China's Civil and Commercial Space Activities and their Implications

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Introduction

I thank the Commission for the opportunity to testify before it on the topic of China's civil and commercial space activities.

The first part of my statement will address the role of space in China's overall development strategy, relating it to different elements of the comprehensive vision of development held by China's leaders. The second part of my statement will survey recent and significant developments in China's civil space programs, setting these in the context of China's space policymaking environment. The third part will discuss China's civil space industry, introducing the major industrial players and the industry's policy landscape. The fourth section of my statement will address the advantages and disadvantages of U.S.-China space cooperation.[1]

Space in China's overall development strategy

The space sector today plays an important role in China's comprehensive development strategy. However, any analysis of the sector's role in overall development is complicated by its unique place and functions in the economy. Moreover, generating concrete benefits to economic development has not been the primary objective of political elites who support the program. As the program has developed and broadened in scope, it has generated more applications and acquired more users in government and enterprises and its potential contribution to China's development has grown.

Sectoral specificity

China's space sector has a complex and evolving relationship to the national economy. Policymakers expect space-sector development to yield positive externalities, such as enabling

[1] This statement is based on sources including: in-person interviews and consultations with current and former participants in the Chinese and U.S. space sectors; primary- and secondary-source documents in Chinese and English, including policy statements, media reports, trade and technical journal articles, and think-tank reports; and remarks made by authoritative Chinese and U.S. space-sector participants at public conferences in China and the United States. Although China's civil and military-intelligence space efforts are closely related, as this panel is about civil space programs, my remarks are confined to civil and commercial space activities. They do not address the relationship between the civil and military space programs, such as civil-military integration efforts.

growth and development in other high-technology industries. At the same time, the space sector has been insulated from many of the pressures affecting the rest of the economy, mainly by its status as a strategic sector and its largely non-market internal relationships.

Because of the space sector's special status, macroeconomic and other aggregate national-level indicators are weak predictors of China's space performance. Prospects for the space sector cannot be directly inferred from the growth of China's gross domestic product or gross national income. Nor can they be read off demographic data, such as characterizations of the workforce's age structure or estimates of the numbers of new scientific and technical university degree holders. Each of these factors will matter, but the relationships between these factors and space-sector outcomes are likely to be non-linear.

Reaching robust conclusions about China's space sector would require an analysis that incorporates national, sector-specific, and firm-level data and models,[2] a process complicated by a lack of reliable information. In the absence of such an analysis, the best inferences that can be drawn about the space sector's role in economic development are primarily qualitative and descriptive. They are also necessarily partial and evolving.

A weak developmental motive

Although the economic impact of China's space activities is growing, for most of the last two decades, economic development was not the primary motive guiding the civil program. By implication, had investments in space during this time focused more heavily on capabilities that directly serve economic goals, the developmental impact of the program would today be greater.

Proponents of the space program since many decades emphasize its potential contribution to economic development. Taking a systemic view of the economy, they argue that space-sector development can "pull" along other sectors. Political elites see the economic, security, and prestige benefits of space activities as inter-related and mutually reinforcing. However, even though the space program has had these economic goals and impacts, concrete development benefits, as we usually think of them, have not provided the main rationale for the program itself or for decisions within it.

The government's allocation of resources in civil space has not been consistent with developmental priorities since 1992, when the human spaceflight program formally began. The areas of space technology known to generate the most direct and reliable contributions to economic development are those with concrete applications, such as telecommunications satellites and remote-sensing satellites for resource management and weather monitoring. The Japanese and Indian space programs, especially in earlier periods, were designed to serve these developmental priorities.

In China, over the past two decades, resources devoted to civil space have been concentrated not in these relatively productive areas, but in a costly human spaceflight engineering program of no evident direct benefit to the national economy. The symbolism of human spaceflight has been an important driver of this effort.

[2] For example, studies of the U.S. space industrial base and its implications for the U.S. economy and national security use these sorts of analyses.

Growth in space usage

Today, the broadening and maturing space program more directly serves specific economic development goals. An important recent change in the relationship of the space sector to the rest of the economy is growth in the usage of space-derived products and services. New indigenously supplied space products and services and new users have emerged. Some of the most rapidly growing new applications are in remote sensing for mapping and surveying, natural-resource management, and urban planning, satellite navigation, weather forecasting, and disaster monitoring and mitigation.

The main users of space-derived data are still primarily central government agencies and large state-owned enterprises,[3] but local and provincial governments and small and medium enterprises are increasingly important. One source reports over 20,000 companies in the surveying and mapping industry alone.[4] Multiple levels of government also participate in large-scale space-related infrastructure projects such as the Digital China Geospatial Network, an initiative that will eventually deliver space-derived data to the public.[5]

The implications of this usage and user growth for economic development are that the space program today has more stakeholders and can be used to advance more policy agendas and commercial interests than ever before. Space is gradually becoming embedded across China's economy and governance structures.

The growing developmental impact of the space sector

Chinese leaders and policymakers tend to describe development in comprehensive terms that extend beyond the economy to include their country's scientific and technological (S&T) modernization, international environment, and domestic political stability. China's space program plays a role in each of these aspects of its overall development strategy.

Economic and S&T modernization goals served by space activities

Space-related industries figure in government plans for building a knowledge economy, increasing domestic consumption, especially of high-technology products, fostering indigenous innovation, and building a sophisticated scientific, technical, and industrial base. High-end manufacturing and information technology, which include satellites and telecommunications, are among the seven new strategic sectors identified in the 2011-2016 Five Year Plan to receive policy support and public investment.

The forms of support and other measures directed at these strategic industries include: direct public investment in research and development; fiscal, tax, and financial policies to support major national S&T projects and indigenous innovation; measures to improve market access; concessional pricing systems for land and utilities; and government oversight of mergers and acquisitions to concentrate

[3] Traditional users include the China Meteorological Administration, the China Oceanic Administration, the Ministry of Science and Technology's National Remote Sensing Center of China, and the Ministry of Environment Protection. Government-owned commercial telecommunications satellite operators, who provide services to millions of individual end users, have been among the largest users for over a decade.

[4] Niraj Singh, "The flight of the dragon," *Geospatial World* vol. 1, April (2011): 32.

[5] The Digital China Geospatial Network has been described as the Chinese version of the U.S. National Spatial Data Infrastructure (ibid, 33).

and consolidate capacity in the manufacturing industries. Space-sector firms are also targets of initiatives to develop globally recognized Chinese brands and create internationally competitive high-technology companies.

Chinese space professionals emphasize that developing space-related products and services will serve the state's goal of moving the economy into the higher value-added rungs of the export ladder. More generally, they say, the high-profile space program will help build international consumer confidence in Chinese technology products, showing the world that "China doesn't just make shoes."[6]

The export of satellite launch services on Long March-series vehicles remains a priority for the Chinese government and space industry. Since 1999, U.S. export control laws, specifically the International Traffic in Arms Regulations (ITAR) system, have prohibited the launch of satellites containing major U.S. components on Chinese launchers, effectively excluding China from the global launch business.

Senior industry figures continue to stress the mutual benefit to be gained from Chinese launch exports to the United States in public statements. At the same time, they appear to have realistically assessed the prospects of reforms to the U.S. export control regime, judging that any reforms are unlikely to open new launch markets to Chinese firms in the foreseeable future.

Competitively priced Chinese launch services present an opportunity for some satellite manufacturers in other countries. To take advantage of cheap launches, the European firm Thales Alenia Space around 2009 developed a satellite devoid of ITAR-controlled technology. However, at least in the short term, an important ITAR-free industry is not expected to emerge, because most international satellite-manufacturing companies still rely heavily on U.S.-made components.

Developing markets occupy an important place in the Chinese space industry's export strategy. The Chinese government and space industry have taken note of the growing demand for space products and services in developing markets. Within the past five years, China has reached agreements to export or effectively donate satellites or launch services to Bangladesh, Bolivia, Indonesia, Laos, Nigeria, Pakistan, and Venezuela. These transactions were not internationally competed sales.

Excluded from important global space markets by restrictions on U.S. technology exports, the Chinese space industry finds opportunities in developing countries that are subject to restrictions similar to those imposed on China. Venezuela and Pakistan are examples of this type of market.

China's approach to space exports also leverages its firms' and government's unique advantage at operating in developing-world markets. Chinese satellite manufacturers are in a position to offer generous terms to buyers in developing countries, for whom price can be a decisive factor. Offering concessional financing terms, providing development assistance (formally or informally) tied to satellite purchases, and even accepting payment for satellites in barter has made it possible for China to create buyers of satellites where none previously existed. These arrangements are made easier by the fact that many buyers in developing countries are governments or state-owned enterprises like their Chinese counterparts.

[6] Remarks by a Chinese space-sector participant.

Chinese official statements frame these space transactions as examples of South-South cooperation and recall the historically close relationship between China and other developing countries. These transactions often also involve technical assistance programs that aim to build capacity for space-asset use and development in the receiving country.[7]

Despite this string of recent deals, expectations for Chinese satellite exports, especially beyond developing markets, remain modest. China's satellite-manufacturing industry is not yet internationally competitive.

Foreign policy agendas served by space activities

Chinese leaders and policymakers emphasize the need to foster international attitudes and institutions that are supportive of their country's peaceful economic rise. The space program serves this end by reinforcing China's position as a capable party requiring inclusion in major international processes affecting space and by enhancing its influence in the developing world.

Conspicuous and autonomous achievements in space also reinforce China's great power status and its membership in the elite club of advanced spacefaring countries. Chinese leaders emphasize the growing importance of space in international and security affairs and in the global economy. Regarding assured access to space as both an economic and national security interest, they fear exclusion from any international process that bears upon how space could be used in the future. Achieving significant space capabilities ensures that China will have a "seat at the table" when decisions about space are made.

China also uses space activities as part of a larger effort to engage developing countries. This approach includes significant and long-standing bilateral space cooperation efforts, such as its program with Brazil. China also provides concessional space exports and technical assistance to poor countries. China is active in multilateral space initiatives with developing countries, including through its leadership of the Asia-Pacific Space Cooperation Organization.

Chinese scholars and policymakers believe it helpful to cultivate China's "soft power," especially among developing countries. Highly visible civil space activities, such as human spaceflight, serve this goal, though they have at times also alarmed China's neighbors and cost it some soft power. Success in space brings China international prestige. Achievements in space are an implicit endorsement of China's political and economic model. Space capability is a marker of modernity and technological progress, signalling that China has overcome a legacy of colonialism and what many in China regard as historical weakness.

Domestic political agendas served by space activities

Chinese leaders and policymakers stress that domestic political stability is a precondition for sustainable economic development. Both proponents and critics of the space program say that it serves an increasingly important domestic political function by bolstering the legitimacy of the regime which created it and by serving as a national achievement in which Chinese, often divided on other issues, can share pride.

[7] Technical assistance is an important form of China's development assistance, discussed in the recently released white paper on "China's Foreign Aid."

Recent and significant trends in China's civil space program

The pace of progress in civil space: Cautious and uneven, but steady

International observers and Chinese media often describe China's civil space program as "soaring" ahead or "leaping" forward. Chinese space professionals familiar with different aspects of the program, however, tend to regard its progress as cautious and unbalanced. They also emphasize that their program is not racing with any other country.

Progress has been steady but not necessarily rapid across the main areas of the civil space program, with some exceptions. The pace of launches accelerated recently. In 2010, China for the first time matched the United States in the number of launches in a single year: 15. By contrast, the human spaceflight program, although reaching new milestones since 2003, has proceeded at a cautious pace. Chinese observers note that their country's crewed launch schedule has been slower than the U.S. Apollo Program's of the 1960s. China has also experienced recent delays and setbacks in satellite production, including the on-orbit failure in 2008 of a satellite delivered to Nigeria, a launch failure in 2009, and delays in launch-vehicle development.

Space policymaking and policy implementation

China's civil space activities are conceived and implemented in a complex policy environment. Diverse institutions and interests are involved in and contend in the space sector. Participants in it frequently point out that their system is difficult to understand, even for insiders, and that systemic reforms begun in 2008 are still incomplete.

A process to rationalize responsibilities and authority over different aspects of the space sector is underway in the form of a comprehensive national space law. When passed, this law will also designate organizations responsible for implementing China's obligations under international agreements. Legal specialists have been developing drafts of this legislation, which may be under review by a committee of members of the National People's Congress.

Despite these changes, several enduring features of the system are discernible. These include top leadership involvement, the influence of elite scientists, coordination by leading small groups, and operational control by the People's Liberation Army (PLA).

Top leadership involvement. Top leaders in the central government have closely overseen the space program since its beginning. Today, Chinese space professionals with program management experience emphasize oversight and attention by political leaders as a factor determining how quickly a program will advance. Leaders will frequently receive briefings on the progress of programs and visit facilities. In some cases, an explicit go-ahead by a senior political leader is needed before a program can advance to its next planned stage. Leaders may even introduce new technical requirements.

Programmatic influence of elite scientists. While program priorities are often handed down from the political leadership to the scientific and technical community, new projects may also originate with individual scientists who entrepreneurially conceive of, advocate for, and push them upward to obtain approval and funding. Examples of this bottom-up process are found in the lunar exploration program and in the Double Star program pursued in cooperation with the European Space Agency.

Coordination by leading small groups. Space activities require the participation of different ministries and organizations, both civil and military, each of which is a stove-piped bureaucracy. Leading small groups fulfil a high-level coordination function among these actors. Usually without a dedicated institutional home, leading small groups pull together representatives from existing offices in participating organizations on an ad hoc, project-specific basis. There are reportedly leading small groups for the lunar projects, human spaceflight, Earth observation satellites, and heavy-lift launch vehicle development.

Operational control by the PLA. Critical space infrastructure, including existing launch facilities, and the day-to-day management of civil space operations, especially in the human spaceflight program, are the responsibility of PLA organs. Within the PLA, the General Armaments Department (GAD) plays the most important role in space activities. In civil space, the GAD acts mainly in and through the Manned Space Engineering Office, the entity responsible for the human spaceflight program. The PLA Air Force plays a role in astronaut training and medicine.

Major recent and planned civil space activities

China's main recent civil space activities span five areas. These include the human spaceflight program, lunar projects, the development of a next-generation heavy-lift launcher, the Beidou/Compass navigation satellite constellation, and new Earth observation satellites. [8]

Human spaceflight program. The human spaceflight program, under the Manned Space Engineering Office, is China's largest civil space program. It began in 1992 with the government's adoption of Project 921, which outlined a three-stage national human spaceflight program, focused on a spaceship, a space laboratory, and a space station. These activities are explained in greater detail in Appendix 1.

> **Shenzhou spaceship.** Between 1999 and 2008, the Manned Space Engineering Office conducted a series of piloted and unpiloted missions to develop the Shenzhou series of crew transportation vehicles. The three crewed missions to date have been Shenzhou 5, the first spaceflight by a Chinese national, in 2003; Shenzhou 6, in which two taikonauts remained on orbit for over a day; and Shenzhou 7, in which two taikonauts performed extra-vehicular activity, one of them testing a Chinese-made spacesuit.
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> **Space laboratory.** The program's space laboratory stage is underway. It involves placing in orbit small facilities, consisting initially of the Tiangong 1 lab, scheduled to launch in the latter half of this year, and to be followed by the Tiangong 2 and 3 labs. Taikonauts will make trips to these facilities lasting up to 40 days to conduct small-scale experiments and technology tests in preparation for building a larger space station. The space lab phase will also develop, test, and refine the capabilities required for longer stays in space and for orbital rendez-vous and docking, necessary for the assembly of the space station.
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> **Space station.** Between 2015 and 2022, China plans to build a larger space station. It will consist of a core cabin module and two separately launched laboratory modules, making it

[8] These remarks will not address Earth observation satellites, the Beidou/Compass constellation of navigation satellites, nor telecommunications satellites, all of which are covered in a comprehensive report on China's aerospace industry recently submitted to the Commission by researchers at the RAND Corporation.

only the third space structure assembled on orbit, after Mir and the International Space Station (ISS). The station will support crews conducting a wide range of space science and applications experiments and work on long-duration flights.

At 60 metric tons in total, the Chinese station will be far smaller than the ISS, expected to weigh about 450 tons once complete. The ISS supports six astronauts on long-term stays, while the Chinese station is planned to support only three taikonauts at a time.

There are reports that the Chinese station will accept to host experiments from international researchers through a selection process that will be open to participants from any country.

During the lifetime of the ISS, the Chinese station will be the only other space station on orbit. If the ISS ends its operational life in 2020 without a successor, there may be a period during which the Chinese station is the only long-term human presence in space.

Lunar exploration program. The lunar program has three stages, referred to as the orbiting, landing, and sample-return stages. In the first (2002-2007), two satellites, Chang'e 1 and a back-up, orbited the Moon and collected images of the lunar surface. Since the start of the second and current "landing" stage (2008-2014), Chang'e 2 launched and entered lunar orbit, where it continues to collect data. Chang'e 3 will launch around 2013 and land on the Moon with a rover. In the "sample return" stage (2015-2020), another small unpiloted vehicle will land on the Moon, collect samples, and return them to Earth. During this third stage, the human spaceflight program will conduct a human lunar mission concept study, which is to be complete by or around 2020.

Next-generation heavy-lift launch vehicle. The space station requires launching payloads each weighing 20 metric tons into low Earth orbit. To this end, China has started developing a more powerful next-generation carrier rocket, the Long March 5. This vehicle is built in the Tianjin area by the China Academy of Launch Vehicle Technology and will launch out of a new site under construction on the southern island province of Hainan, reportedly by 2014. With an expected capacity of 25 tons to low Earth orbits and 10 tons to geosynchronous orbits, the Long March 5 will increase the range of payloads deliverable and orbits reachable by Chinese vehicles, adding the capability to launch larger telecommunications satellites. Other Chinese launchers are also reported as in development.

China's civil space industry

Major industrial players

Two major players dominate China's space industry: China Aerospace Science and Technology Corporation (Casc) and China Aerospace Science and Industry Corporation (Casic). Both of these entities are large state-owned enterprise (SOE) groups that subsume under them vast and diverse facilities and organizations performing research, development, and production in different parts of the country.

The larger of the two companies, Casc, has focused on more powerful launch vehicles and larger satellites. Casc also subsumes China Great Wall Industry Corporation, the subsidiary responsible for the international marketing of Chinese launch services and satellite systems. In 2009, Casc

acquired China Satellite Communications Corporation (China Satcom), expanding its activities into the operation of telecommunications satellites. The smaller Casic has focused on missiles and on smaller satellites and launchers.

Casc and Casic are both involved in civil and military space technology and both are also involved in other civil industries, ranging from the industrial production of mechanical parts and components to other high-technology products and services, such as large-scale security systems. Casc and Casic's major clients are the government organs that run the space program; large parts of both the civil and military space budgets drain into these two companies.

Besides these two major industrial groups, a growing number of small and medium enterprises are involved in the space sector as users and processors of space-derived data and space-based services.

The space industry's policy landscape

At a general level, the space industry enjoys stable, predictable demand for its products from government customers and a stable space policy environment. Casc and Casic's near- and long-term demand expectations are based on the Five-Year Plans and even longer-term national strategies. These companies do not contend with abrupt program changes and fluctuating budgets in the way firms in other countries do.

Other features of the space industry's policy environment, however, are far less stable. Relations between and the responsibilities of agencies in the space sector are shifting and contentious. At the industry and enterprise-group levels, broad and deep reforms have been implemented several times.

The object of these reforms is a transformation of the space industrial base. Like policies targeting other major defense-industry SOEs, these measures are intended to make the space enterprise groups more efficient and behave more like commercial entities. Casc and Casic have undergone several rounds of reorganization and consolidation and internal reforms intended to introduce market mechanisms into their governance.

Another industrial strategy for the space sector is also taking shape. Central, provincial, and local governments are investing in several space-technology industrial hubs near major historical centers of aerospace research, development, and production across the country. These efforts will leverage existing local competencies to create economies of agglomeration and clusters of networked expertise, conditions usually regarded as conducive to innovation, firm specialization, and small-business development in the lower tiers of high-technology industries.

In addition, China is entering a phase of space-sector development during which even greater emphasis is placed on the commercialization of space technology. A policy priority during this time is making space more relevant to lives of ordinary people and increasing domestic demand for space-related goods and services.

The space industry can be expected to increase its efforts to develop and market commercial ground-based applications of space technology. Historically, the most important domestic consumer market for commercial space applications has been for telecommunications services. More recently, commercial "spin-offs" such as nutritional supplements and agricultural produce

made using space-treated inputs have been prominently advertised, though their commercial success and impact is unclear. In coming years, some of the most important space-related products are likely to be receivers and applications that use (perhaps not exclusively) the Compass signals and applications that utilise geospatial data for mining and other resource-management activities.

An evolving international strategy for industry?

A recent shift is detectible in how Casc and, to a lesser extent, Casic orient themselves toward global commercial space markets. The contours of a new approach are still only emerging, and it remains unclear whether it is indeed new and whether it will succeed. Nevertheless, recent developments and statements suggest an approach consisting of three major elements: a new communications effort; a reorientation toward different space products; and a move into new sectors outside space.

Communications to foreign audiences. The Chinese space industry is trying to take control of and improve its international image. At senior levels, there is a recognition that the Chinese space industry has not been proactive enough in communicating its own message abroad, letting its detractors define it. In an apparent rebranding and publicity effort, the industry is selectively seizing opportunities for international exposure. For example, Chinese delegations including Casc and sometimes Casic representatives are making more frequent and visible appearances at international space conferences. Chinese companies are making more information available and producing new promotional material. China Great Wall Industry Corporation recently advertised its launch services in Space News, a widely read U.S. trade publication. Casc is opening an office in Washington, DC.

Exploring space-component exports. The space industry has also expressed a new interest in the export of satellite components, including to Western markets. These products would be less politically sensitive than launches and Chinese producers could sell them competitively. Attention to this area appears to supplement, rather than substitute, a long-standing effort to export launch services and other system-level solutions.

Expanding into new high-technology export sectors. The space industry also expresses an interest in expanding into export sectors outside space. These companies seek to build on their competencies in related high-technology sectors to export new products. For example, one space industry firm has expressed interest in exporting clean energy products, including solar panels. In developing in these new areas, this major industrial player hopes to become a Chinese version of Boeing or GE, global companies that deliver products and services in a range of high-technology civil and military sectors.

Advantages and disadvantages of U.S.-China civil space cooperation

The United States and China increasingly interact in space and already engage in space-related activities that could be termed cooperative. For example, the United States provides China with warnings of imminent orbital conjunctions between Chinese space assets and other space objects, because preventing another debris-producing event serves U.S. interests. Both countries also participate in many of the same multilateral processes addressing space issues.

Decision makers and policy makers exploring whether, when, and how the United States should cooperate with China in additional ways face an elaborate set of choices. The options before them are many and include the current policy of almost no cooperation. Examples of options for cooperation at different levels of sharing, risk, and potential pay-off, are listed in Appendix 2.

As decision makers, policy makers, and the public debate the advantages and disadvantages of cooperating with China in space, several considerations could helpfully inform the conversation.

A vision of a desirable outcome

Any answer to the question of whether the U.S. should cooperate in space with China should be logically derived from an explicit answer to a more fundamental, conceptually prior question: What type of space actor does the United States hope China will become?

If the United States and the international community hope that China becomes a "normal country" in space, then they should seek to foster, rather than stifle, China's commercial exploitation of space and civil space activities. As China invests in and derives greater benefit from space, it will acquire the same stake in creating a predictable, stable, safe, and sustainable space environment that the U.S., Canada, Japan, and European and other countries already share. There are signs of a shift in this direction among observers in China.

If, on the other hand, decision makers believe that it is undesirable or improbable that China become a regular, integrated spacefaring country, then they will need to carefully assess how much they can influence China's space-sector development. This assessment could evolve with changes in the space environment, the commercial and international availability of space technologies, China's capacity to autonomously develop space technologies, and third-party attitudes toward China's role in space.

The domestic incidence of international cooperation

The discussion of U.S.-China space cooperation should recognize that every form of international cooperation has domestic effects. Any form of cooperation or non-cooperation with the United States will empower some actors within the Chinese space establishment at the expense of others. Premised on the right conditions, international cooperation projects can make civilian actors more prominent and influential within the Chinese space sector.

For example, international projects can be designed to enhance the role of the Chinese Academy of Sciences, the China National Space Administration, and the Ministry of Foreign Affairs, all civil organizations with an interest in establishing China's reputation as a reliable international partner in space. Cooperative projects designed without this awareness could symbolically and materially reinforce the military's control of the space sector.

The changing costs and benefits of the status quo

The debate over U.S.-China space cooperation should be broadened to take into account the full range of changing costs and benefits to not cooperating with China in space.

Other countries are beginning to build relationships in space with China that exclude the United States.

While China's capabilities in space are known to U.S. observers, its intentions are not. The status quo may deprive the United States of options and tools for learning about these intentions. Cooperating could open avenues to learning how China's leaders understand their country's interests in space and the means to pursue them and how they make choices.

China is one of very few countries where space budgets are stable and might grow. That makes it an important potential partner for large future missions and, possibly, a costly one to exclude. The Chinese market for space-related products is also large and growing, and may develop in a way that excludes U.S. participants more effectively than it would if the bilateral relationship were more robust on space issues.

Cooperation, especially on technical projects, creates an opportunity to engage China's emerging space policy community at a pivotal time. Space is a highly technical policymaking area in which leaders are likely to rely on the input of specialists, especially scientific and technical personnel who work in the sector. There is growing awareness within China that a more systematic and institutionalized process for channelling space expert advice to decision makers is needed.

A community of space experts able to play this policy role is coalescing. So far, however, this community remains nationally focused with relatively little exposure to international ideas and perspectives and with an uncertain grasp of evolving U.S. space policy and interests and of trends in the space environment.

At the same time, the Chinese space program is entering a phase during which the demand for this community's expertise will grow, as major space policy decisions present themselves. For example, political leaders will have before them a choice about whether and how China should send taikonauts to the Moon, and whether it should do so alone. The impact of the space policy community on policy outcomes is likely to grow as such questions arise.

Engaging this nascent community in dialogue and introducing it to more international perspectives and new ideas could serve U.S. interests. Developing long-term relationships with these space professionals could also provide the United States with additional points of contact and channels of communication into the Chinese space system, both of which could prove valuable in a crisis.

Conclusion

Please accept my sincere thanks for the opportunity to share with you the outcomes of my research and thoughts. I would be pleased to answer any questions at the hearing or in writing.

Appendix 1: China's human space flight and space exploration programs

Milestones in the development of the Shenzhou-series crew transportation vehicle

In 1992, the human spaceflight program is initiated with the adoption of Project 921, a strategy outlining a three-stage strategy to begin with the development of a crew transportation vehicle, the Shenzhou capsule system.

In 1999, China conducts its first unpiloted spaceflight test. Tests in 2001 and 2002 (March and December) follow.

In 2003, China accomplishes its first human spaceflight mission. Yang Liwei orbits the Earth 15 times and becomes the first Chinese national in space.

In 2005, the Manned Space Engineering office conducts a second piloted mission, Shenzhou 6, a longer, multi-person mission. Fei Junlong and Nie Haisheng orbit the Earth 76 times and conduct scientific experiments on orbit.

In 2008, the program enters a second stage with the launch of Shenzhou 7. This mission's crew conducts extra-vehicular activity (EVA) and space science and technology tests, including tests involving data relay to an accompanying satellite. Taikonauts Zhai Zhigang and Liu Boming, wearing Chinese-developed and imported Russian spacesuits respectively, perform China's first EVA, lasting about 20 minutes. The main Shenzhou 7 "breakthroughs" relate to the testing of the Chinese-made Feitian EVA spacesuit, EVA training, and airlock technology. China is only the third country to possess the technology needed for EVAs.

Plans for the space laboratory

The second stage of China's human spaceflight program involves the launch of a space laboratory that will test space applications and develop capabilities required for the on-orbit assembly and operation of a larger space station.

The launch of the unpiloted Tiangong 1 is scheduled for the second half of 2011. It will serve as a platform for tests of rendez-vous and docking capabilities. On the current schedule, the unpiloted Shenzhou 8 will dock with Tiangong 1 in 2011. The crewed Shenzhou 9 and 10 will also dock with Tiangong 1.

Tiangong 2 will launch around 2013, followed by Tiangong 3 around 2015. Tiangong 2 will support a crew of three for about 20 days. It will refine capabilities required for orbital rendez-vous and docking and longer-term taikonaut stays on orbit. Tiangong 3 will support a crew of three for about 40 days. These crews will carry out small-scale space science research and applications work, accumulating experience for work on the space station. Tiangong 3 will test new life support systems and the on-orbit replenishment of air and propellant.

Plans for the space station

The current human spaceflight program culminates in the construction of a 60-ton, three-module station on orbit, capable of supporting a long-term human presence in space.

At its largest, the space station will include a core cabin module, two laboratory cabin modules, a docked Shenzhou piloted spaceship and a docked Shenzhou cargo vessel. The combined weight of the three modules will be 60 metric tons.

The core cabin module will launch in 2020, followed by he laboratory cabin module 1 in 2021 and the laboratory cabin module 2 in 2022.

The station will support a crew of three astronauts for long-duration flights. During their time on orbit, they will conduct a wide range of space science and applications experiments and work. These activities will span microgravity science, space life science, space astronomy, space physics, and tests of new application technologies.

The Lunar Exploration Program

The lunar program has three stages: orbiting, landing, and sample return.

Orbiting stage. In the first stage, 2002 to 2007, two satellites, Chang'e 1 and a back-up, orbited the Moon and collected scientific data, including images of the lunar surface.

Landing. During the second and current stage, 2008 to 2014, a third satellite, based on the first-stage vehicles, was developed to test additional new technologies. In late 2010, Chang'e 2 launched and entered lunar orbit, where it continues to collect data. The Chang'e 3 satellite will launch around 2013 and land on the Moon, releasing a rover that will operate on the lunar surface for three months. A Chang'e 4 vehicle will serve as a back up to Chang'e 3.

Sample return. In the third stage, 2015 to 2020, a small capsule will land, collect samples using newly developed sampling and drilling machines and robotics, and return the samples to Earth.

Appendix 2: **Options for U.S.-China space cooperation projects and efforts**

Examples of options for low-level cooperation that include relatively little sharing and carry limited risks include:

- minimal bilateral civil-scientific cooperation with no hardware sharing: such as data exchange, briefings on space science activities, and site visits;
- multilateral cooperation to promote international data sharing and interoperability;
- creating arrangements and protocols to systematically collect and share biomedical data on astronauts and taikonauts.

Examples of medium-level cooperation that include some sharing and some, potentially manageable, risk include:

- hosting small Chinese scientific payloads on the ISS or on U.S. assets;
- inviting Chinese taikonauts to fly on the ISS, in the same way as other non-Americans are invited on missions to the station upon the Russian Soyuz and the U.S. Shuttle (and its eventual successor) transportation vehicles.

Examples of substantial cooperation that require sharing hardware and accepting a level of mutual reliance, high levels of risk, and high visibility, and which could also generate important political rewards include:

- jointly developing large instruments for flight aboard the ISS with Chinese institutions;
- jointly building a new unpiloted spacecraft, such as a new space telescope or satellite;
- allowing a Shenzhou-series or other Chinese vehicle, with or without crew, to dock with the ISS;
- inviting China to be a hardware-contributing partner on major new multi-national exploration projects, such as a mission to Mars.

Examples of options for fostering industry-led or commercial activity between the two countries include, in increasing order of significance:

- reforming or adjusting the export control regime to allow relatively circumscribed trade in space products, such as on small satellite components;
- reforming or adjusting the export control regime to allow trade in important space-related goods and services, such the Chinese launch of U.S.-made satellites;
- reforming the export control regime to allow the on-orbit delivery of turnkey satellite systems to users in China.