and issues that could be further explored. These include theoretical challenges, empirical questions, and methodological opportunities.

4.1. The instrumental use of practices

While this project did not dwell on the micro-foundations of practice performance or individual motives for reproducing practices, it suggests questions about this level of analysis. According to practice theorists, actors reproduced representational practices in part because these were well understood and tapped into their typically un-scrutinised common background knowledges. These same features of representational practices made them rhetorically effective vis-à-vis particular audiences. Did individual actors naively and un-self-consciously perform
these practices? Or did individual actors make strategic choices to utilise these practices because they recognised that they were useful means to their ends? Or did they do both? Preliminary evidence suggests the latter.

These questions intersect with issues examined in the fields of engineering ethics and the ethics of science and technology. Scholarship in these areas is concerned with how actors allocate responsibility, authority, control, autonomy, and other normative goods across humans and machines in their practices. For example, researchers in these fields explore how engineers discursively shift the burden of responsibility for catastrophic technical failures from human decisionmakers to automated systems.\textsuperscript{1179} Like the air and space specialists in this study, these engineers tap into background philosophies of human-machine relations when they engage in these practices. Scholars who study the ethics of automation explore and engage these same philosophical assumptions and ideas when they discuss the appropriate limits of decision-making by machines in warfare. Far from theoretical, these questions arise in concrete form as automated, autonomous, or remotely piloted systems, such as drones and unmanned satellites, play greater roles in defense.\textsuperscript{1180} These normative perspectives on technology could enrich the study of representational practices within specialist communities and vice-versa. Cross-fertilisation between these areas appears promising.

\subsection{4.2. Mechanisms for the diffusion and maintenance of specialist cultures}

This research suggests that cultures internal to specialist communities traveled across national borders. It also hints at some of the channels through which background knowledges and representational practices reached new communities. Specialists routinely engaged in

\begin{footnotesize}
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\item \textsuperscript{1179} I thank Park Doing for this insight.
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activities that allowed them to disseminate their knowledges and practices to sectoral fellows in other countries, including by participating in international conferences and meetings, reading and publishing in internationally circulated journals, and participating in international cooperation projects and trade. Through these media and at these occasions, transnational specialist communities emerged in the air and space sectors. These examples invite further research on the mechanisms that diffuse and maintain transnational specialist cultures.

4.3. China-U.S. relations in other sectors

This research suggests that specialist communities’ practices may help or hinder China-U.S. trade, industrial integration, and technical cooperation in high-technology sectors beyond air and space. Examples of other sectors in which these processes may have occurred include nuclear energy, biotechnology, and computer hardware and software development and manufacture. A cursory glance suggests that extending this analysis to additional high-technology sectors could shed further light on why and how pockets of competition and cooperation coexist in the China-U.S. relationship.

In particular, there is promise in expanding this study to include a third, contrasting sectoral case of bilateral relations during the same period: the cyber technology sector, comprising both software development and hardware manufacture. Examining this case would require surveying China-U.S. relations in this domain and investigating the emergence of specialist cultures in the cyber security and cyber commerce communities of these two countries. In contrast to the air and space sectors, in which a transnational specialist culture was shared across China and the United States, the cyber technology sector shows evidence of two distinct national specialist cultures. Future research could explore why and how this situation obtained
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despite substantial bilateral industry integration in this sector. It could also evaluate the prospects for bilateral trade and security relations in this increasingly contentious area.

A study of the cyber sector could add value to this overall research effort in several ways. First, studying cyberspace would provide indications of whether and how this theoretical framework can be extended to other high-technology sectors, helping to define the boundary conditions of my claims about air and space. Moreover, trade and security challenges in cyberspace are intertwined with those in space, requiring one to address the linkages and contrasts between these different areas. Second, an analysis of China-U.S. relations in cyberspace would illustrate that specialist cultures can remain localised despite significant international trade in a high-technology sector. A comparison of the air and space cases with this contrasting domain could help establish and demonstrate that the trans-nationalisation of the aeronautic and space specialist cultures was a historically contingent process, rather than an inevitable consequence of economic globalisation and technological diffusion. Examining this new case could lend empirical support to or cast doubt upon this part of the argument.

4.4. Trade and cooperation between other countries in air and space

This project raises the question of whether the representational practices of aeronautic and space specialists help or hinder trade and cooperation in other international relationships. At first glance, some of the processes shaping China-U.S. relations in these sectors also appear to be at work in other pairs and groups of states in the air and space sectors. For example, industrial integration between the economies of the United States and Europe is far greater in aircraft manufacture than in spacecraft manufacture. The same is true of China and Japan. More broadly, global trade, industrial integration, and technical cooperation tend to be more substantial in the air sector than in the space sector by most measures.
However, there are significant exceptions to this trend, indicating that it is by no means inevitable or given. Space was the site of some of the largest, most costly, and riskiest technical cooperation projects, even between antagonists at the height of the Cold War. Over the two decades under study, the two former rival superpowers together constructed and operated the ISS. During that period, U.S., Russian, and Ukrainian firms collaborated to jointly manufacture and operate launch vehicles, sharing items export-controlled as missile technologies. Substantial industrial integration and technical cooperation between strategic adversaries were possible in space.

Since 1989, perhaps the most potent determinant of the level of trade, industrial integration, and technical cooperation in both global sectors has been the U.S. export control regime. This rigid set of measures persists at least partly because U.S. sectoral specialists sustain it as necessary and legitimate in their representational practices. Further research could investigate these propositions or generate alternative explanations for this sectoral variation at the global level and for the persistence of particular U.S. export controls.

### 4.5. Other forms of representational practice

This research on specialist cultures focused on how experts represented sociotechnical systems in discourses, but specialists also represented human-technology configurations in countless other forms. These included visual modes of representation, such as illustrations, photographs, charts, maps, and tables. The methods used to detect and understand specialist cultures in the two sectors could be enhanced by complementing them with methods to observe and analyse these other forms of representation. Qualitative research in political science and in
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**Final remarks**

In sum, this project offers a glimpse into relations between great powers in demanding, strategic high-technology sectors through the window of China-U.S. relations in air and space between 1989 and 2009. The findings of this research are of limited generalisability in a theoretical sense, but can nevertheless illuminate phenomena in other areas and interest researchers focused on other topics. For example, the findings of this project may interest researchers studying other areas of the China-U.S. relationship, contemporary relations between other major powers, international politics in different high-technology sectors, other aspects of air and space policy in these or other countries, the management of dual-use technologies and strategic trade issues, the ethics of technology policy, and specialist communities in various contexts.
References

“A Brief History of the FAA.” Federal Aviation Administration, February 1, 2010.
http://www.faa.gov/about/history/brief_history/.
A Consensus for Change: Avoiding Aviation Gridlock and Reducing the Accident Rate.

516


521
Cogburn, Derrick L. “Cyberinfrastructure and Epistemic Communities” (2006).
Commercial Aircraft Corp. of China and Boeing Sign Collaboration Agreement to Partner in Areas Advancing Commercial Aviation Industry Growth. Beijing, China: The Boeing Company (Boeing China Communications), March 6, 2012.


Dolven, Ben. “Dogfight over China: The Battle Between Boeing and Airbus Is Intensifying as Chinese Airlines Consolidate to Create the World’s Fastest-growing Commercial Aircraft

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“FAA to Accept Type Certification on ARJ21-700.” *China Civil Aviation Report,* 2012.


Launius, Roger D. “Perceptions of Apollo: Myth, Nostalgia, Memory or All of the Above?” *Space Policy* 21, no. 2 (May 2005): 129–139.


Liu Linzong (刘林宗), Pang Zhihao (庞之浩), Xie Tao (谢涛), and Ding Nan (丁楠). Lunar Exploration Story (探月的故事). Beijing, China: China Astronautics Publishing House, 2008.


——. *The Decision to Go to the Moon: Project Apollo and the National Interest*. Chicago, IL: University of Chicago Press, 1976.


Neumann, Iver B. “Returning Practice to the Linguistic Turn: The Case of Diplomacy.” 


Ning Ling (宁凌), Wang Chun (王春), and Rong Hui (荣晖). *Confrontation in Space (太空对抗)*. Beijing, China: Military Affairs Literature Publishing House, 2006.


Wang Wanchun (王万春), Li Chunzhao (李纯钊), An Peng (安鹏), and Li Ping (李平). *March into Space (进军太空)*. Beijing, China: Blue Sky Publishing House (蓝天出版社), 2008.
Wilkinson, Stephan. “‘Be Quick, Be Quiet and Be on Time’: Lockheed Genius Kelly Johnson’s Words Summed up the Philosophy Behind Several of History’s Most Innovative Airplanes.” *Aviation History*, 2010.


Zhang Yan (张艳). “Using Wisdom to Initiate an Undertaking, Using Painstaking Care to Enrich Human Life - An Interview with the Chinese Academy of Sciences Space Science and Applications Research Center’s Professor Meng Xin (用智慧开创事业 用心血充实人生——中国科学院空间科学与应用研究中心孟新教授专访).” Chinese Scientist (科学中国人) no. 5 (2008).


