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Overview and assumptions

I want to thank the commissioners for their invitation to speak on the important topic of the status of and approaches to technology development and innovation in China's space program. It is an honor to be a part of this hearing being held at an exceptionally dynamic time in the development of China's space program.

Over the last decade and a half the Chinese space program--much like China's broader military modernization--has made *steady and significant* progress in the acquisition, development and application of increasingly advanced space technology, knowledge and platforms and systems, especially in the incremental execution of the manned space program, the lunar program, improved launch vehicles, the Beidou satellite navigation system and anti-satellite warfare.

Challenges remain, however, especially around China's ability to continue to innovate in a way that will allow it to create new--rather than merely leverage old--technologies and applications. China seems aware of its innovation challenge and it is clear that in addition to the steady and significant progress of the last 15 years, China's space program of 2015 is also marked by a growing amount of activity in terms of engagement with foreign partners and reform of internal structures, processes and modes of thinking.

Before providing a more in-depth assessment of this active time for China's space program , I first want to articulate two core assumptions. First, that China's space program has several critical and generally consistent objectives driving its growth: prestige and supporting human advancement are important, of course, but the more fundamental goals are to support China's comprehensive national development and the salutary objective of being the most technologically advanced country in the world by 2050.

The program is also an important cog in China's growing aerospace and defense export strategy. China is the seventh largest defense exporter in the world, according to IHS Jane's--including exports of space technologies. It is increasingly seeking to establish export markets for its aerospace and defense products, less for the economic impact that these exports bring and more for the geopolitical influence and soft power they confer on China in countries that either hold natural resources or economic influence, border regional competitor India or are located in strategically vital region of the world. A cursory survey of active or planned space launches of foreign owned satellites in China includes launches on the behalf of Venezuela, Indonesia, Pakistan, Nigeria, Bolivia, Sri Lanka and Belarus while China has a long-standing space partnership with Brazil.

The second assumption is that China's space program does not have structures in place that make meaningful divisions between military and civil programs and those technologies acquired and systems developed for ostensibly civil purposes can be applied--and most frequently are --for military purposes. This dynamic indicates that China's space program is also a critical element in the country's on-going military modernization program.

A program with Chinese characteristics

A key theme of discussions both within China and among those watching China's military modernization and technological development--including development of China's space program--is that this innovation is happening with "Chinese characteristics"; that is, while China's space program has leveraged the history, science and technology of more advanced space programs--especially Russia's-- the program has been emphatically marked by its ability and desire to apply these lessons and technologies within a context marked by the distinguishing characteristics described below.

Centralized control: China's aerospace and defense community and industry is highly-centralized --with the PLA in control of the program and exerting influence not only over military applications and programs, but also civilian--and relies on large state-owned enterprises that either have strong commercial / civil elements to their business or have close relationships with other state-owned enterprises that do. Two conglomerates dominate the space industry.

China Aerospace Science and Industry Company (CASIC) operates about 620 subsidiaries, both companies and research and development institutes. China Aerospace Science and Technology Company (CASC) operates about 130 subsidiaries, including eight major research and development institutes. Together the two firms employ approximately 250,000 people. Both CASC and CASIC develop systems and equipment, such as launch vehicles, for the space program and also develop military systems, such as missiles, for the PLA. Nearly all products and systems are capable of fulfilling both explicitly military and civil purposes.

The close and frequently opaque ties between the state-owned enterprises, civilian aerospace and the central Chinese government allows China to acquire technology through civilian enterprises that can then be reverse engineered and adapted for China's specific military or dual - use purposes-- a sort of "acquisitional osmosis." This civil-military integration is a key element of the development of China's space program.

Incremental and steady pace: As a second generation space power imbued with a strong sense of deliberate purpose to achieve goals that are in many cases decades away and possessing strong political and financial support, China is not currently compelled into a "space race" that would require an urgent or particularly risky development approach.

Rather, China has repeatedly demonstrated an effective model in both the aerospace and defense industries that relies on incremental development and prototype launch of technologies over rapid full system development. This steady approach to technological improvement and development is central to the most recent successes of the space program, such as the Tiangong and Chang'e programs that used multi-phase deployment programs to demonstrate and study technologies before fully developing final systems or pursuing more ambitious applications of these technologies.

Funding and political support: Because the space program is so closely tied to China achieving its goal of national development, military modernization, expanding geopolitical influence and becoming the global science and technology leader by 2050 and to China's geostrategic ambitions in the Western Pacific and beyond, the program enjoys considerable funding and political support.

Strategies for acquiring space and aerospace technologies:

Perhaps the most distinguishing characteristic of the Chinese space program -- indeed the whole of China's on-going military modernization and technological development--is the varied means through which China has sought to acquire the technologies and science critical to the further growth of its space program. Four linked methods are of particular interest.

International Relationships: China has been very active in and successful at developing relationships with foreign organizations, industry and academic and research institutions that have provided enhanced access to technologies, best practices and scientific knowledge, which has, in turn, underpinned a significant amount of China's recent aerospace progress. A cursory review of China's State Administration for Science, Technology and National Defense's (SASTIND) website shows China National Space Agency (CNSA) engagement with an impressive range of countries' space programs in 2014: Turkmenistan, Algeria, Russia, Holland, Italy, India, Germany and Sudan as well as the European Union. This list reflects not only China's desire to acquire new technologies from technologically advanced states (Europe and Russia), but also its ambition to export space technologies to states with space programs lagging behind China's.

Russia has long been the most significant supplier of aerospace and defense technologies to China and has been the most significant technological patron to China's space program, particularly in support to China's spacecraft development, astronaut training and the provision of a spacesuit for China's first spacewalk. China's current modular design for its space station strongly resembles Russia's Mir space station.

The aerospace relationship between Russia and China was reinvigorated in May of 2014 as U.S. and Western sanctions against Russia in response to the annexation of Crimea and support for separatists in Eastern Ukraine forced Russia to seek import substitution alternatives for its defense industry and newly reformed space industry. During the course of a series of international events between May and November 2014--the St. Petersburg International Economic Forum in May and the G-20 Summit and China Airshow in November-- Russia and China signed several collaboration deals related to space and aerospace activities. Deals included agreements to establish a joint high-level working group for strategic space coordination and to continue negotiations on the exploration of Mars and Venus; memorandums of understanding on cooperation between Russia's GLONASS navigation system and China's Beidou navigation system; and a strategic partnership between Russian state owned defense technology firm Rostec and CASIC.

During the China Airshow in November, Roscosmos--the Russian space agency--and China National Space Agency discussed opportunities to collaborate on navigation satellites, remote sensing, production of electronic component parts, materials science, construction of spacecraft and rocket engines and manned programs. The two organizations also discussed the possibility of an exchange of manned spacecraft visits to Russian and Chinese orbiting stations. In their entirety, these deals constitute an exceptional opportunity for China to not only leverage more Russian space technology, but also to attempt to penetrate an in-need Russian market with space and aerospace exports.

Europe also continues to be an important source of technology and know-how for China's space program, through direct engagement with the European Space Agency (ESA) as well as the national space agencies and industries of individual European states.

China and the ESA have a relatively long history of successful collaboration, including the successful Double Star mission, which launched two satellites into orbit in 2003 and 2004 to study the planet's magnetosphere. In January of 2015, the relationship took a significant step forward as the Chinese Academy of Sciences and the ESA announced a call for proposals for a jointly developed robotic space mission that will be launched in 2021. The program is the result of two planning meetings in 2014 that assessed challenges of the program, laid out parameters of collaboration and discussed technologies of interest to the effort. According to presentations delivered at the first of these conferences held in Beijing in February 2014, any element of the mission--platforms, payload, system integration and testing, launch services, spacecraft operations, receiving stations, science operations and science exploitation--can be provided by China, Europe or jointly.

China also has established collaborative relationships with the space programs within individual European states and with European space industry, particularly France, Italy, Germany and the United Kingdom, all of which view China's growing space program as a high priority target for exports of robust domestic space industries that are dealing with budgetary pressures in home markets.

For example, in December of 2013, the UK Space Agency announced a new five-year, £80 million Global Collaborative Space Program designed to allow the UK to access new international markets for British industry and to share British expertise. China was explicitly mentioned as a priority market in UK government releases about the initiative. In addition, on 30 January of 2015, China's SASTIND announced that China and France signed agreements to foster collaboration across a range of hi-tech sectors, including satellites. China has previously collaborated with France on the China France Oceanography Satellite (CFOSat), which was built jointly by the CNSA and Centre National d'Etudes Spatiales (CNES), the French national space agency.

Academic and research institutes: China also uses growing connections between domestic and foreign academic and research institutions to acquire technologies and know-how in both licit and illicit ways. As with the line between civil and military industry activities, the line between academic and military research is blurred in China, meaning that the typically open and engaging world of academia and scientific research can be an effective avenue for the transfer of scientific knowledge and advanced technologies.

U.S. authorities, including Federal Bureau of Investigation, have expressed growing concern about the general proliferation pathway of academia over the last several years, either via foreign students studying in American institutions or through witting or unwitting American academics and researchers that export controlled technologies through foreign students with whom they work.

Of course, not all knowledge gained through academia is done so in a surreptitious fashion. China's research institutes and universities offer an additional means of engagement with states possessing advanced space and aerospace programs through conferences and collaborative research initiatives.

In May of 2014, Science and Technology China and United Kingdom Trade and Industry co-funded the 9th UK-China Workshop on Space Science and Technology held in Shanghai. The event was organized by Rutherford-Appleton laboratory in the UK and China's Beihang University, according to a press release on the event from the UK government. Attendees included 40 delegates from the United Kingdom and 150 from China. A total of 61 areas for collaboration were identified and 26 memorandums of understanding were signed for collaboration in earth observation / remote sensing, planetary exploration and training. Specific examples of collaboration included an offer from CNSA to use UK instruments and payloads on CNSA space exploration vehicles.

Another significant collaboration between research / academic institutes is the Launch Joint Laboratory, a 2012 initiative between the University of Strathclyde in Glasgow, Scotland and the China Academy of Launch Vehicle Technology (CALT), a subsidiary of CASC. The Laboratory is based at Strathclyde, but provides research funds two CALT engineers to work at the university. The purpose of the program is to advance research in key areas such as mechatronic mechanisms, space robotics for satellite servicing and refueling, sustainable space exploration and related manufacturing technologies.

Espionage: It is difficult to develop a comprehensive picture of how much aerospace and defense technology China acquires through espionage, but open source reporting on the subject strongly suggests that espionage, both traditional forms and cyber-espionage, constitute an important avenue for the acquisition of aerospace and defense technology, including space-focused technologies.

A March 2014 Department of Justice report detailing major US export enforcement, economic espionage, trade secret and embargo-related criminal cases from January 2008 through March 2014 included over two dozen cases of prosecuted espionage regarding / theft of controlled items relevant to China's space and broader aerospace programs, such as: multiple cases focused on thermal imaging cameras and aerospace grade carbon fiber as well as cases involving electronics used in military radar and electronic warfare; radiation hardened materials and gyroscopes; military accelerators; military optics; unmanned systems; rocket / space launch technical data; restricted electronics equipment; source code; and the theft of space shuttle and rocket secrets for China.

China is also pursuing the illicit acquisition of advanced aerospace technologies from the United States via cyber-espionage, though direct attribution of cyber-attacks is exceptionally difficult. China's cyber-espionage capabilities and activities have received particularly acute attention since the release of a series of high-profile reports in early 2013, including reports from the US Defense Science Board, the private Internet security firm Mandiant, and a classified National Intelligence Estimate, elements of which were leaked to the press. Collectively, these reports and several subsequent U.S. government and private sector reports describe a significant and sustained cyber-espionage campaign against US companies in a variety of industries emanating from China and initiated by the Chinese government. Satellites, defense, aerospace and telecommunications were all listed among targeted industries.

Joint ventures and acquisition of Western aerospace and technology companies: China has also engaged in several joint ventures with Western aerospace companies, including American aerospace companies. These deals provide an additional mechanism for the proliferation --knowing and unknowing--of technologies from Western companies to China's web of closely linked commercial and military aviation enterprises.

China's aerospace industry has also made over a dozen significant acquisitions of Western commercial aerospace and aerospace technology companies--including several US companies--over the last five years. These acquisitions have been strongly focused on commercial aerospace companies with competencies in light aircraft and technology areas, such as aero-engine development and sensors that can support China's efforts to fill the People's Liberation Army's most pressing defense technology gaps. None of the acquisitions have been explicitly focused on space technologies--though the 2013 acquisition of Luxembourg sensor company constituted CASIC's first direct foreign acquisition--but it is certainly an approach that could be applied to adjacent aerospace industries to help fill technological and scientific gaps affecting the trajectory of China's space program.

Strengths and successes of China's space program

China's attempts to acquire technology via foreign sources have been pivotal in driving China's space program's successes to date and in closing the gap on more technologically advanced states. Below is a list of key products and programs and recent areas of technical success for China's space program:

Satellite launches: China has over 100 satellites in space currently, according to IHS Technology. These satellites are performing many missions, including explicitly commercial functions. However, given the PLA control and closely-linked civil-military elements of the program, it is reasonable to believe that most satellites have the capacity to carry out both civil and military functions and those that can, will be tasked to carry out both.

Yaogan: The launch of five triplets of Yaogan satellites--an advanced electro-optical synthetic aperture radar and electronic reconnaissance satellites--since 2010 has created concerns in the U.S. military that the architecture is a maritime signals intelligence system designed to replicate elements of the U.S. Navy's Naval Ocean Surveillance System and will be used to observe naval deployments in the Western Pacific.

Gaofen: The Gaofen satellite is a satellite used for optical and radar reconnaissance of the earth. The Gaofen was launched in 2013 and is a high resolution optical satellite with 2 meter resolution.

Shijian: The Shijan system is a terrain mapping system satellite with the capacity to produce 3-D terrain models that is also thought to possess infra-red sensors capable of detecting missile launches. It could be used as an early warning system for the PLA.

Beidou Satellite Navigation Network: The Beidou (Compass) system constitutes China's attempt to develop a global navigation system to compete with (or at least reduce Chinese commercial, civil and military reliance on) the U.S. run Global Positioning System and Russian run GLONASS. The system became operational in late 2012 at a regional level and China anticipates having a fully operational global system in 2020. The global system will include 35 satellites: five in geostationary earth orbit, 27 in medium earth orbit and three in inclined geostationary orbits. Beidou will consist of "open" and "restricted" services navigation, timekeeping and positioning functions and is expected to be a critical component of China's missile and intelligence, surveillance and reconnaissance capabilities.

Manned program: China's manned program is among its most compelling successes to date and includes activities around the Shenzhou series of spacecraft, Tiangong-1 space lab and on-going development of subsequent Tiangong missions, including the development of Tiangong-3, a large space station expected to be assembled around 2020, at approximately the same time the International Space System is scheduled to lose its funding.

China's manned space program is following a three-step strategic plan, which began with the successful completion of the Shenzhou-5 to Shenzhou-7 missions from 2003 to 2008 and was designed to launch Chinese astronauts into low earth orbit, conduct multi-day and multi-manned spaceflights with a safe return to earth. China is currently in the second stage of the plan, which seeks to introduce and perfect extravehicular activity, rendezvous and docking, launching a habitable space module into space and performing short-term manned space applicable experiments. This stage involves the launch of up to three Tiangong missions. Tiangong - 1 successfully docked with Shenzhou 10 on 13 June 2013 and performed a manual re-docking exercise on 23 June. No future manned missions have been announced and the spacecraft is expected to stay in orbit until its fuel runs out in approximately two years. Tiangong-2 is expected to be launched in 2015 or 2016 and will focus on earth and space observation missions.

Long- March Launch Vehicles: China has made progress in the development of the next generation of Long March / Chang Zheng launch vehicles. LM-5 is expected to have its first launch in 2015. The LM-5 is a heavy lift rocket capable of launching up to approximately 25,000 tons into space--more than double the current capacity of China's launch vehicles to place assets in geostationary orbit--and is expected to be the rocket used to launch the Taingong-3 space system and its modular components into orbit. The LM-5 is expected to be around 60 meters long with a core diameter of 5.0 meters. The three main stages are reported to use liquid oxygen and liquid hydrogen YF-77 engines mounted together, being developed by the Beijing Aerospace Propulsion Institute. China is currently building a fourth launch site at Hainan Island in order to accommodate the LM-5.

Additional LM vehicles are expected to include the LM-6, which will be used to lift payloads of 1,000 kilograms to 600 kilometer orbits; the LM-7, which is expected to lift payloads of 5,500 kilograms to 700 kilometer orbits; and the LM-11 the largest solid fuel rocket in the Chinese fleet, which is expected to be launched in 2016.

Kuaizhou Launch Vehicles: China has also developed a solid fuel launch and transportable launch vehicle known as Kuaizhou designed to be able to rapidly launch microsatellites into orbit during times of crisis. While China has focused on Kuaizhou's utility in responding to fast-moving natural disasters, the capability could also be used to rapidly replenish or augment satellite coverage in space during a security or military crisis or conflict.

Tianlian data relay: The Tianlian data relay constellation was completed in July of 2012 and will be a critical component facilitating communication from and to China's space-based civilian, commercial and military assets.

Lunar exploration program: The lunar program, like the manned space program, consists of three discrete stages designed to build upon the incremental advancements of the previous stage. Stage one (2002 - 2007) included the orbiting of Chang'e 1 around the moon. Stage two (2008 to 2014) included the launch of Chang'e 2 into a lunar orbit to collect data. Chang'e 3 landed on the moon and released the Yutu rover, which conducted a short exploration of the surface of the moon. On 1 November 2014, the Chang'e 5 T1 return vehicle landed safely on earth, successfully completing its mission to obtain experimental data and validate re-entry technologies such as guidance, navigation and control, heat shield and trajectory design for use during the third phase of the program set to begin with the launch of Chang'e-5 scheduled for 2017 or 2018.

Anti-satellite capability: China's 2007 kinetic strike against one of its expired weather satellites clearly demonstrated China's anti-satellite warfare capacity. While subsequent kinetic tests have not taken place, China continues to demonstrate capabilities -- such as co-orbital satellites equipped with robotic arms and high altitude missile tests--that show China's evolving capability to threaten competitor and potential adversary military satellite architectures.

Innovation challenges and technology gaps

As much progress as China has made in the last ten to fifteen years, the space program still faces developmental tests that will require it to mature enhanced skills and structures and get beyond the mere leveraging of civil-military integration and innovation initiatives focused on single technologies rather than complete systems. China will be required to create new technologies and perfect complex systems to move its program forward, meaning that the space program is currently confronted with an innovation challenge that is likely to grow more acute in the next decade as its space technologies advance to parity or beyond that of its closest partners.

China's ability to address three significant gaps-- integration and mindset; technical and scientific; and organizational--will determine the pace with which China is able to meet its current innovation challenge.

Integration and mindset gaps: China's space program is still developing its capacity to innovate in the more complex, highly-engineered and systems-focused sectors, such as aero-engines / propulsion systems, advanced sensors and C4ISR systems (outside of unmanned systems, an area in which China has demonstrated rapid growth). China's innovative capacity has long been focused on single technology innovation rather than systems focused innovation, and making this shift in mindset and approach, even with high levels of funding, will require time.

Technical and Scientific Gaps: A review of the focus-areas of China's extensive international engagement as well as writings by members of China's space industry and scientific community reveal several technical areas in which China's current space technologies and know-how are lagging:

- Engines / propulsion systems
- Sensors / remote sensing
- Radiation hardened components
- Satellite navigation systems
- High-speed communications for deep space
- Integrated applications
- Engineering standards and best practices
- Space science
- Carbon fibers

Organizational gaps: China's complex and overlapping network of centrally-controlled companies and subsidiaries supporting the aerospace and defense industry broadly has not engendered sufficient competitive dynamics to drive high-degrees of more systems-focused innovation.

China's attempts to drive innovation

China has recognized these three vulnerabilities and is in the midst of an effort to reduce inefficiency and redundancy; change mindsets; drive innovation; and, ultimately, provide China's aerospace and defense industry with sufficient scale to compete with the largest and most capable of Western primes both in terms of technological capability and in the global aerospace market. China's attempts to address its space innovation challenge include the following components.

Funding: China has demonstrated a sustained financial commitment to its space program and the industry that supports it. In August of 2014, CASIC signed a funding deal with the Industrial and Commercial Bank of China (ICBC) to support CASIC's development of a "new generation of technologies" related to space launch technologies, unmanned systems, 3D printing technologies, sensors and communication systems. The funding was also designed to support CASIC's renewed focus on exports, especially to Russia. The value of the funding deal is not immediately known, but is suspected to be between the hundreds of millions of dollars and low billions of dollars.

In addition, in January of 2015, CASIC and the China Construction Bank signed a new strategic cooperation agreement designed to strengthen cooperation in the development of the next generation of spacecraft and launch applications as well as cloud manufacturing platforms. According to SASTIND, the deal extended CASIC's credit line with the China Construction Bank from 10 billion yuan to 20 billion yuan (from around $1.6 billion to $3.2 billion).

China has also sought to drive increased funding thought to be required to enhance competitiveness and innovation in China's aerospace and defense industry through the private placement of stock in state-owned companies. In December of 2013, Aerospace Communications Holding, a subsidiary of CASIC, raised approximately $127 million through the sale of just over 9 million shares of stock to select Chinese companies, including CASIC and its subsidiaries, which accounted for roughly 25% of the placement. The money raised through the stock sale will be used in part to help ACH expand its international presence and technological base through mergers and acquisitions.

Industry consolidation: The most impactful of the current reforms affecting China's aerospace and defense industry is the recent move toward consolidation of core state-owned enterprise activity, including activities carried out by CASIC and CASC, the industry pillars of China's space program. In June of 2014, SASTIND somewhat unexpectedly announced the signing of a cooperation framework agreement between CASIC and CASC that would require the two companies to "deepen consolidation further in order to improve competitiveness and sustainable development and support the realization of a strong space, military and aerospace industry", according to SASTIND. CASC's activities are more focused on space, but both companies produce satellites, communications equipment and missiles.

While the agreement does not explicitly mention merging the two companies, it does create a pathway for such an eventual move if SASTIND believes it would further enhance competitiveness with Western aerospace and defense primes and if such a complicated and politically tricky move could be effectively accomplished. CASC and CASIC were originally established through the breaking up of the Chinese Aerospace Corporation approximately 15 years ago.

The CASC and CASIC consolidation agreement is just one of a series of agreements and measures taken recently to consolidate commercial aerospace (2008) and shipbuilding (on-going) and to engender increased collaboration across its heavily redundant defense industrial base.

China's efforts to address its innovation challenge are likely to help move its space program beyond its current state, but, given the massive challenge associated with restructuring these large organizations and engendering new mindsets and processes into well-established organizations, it is unlikely that the full effect of these reforms will be felt until the end of the decade or beyond.

Effects of U.S. Export Control Restrictions

U.S. export control restrictions have affected the ability of China to procure or acquire critical technologies either directly from the United States and its space industry or indirectly through non-sanctioned providers, especially in Europe. China continues to lobby against both the U.S. space trade restrictions and broader U.S. and European Union arms bans against China. During the signing of the most recent agreement between China and France on 30 January of 2015, Chinese Premier Li Keqiang lobbied French

Prime Minister Manuel Valls, to "ease restrictions on export of high technology products to China", indicating that China still viewed these measures as an obstacle to the development of its space industry.

However, the combination of current U.S. policies, broad shifts in the global space industry and market and China's growth as a potential market are shaping both proximate challenges to the U.S. space industry as well as possible larger future strategic challenges to U.S. space policy and programs while not effectively managing the flow of advanced--even if not American--space and dual use technologies to China.

Concern over U.S. export controls on space-related items and confusion over which items are on the list of banned items for export and, importantly, which ones will be in the future, has led international industry, especially the European space industry, which has far less severe export guidelines for space technologies, to endeavor to design ITAR-free solutions, effectively cutting out U.S. based suppliers of ITAR - restricted items from international supply chains. Indeed, the presentation on Technical Constraints for the China Academy of Sciences - European Space Agency Joint Mission delivered at the first planning workshop between the two institutions in February 2014 highlights the importance of the "entire space segment" being "ITAR free."

The increasingly competitive and lucrative space industry is driving interest from high-end suppliers in the West in working with China on programs that do not involve the transfer of explicitly military technologies. The end-result is that more advanced--though not U.S.--space technology is being transferred to China *and* U.S. companies are increasingly being cut out of the supply chain for European partners or, alternatively, many U.S. companies are beginning to reconsider creating products that could be export controlled. Both outcomes have the potential to affect the U.S. space industrial base.

A longer-term concern related to U.S. refusals to engage China collaboratively on space science and technology issues is that over-time U.S. relationships with allies and partners could suffer, especially after the early 2020s when, barring a shift in current plans, China will be the only country in the world with a habitable space station. Space connections between U.S. allies and partners and both Russia and China are already being made. In early 2012, ESA openly discussed the possibility of Chinese space craft docking at the International Space Station--the U.S. has prohibited China's ability to access the station--or that a European spaceship will dock at the Chinese space station. Russia, too, has discussed similar manned spacecraft exchanges with China and is working with ESA on the ExoMars program after NASA removed itself from the program in 2011.

Certainly, the U.S. remains Europe's closest and most important space partner, and terrestrial geopolitical environments have shifted in a way that could limit the depth of engagement between these partners and Russia and China. Still, in a complex and uncertain geopolitical, economic and technological landscape, it is worth considering some plausible, if currently unlikely, scenarios in which U.S. export control and space policies enable growing isolation in space and what types of new or different policies, relationships, capabilities or approaches may be required to avoid this isolation.

Recommendations

Continue the export control review and refinement with a focus on increasing protection of a small number of systems and technologies that the U.S. is and should be unwilling to offer to the open market, for example technologies related to manned spaceflight. Such a fencing off of critical technologies should also allow U.S. companies to engage more fully around markets for technologies that do not pose a significant risk of supporting a shift in China's military capabilities and that China is likely already receiving through other technologically advanced suppliers.

Increase engagement with academia and law enforcement / intelligence to better understand technology transfer and proliferation challenges posed by cross-border academic interactions in areas of interest to China's intelligence services while maintaining the integrity and utility of the majority of these academic exchanges.

Engage China on space science, a relatively low risk area of engagement, that China's Academy of Science has identified as an area of development.

Increased / improved cross-government and industry engagement with allies and partners in space, cyber and joint domains.