BUILDING FOR THE FUTURE: CHINA'S PROGRESS IN SPACE TECHNOLOGY DURING THE TENTH 5-YEAR PLAN AND THE U.S. RESPONSE

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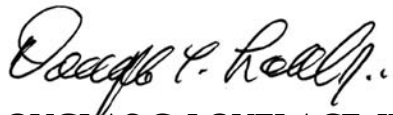
FOREWORD

China's space program has achieved spectacular success in recent years. Since 2003 China has launched two human space flight missions, destroyed a satellite with a direct ascent anti-satellite weapon, and launched a moon orbiter. In this monograph, Mr. Kevin Pollpeter assesses China's rise as a space power and its implications for the United States. He argues that China's use of space power is part of an integrated approach to increasing its comprehensive national power and achieving great power status. As a result, China's increasing space power challenges the United States militarily, economically, commercially, and politically.

China's increasing space capabilities will erode the U.S. lead in space in both absolute and relative terms. Nevertheless, the loss of preeminence in space need not result in the United States losing its role as the leading space power. To maintain its lead, the United States will not only need to improve technologically, but also train and keep a competent workforce, develop new and innovative ways to compete commercially, and expand the role of space in its exercise of soft power. To this end, this monograph offers valuable insights into China's rise as a space power as well as a number of policies designed to respond to the challenges it presents.



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SUMMARY

The advance of the Chinese space program has laid a foundation for that country to enter into the top tier of space powers. In recent years, China has made important progress across a broad range of space technologies including launchers, launch schedules, satellites, and human space flight, and has taken a leading role in regional space cooperation.

This monograph examines how the United States should respond to China's rise as a major space power based on China's space activities during the period of the Tenth 5-Year Plan (2001-05). It finds that the Chinese space program made impressive gains during the Tenth 5-year Plan, but when compared with the other major space powers, China's space technology still lags behind.

China's burgeoning space program provides opportunities for China to use the benefits derived from space power to become a more influential and respected nation. While China does not have an official grand strategy, the Chinese leadership appears to have reached a consensus on a plan which sustains the conditions necessary for economic growth and military modernization in the context of operating in a unipolar world dominated by the United States. This strategy is designed to ultimately usher in a multipolar world in which China is one of several great powers by protecting China's core national interests against external threats and by shaping the international system in which it operates.

To this end, China's space program is intended to portray China as a modernizing nation committed to the peaceful use of space while at the same time serving China's political, economic, and military interests. It

contributes to China's overall influence and provides capabilities that give China more freedom of action and opportunities for international leadership. Militarily, the People's Liberation Army is undergoing reforms to transform itself into a military that is reliant on information for winning wars. Economically, China's support for its space program lies in its potential as a driver for economic and technological advancement. Commercially, China is positioning itself as a low cost provider of space technologies and launch services. Commercial services not only increase revenues for the space industry but have also been used to advance China's diplomatic interests with oil-rich countries. Politically, China's expanding international cooperation on space activities portends a more influential foreign policy. Domestically, by developing a robust space program and participating in high-profile activities such as human space flight, the Communist Party demonstrates that it is the best provider of material benefits to the Chinese people and the best organization to propel China to its rightful place in world affairs.

China's rise as a space power will present military, economic, and political challenges to the United States. Uncertainty over China's pathway to potential major power status, the possibility of a conflict over Taiwan, and the inherent dual-use nature of space technologies means that China's improving space capabilities could be used against the U.S. military. China's efforts to develop its space program to transform itself into an economically and technologically powerful country may also come at the expense of U.S. leadership in both absolute and relative terms. China has also been able to use its space program to further its diplomatic objectives and to increase its influence in the developing world and among second-tier space powers.

China's increasingly capable space program will have a net negative-sum effect on the United States and requires both domestic and international responses by the United States. Domestically, the U.S. Government and industry must improve the health of its space industry through better program management, attracting and retaining a competent workforce, and increasing funding to develop cutting edge technologies. Internationally, the United States must take into account China's growing presence in world affairs, including space activities.

The rise of China as a space power also raises the question of whether the United States should cooperate with China in space. The difficulty in deciding an appropriate response arises from the inability of both sides to determine whether their relationship will be friendly or hostile. Nevertheless, the United States is presented with four policy options to meet the changing dynamics presented by China's space program: contain, compete, cooperate, and do nothing.

Containment is the least viable of the four options, and as China becomes more integrated with the world, it will become even less practical.

Competition may also be problematic. U.S.-China relations may be ambivalent, but extensive cooperation does take place in many araeas, and it is not apparent how defining China as a competitor in a space race will further relations. It is also not apparent whether the American public will support a race which will require additional funding with little short-term gain.

Cooperation, on the other hand, has the potential to increase transparency and trust and to lessen competitive aspects that may lead to armed conflict. A policy that treats China as a friend, however, has its own shortcomings. Because China's strategy is designed

to further its own national interests and because its interests are often not aligned with U.S. interests, it is unlikely that assisting China in increasing its space power may eliminate these differences and may, in fact, exacerbate them.

Doing nothing is a safe option that does not risk the transfer of technology or expertise. A policy of inaction does risk ignoring the possible benefits of cooperation.

While the inherent military nature of China's space program and its lack of transparency preclude most forms of cooperation, the United States can cooperate with China in beneficial ways that do not transfer technology or expertise. These include coordinating scientific research and increasing the safety of human spaceflight by establishing a code of conduct to rescue imperiled astronauts. Consequently, the challenge for the United States is to manage the positive-sum and negative-sum consequences of China's ascendant space program by improving its space industry, better enabling its military to counter space-based threats, and engaging in cooperative activities that improve science and increase the safety of human space flight.

BUILDING FOR THE FUTURE: CHINA'S PROGRESS IN SPACE TECHNOLOGY DURING THE TENTH FIVE-YEAR PLAN AND THE U.S. RESPONSE

INTRODUCTION

China's launch of its first human space flight mission in 2003 has raised concerns about the U.S. ability to maintain its lead in space technology. In recent years, China has made important progress across a broad range of space technologies including launchers, launch schedules, satellites, and human space flight. It established a robust remote sensing network consisting of meteorological, land resources, and oceanography satellites, as well as a satellite navigation and positioning system. China also conducted more launches and more complex launches than at any other time in its history. It has developed a solid-fuel launcher for small and micro-satellites, signed agreements to export satellites, and taken a leading role in regional space cooperation. While China has started from a low base, it has laid a foundation to become a major space power.

The United States, on the other hand, maintains the world's most advanced and largest space program. Most of the world's commercial satellites are manufactured by U.S. companies, it conducts the most space exploration activities, and spends as much on national-security space activities as all other countries combined.[1] In recent years, the United States announced plans to return humans to the moon. But much of the space program has encountered difficulties, including the fatal break up of the space shuttle Columbia and systemic problems affecting its national security space program. Every next generation U.S. satellite being

developed ran over budget and behind schedule and experienced technical difficulties.[2] In contrast to the Chinese program, the United States appeared to be losing its edge in space technology.

This monograph examines how the United States should respond to China's rise as a major space power based on China's space activities during the period of the Tenth Five-Year Plan (2001-05). For the purposes of this monograph, space power is defined as "the pursuit of national objectives through the medium of space and the use of space capabilities."[3] The monograph will first outline China's space goals and then examine its activities during this period as well as discuss China's goals for the Eleventh 5-year Plan (2006-10). It will then determine how the space program contributes to China's goal of becoming a major power through the application of comprehensive national power (CNP) and draw implications for U.S. national security. Finally, it will examine possible U.S. military, economic, and diplomatic responses to China's space program.

The monograph finds that over the long term, China's rise as a space power will present military, economic, and political challenges to the United States. Uncertainty over China's pathway to potential major power status, the possibility of a conflict over Taiwan, and the inherent dual-use nature of space technologies means that China's improving space capabilities could be used against the U.S. military. China's efforts to develop its space program to transform itself into an economically and technologically powerful country may also come at the expense of U.S. leadership in both absolute and relative terms. Finally, with the exception of its anti-satellite (ASAT) test in January 2007, China has been able to use its space program to further its

diplomatic objectives and to increase its influence in the developing world and among second-tier space powers, which could diminish U.S. power in the space diplomacy arena.

China's increasingly capable space program will have a net negative-sum effect on the United States and requires both domestic and international responses by the United States. Domestically, the U.S. Government and industry must improve the health of its space industry through better program management, attracting and retaining a competent workforce, and increasing funding to develop cutting edge technologies. Internationally, the United States must take into account China's growing presence in world affairs, including space activities. While the inherently military nature of China's space program and its lack of transparency preclude most forms of cooperation, the United States can cooperate with China in beneficial ways that do not transfer technology or expertise. These include coordinating scientific research and increasing the safety of human spaceflight by establishing a code of conduct to rescue imperiled astronauts. Consequently, the challenge for the United States is to manage the positive-sum and negative-sum consequences of China's ascendant space program by improving its space industry, better enabling its military to counter space-based threats, and engaging in cooperative activities that improve science and increase the safety of human space flight.

GOALS

China's space program, as well as its entire economy, is guided by a series of economic policy

decisions generated every 5 years. Appropriately called "Five-year Plans," these documents outline specific industrial goals spanning every sector of the Chinese economy from agriculture, to steel, to semiconductors. At the time of writing, China is in its Eleventh Five-year Plan, which governs the period from 2006-10. The Tenth Five-year Plan, the subject of this monograph, covers the period from 2001-05.

In November 2001 the China National Space Administration (CNSA) published its Tenth Five-year Plan, of which only elements have been publicly released. China committed to spend more than 5 billion yuan (~$603.9 million) on the research and development of civil space technology. According to Luan Enjie, then head of the China National Space Agency (NSA), China's broad goals for the Tenth Five-year Plan included:

- Establishing a varied remote sensing system that has long-term stability and an integrated space-ground application system.
- Setting up a preliminary satellite navigation and positioning system application industry.
- Establishing a satellite communications system that can basically meet domestic market needs.
- Strengthening the capability to provide commercial launch services.
- Carrying out space science research and deep space research by beginning to research the moon.
- Striving to be a major power in space research.
- Launching nearly 30 satellites.
- Developing small satellites.
- Carrying out human space flight.
- Striving to be a major power in space research.[4]

Specifically, China planned to develop eight new civil satellites. These included one *Haiyang* ocean monitoring satellite, two *Fengyun-3* meteorological satellites, two earth-space science satellites, and three environmental and disaster monitoring satellites. China would improve its communication satellites for both military and civilian use by developing Ku and C band communications technology comparable to world technology levels. China also planned to upgrade its satellite navigation system, though no specifics were given.[5] In addition, China was to develop a small satellite, a new generation of launch vehicles, as well as lunar exploration technologies.[6]

TENTH FIVE-YEAR PLAN ACCOMPLISHMENTS

Space Launches.

China launched a total of 28 satellites and spacecraft on 26 launchers for a 100 percent success rate for nontest launches. Launches steadily increased from just one in 2001 to a peak of eight in 2004. See Table 1.

Year	Satellites	Spacecraft	Total	Launches	Failures
2001	0	1	1	1	0
2002	3	2	5	5	0
2003	6	1	7	7	0
2004	10	-	10	8	0
2005	4	1	5	5	0
Totals	23	5	28	26	0

Table 1. Total Chinese Nontest Space Launches, 2001-05.

2001. The year 2001 was a low point for the Chinese launch industry, with a single launch of the unmanned space capsule *Shenzhou-2* in January.

2002. During 2002, China launched five spacecraft on five rockets. Most notably, China launched two unmanned *Shenzhou* capsules in March and December. In May China launched two satellites—a *Fengyun-1D* meteorological satellite and a *Haiyang-1* ocean monitoring satellite—into orbit on a *Long March-4B* (*LM-4B*). In addition, the first test launch of the *Pioneer-1* solid-fuel rocket was conducted in September, though unsuccessfully. Later that month, it was announced that China had a total of nine satellites in orbit, the most for China at any one time up to that point.[7]

2003. In 2003, China announced it would launch eight domestic satellites and one spacecraft.[8] China, however, managed launching just six satellites and one spacecraft. Most notably, China conducted its first human space flight mission on October 15. China also launched its second *Beidou* navigation and positioning satellite in this year. In September, a second *Pioneer-1* rocket was launched, this time successfully. Five of the launches for 2003 occurred during a 3 1/2-month window from October 15 to December 30. These launches were conducted from three different launch sites with all unmanned missions being controlled from Xi'an and with each launch requiring different software and control teams.[9]

2004. Because of the many strides made in space technology, 2004 has been called the year of "the four mosts." In 2004, China launched 10 satellites upon eight rockets, all of them government launches. This was the most launches conducted in a year by China, demonstrating an increased ability to maintain a regular operational tempo in terms of launch and

satellite control. At the beginning of 2005, China had 19 satellites in orbit.

Contributing to the impressiveness of these accomplishments was the conduct of seven of the eight launches during a 4-month period between July 25 and November 18. The *Long March-2C* (*LM-2C*) rocket also distinguished itself with the unprecedented accomplishment of launching five times from three different launch sites and carrying six satellites into orbit in 1 year.

The fourth accomplishment of 2004 was the reduction of launch preparation times from 45 days to 23 days. Preparation time for satellites at the launch site was also reduced.

Other highlights for this year included the launch of a *Ziyuan-2* environmental monitoring satellite to form a three-satellite network for more timely earth observation. In addition, the launch of two recoverable satellites in August and September demonstrated an ability to quickly launch satellites from the same launch site. The 19th recoverable satellite was launched from the Jiuquan Launch Center on August 29 and remained in operation for 27 days, returning on September 25. Two days later, the 20th recoverable satellite was launched from the Jiuquan Launch Center.[10]

2005. In 2005, China conducted just five launches by orbiting one spacecraft and four satellites. China launched the *Shenzhou-6*—its second human space flight mission—this time with two astronauts. Other notable launches include two recoverable satellites on August 2 (*FSW-21*) and August 29 (*FSW-22*) from the Jiuquan Launch Center. The *FSW-21* mission returned on August 29, the same day the *FSW-22* was launched. Not only did the missions prove China could launch two missions from the same launch center in a short

period of time, but also that command and control teams can work continuously in maintaining a mission while preparing for a second mission. The launch of the *Apstar-6* satellite on a *LM-3B* on April 12 was the first time in 6 years China launched a commercial satellite.

Launch Vehicles.

China formally began researching and developing its next generation launchers on May 10, 2001.[11] This new family of launch vehicles offers increased reliability and adaptability and will be powered by "nonpoisonous" and "nonpolluting" engines that will provide more thrust than the current generation of launch vehicles.

These new launchers will, in part, support China's human space flight and lunar exploration programs by launching a space station into Earth orbit and satellites to the moon. The new generation of rockets will be divided into light, medium, and heavy-lift versions and will be able to send a 1.5 to 25 ton payload into low-Earth orbit (LEO)[12] and a 1.5 to 14 ton payload into geosynchronous orbit (GEO).[13]

The first launch of the new rocket is uncertain. CNSA Vice Administrator Luo Ge in April 2006 stated the launch would occur by 2011.[14] More recently, Huang Chunping, the former head of the manned spaceflight launch vehicle system, gave a launch date of 2014 or 2015.[15]

In addition to developing a next generation launch vehicle, China completed the development of a smaller solid fuel rocket, called the *Pioneer* (*kaituozhe*), designed to launch micro and small satellites and to provide a capability to "rapidly enter space." Though advertised

as built for the commercial small satellite launch vehicle market, an article in *Aerospace China* lists the *Pioneer's* benefits as "stressing low cost design and a variety of users, it is able to meet the special needs of the military for launching small payloads."[16] Indeed, it is the *KT-1* that is believed to have been used to conduct China's ASAT test on January 11, 2007.

The *Pioneer* has two variants. The *KT-1* is a four-stage booster based on the military *DF-21* and is designed to launch satellites weighing less than 100 kilograms into orbit. Its sister launcher, the *KT-2*, is based on the *DF-31* intercontinental ballistic missile and can lift up to three 100 kg payloads or one 400 kg payload. Both variants are road-mobile.[17] The first test of the *KT-1* was in September 2002 and was unsuccessful,[18] but a second *KT-1* was successfully launched in September 2003.[19]

Satellites.

China made steady progress in satellite development during the Tenth Five-year Plan. China now has three different types of remote sensing satellites—meteorological, ocean, and earth resources—in orbit on a continuous basis. These systems are able to provide different types of information to monitor weather and disasters. China has also established its first satellite navigation and positioning system.

Fengyun. China's first *Fengyun* (*FY*)-class meteorological satellite was launched in 1988. China has two series of *Fengyun* satellites, the *FY-1* and *FY-2*, two of which were launched during the Tenth Five-year Plan. The *Fengyun*-2 (*FY-2*) is similar to the *Fengyun-1* but with improved sensors.[20] The *FY-2* has a service life of 3 years[21] and can normally take 28 images per day.[22]

China is currently developing a *FY-3*. Chinese press reports boast that it will reach higher technical standards than the U.S. *NOAA-15* satellite—a spacecraft launched in 1998.[23] A *People's Daily* article from 2002 states that China planned to launch two *FY-3s* by the end of 2008.[24] By November 2007, however, no launch had occurred.

Ziyuan. The *Ziyuan* earth monitoring satellite is a joint project with Brazil, in which China has a 70 percent stake.[25] China launched three *Ziyuan* satellites from 2002-04, which formed a network to provide timely coverage of the Earth.

Ziyuan satellites have included a 20-meter resolution optical imager, and 80-meter and 160-meter resolution infrared sensors. It also has two wide band imagers with a resolution of 256 meters.[26] The *ZY-2* is reported to have an imager with a resolution of three meters.[27]

Haiyang. Development of the *Haiyang-1* (*HY-1*) was a goal of China's Ninth Five-year Plan and is China's first ocean monitoring satellite. The satellite will observe the characteristics of seawater, including chlorophyll density, sea surface temperature, suspended sand content, yellow materials, and maritime contamination.[28]

The first *Haiyang* was launched on May 15, 2002 and cost 200 million yuan (~$24.2 million) to manufacture.[29] The satellite is a small satellite, weighing only 360 kilograms.[30] The *HY-1* has a color scanner with a 1,100-meter resolution. It has two infrared sensors, eight visible light sensors, and an imager with a 250-meter resolution.[31]

Beidou. The *Beidou* satellite system is China's regional satellite navigation and positioning system. After the launch of the first two *Beidou* satellites on October 31 and December 21, 2000, China was said to have

established its own satellite navigation and positioning system to be used primarily for road, rail, and ocean traffic. The third *Beidou* satellite was launched on May 25, 2003. Despite these successes, Chinese officials describe *Beidou* as a preliminary system that is unable to meet China's future needs.

Beidou is based on a system called radio determination satellite service (RDSS) involving at least two satellites in geostationary orbit, at least one ground station, and customer receiver/transmitters which communicate with each other. This system can achieve accuracies up to 20 meters. While the *Beidou* system cannot achieve the accuracies of the U.S. global positioning system (GPS), it does have the advantage of allowing two-way communication between the signal provider and the customer and can be used in vehicle location systems that can provide anti-theft and engine monitoring services. *Beidou* will eventually be replaced by a system similar to the U.S. GPS that will be free of charge.[32]

Communication Satellites. China launched two communication satellites during the Tenth Five-year Plan, the *Chinasat-22* in November 2003 and the *Apstar 6* manufactured by Alcatel in April 2005. The *Apstar 6* is advertised as providing enhanced reception quality over an area extending from India and China to Australia.[33]

China boasted that the orbiting of the *Apstar 6* was its first commercial launch in 6 years. The significance of this event is somewhat less than advertised, however. The *Apstar 6* is owned by APT Satellite Holdings, a Bermuda-registered corporation with its principal office in Hong Kong. While technically a commercial launch, the principal ownership of the company by Chinese government entities most likely

dictated the use of Chinese launch services. APT Satellite Holdings' principal shareholders include the China Aerospace Science and Technology Corporation (CASC) and the China Telecommunications Broadcast Satellite Corporation (Chinasat), both Chinese state owned enterprises. Another principal shareholder, CASIL Satellite Holdings Limited, is a publicly owned subsidiary of CASC that is listed on the Hong Kong stock exchange.[34]

China also made progress in improving its ground segment for communication satellites. By the end of 2005, China had more than 80 international and domestic telecommunications and broadcasting stations and 34 satellite broadcasting and TV link stations.[35]

Moreover, in 2005, China completed its "Village Television Broadcast Project," a program aimed at bringing television to more than 100,000 villages located in remote areas of Western China. China also surpassed its goal of expanding phone service in rural areas, with 98 percent of administrative villages now having phone service.[36]

Human Space Flight.

China's human space flight program is the space industry's most difficult and largest mission.[37] China conducted five launches of the *Shenzhou* during the Tenth Five-year Plan, two of which were manned. On October 15, 2003, China launched its first astronaut into space on the *Shenzhou 5*. This mission lasted less than 24 hours but proved that China was capable of safely sending a human into orbit and returning him to Earth. China's second manned space flight occurred on October 12, 2005, and lasted 5 days, with a crew of two. China's human space flight program can be expected

to increase in difficulty and is planned to eventually result in a permanently-manned space station.

Space Science.

Lunar Program. China's lunar program was officially announced in January 2003, but planning for the endeavor had been going on for years.[38] The first stage occurred in 2007 and involved sending a satellite to take three-dimensional images of the moon. Eventually China wants to land a robotic vehicle on the moon much in the same way as the United States landed a robotic vehicle on Mars.

Double Star. The Double Star satellite project is the result of an agreement signed on July 9, 2001, between the China NSA and the European Space Agency (ESA) to research the effects of the Sun on the Earth's environment.[39] China's two satellites have joined the four ESA satellites of the Cluster project to form a monitoring network. The first launch occurred on December 30, 2003, and the second satellite was launched on July 25, 2004.[40]

Satellite Export.

China announced agreements in 2004 and 2005 to export its first satellites. A contract was signed in December 2004 between the Nigerian government and the China Great Wall Corporation for China to build and launch the satellite, provide operating services, and train Nigerian technicians in its operation.[41] The Nigerian Communication Satellite is based on the *Dongfanghong-4* communication satellite and was launched on May 14, 2007. China also signed a similar agreement with Venezuela for a telecommunications satellite to be launched in 2008.[42]

Cooperation.

China took steps to take a leading role in regional space cooperation during the Tenth Five-year Plan. In October 2005, China, Bangladesh, Indonesia, Iran, Mongolia, Pakistan, Peru, and Thailand endorsed the Asia-Pacific Space Cooperation Organization convention to promote multilateral cooperation in space science, technology, and applications and agreed to headquarter the organization in Beijing. Since then, Turkey also signed the convention. China submitted the convention to its legislature in June 2006, which will take effect when the legislatures of at least five signatories approve membership.[43]

China has also increased its cooperation with the ESA. In 2004, ESA and the National Remote Sensing Centre of China (NRSCC), an entity under the Ministry of Science and Technology, began a 3-year earth observation program called "Dragon." The Dragon program focuses on science and applications development in China mainly using data from ESA's *Earth Remote Sensing (ERS)-2* and *Envisat* missions. The objectives of this cooperation are to promote the use of ESA data from the ERS and *Envisat* satellites, to stimulate Earth observation science, to publish coauthored research results, and to provide training in processing, algorithm, and product development from ESA earth observation data of land, ocean, and atmospheric conditions.[44]

While developing its own indigenous satellite navigation and positioning system, China agreed in 2003 to invest 200 million Euro in the *Galileo* satellite navigation and positioning system. According to this agreement, China will invest 70 million Euro in

space technologies and 130 million Euro on ground infrastructure and applications. Since then, China's participation in *Galileo* has been reduced. The political rationale pushed by Brussels for cooperating with the Chinese, a major factor driving the agreement, lost steam after the Dutch and French rejected the European constitution in 2005 and industry advocates used the opportunity to voice concerns over the agreement. European businesses wanted to cut China out of the market by developing as much of the technology as possible themselves. The aerospace industry also had reservations that U.S. export controls may not permit them to use critical U.S. technologies in *Galileo* due to the possibility of their diversion to China.

Due to these concerns, China will continue to invest in domestic ground infrastructure and applications but will minimize the development of technologies for the space segment. In accordance with this, China will set up a center at Beijing University in cooperation with the ESA, the European Commission, and the Chinese Ministry of Science and Technology, called the China-Europe Global Navigation Satellite System Technical Training and Cooperation Center. This organization will facilitate joint ventures between Chinese and European companies involved in the research and development of satellite navigation and positioning products.[45]

While China's cooperation with Europe has been diminished, its cooperation with Russia is increasing. In September 2005, the head of the Russian Federal Space Agency stated that cooperation with China reached a "fundamentally new level" with 29 new projects added to the cooperation program for 2004-06. Exact details remain unknown, but in 2006 Russia and China announced a joint Mars exploration mission to land a

robotic explorer on the red planet and then return it to earth.[46] Cooperation on a lunar program and satellite communications has also been discussed.[47]

ASSESSMENT

The period of the Tenth Five-year Plan occasioned a significant improvement in all aspects of China's space program. For example, during the previous Five-year Plan, China allocated just 1.7 billion yuan (~$205.3 million) to civilian space activities—less than half the 5 billion yuan (~$603.9 million) budgeted for the Tenth Five-year Plan. China's 26 launches during this 5-year period are nearly half the total number of successful launches (54) conducted before 2001. China also launched two new types of spacecraft: the *Shenzhou* manned spacecraft and the *Haiyang* oceanographic satellites, and existing satellite classes underwent improvement.

While the Chinese space program made impressive gains during the Tenth Five-year Plan, when compared with the other major space powers, China's space technology still lags behind. Taking imagery satellites as an example, China's *Ziyuan* satellite has just a three-meter resolution and remains behind even commercial remote sensing technology resolutions. Commercial remote sensing provider *Geoeye*, for example, offers one-meter imagery and plans to offer 0.41-meter imagery. Similarly, the *Beidou* satellite navigation and positioning system is a regional system that offers accuracies to 20 meters. The U.S. GPS constellation, on the other hand, offers a global service with accuracies of several meters.

Rocket Rate	Capabilities	Total Launches	Failed Launches	Success Percentage
LM-1	LEO	2	0	100
LM-2	LEO	1	1	0
LM-2C*	LEO	28	0	100
LM-2D*	LEO	6	0	100
LM-2E*	LEO/GEO	7	2	71
LM-2F**	LEO	6	0	100
LM-3	GEO	13	3	77
LM-3A*	GEO	8	0	100
LM-3B*	GEO	7	1	86
LM-4B*	LEO/GEO	10	0	100
Total		88	7	92

*Marketed to international customers
**Dedicated for *Shenzhou* missions

Table 2. *Long March* Family Success Rates.

China's progress in launchers and launches is also mixed when compared to the other major space powers. China successfully launched all of its *Long March* boosters during the Tenth Five-year Plan. The last launch of 2005, which orbited *Shenzhou 6*, was the 46th straight successful launch of the *Long March* series. The *Long March* booster reached a 92 percent success rate based on 88 launches, a figure approaching international standards. The success rates of the *Long March* family vary widely depending on launcher, however. The *LM-2C* continues to be a solid work horse with no failures and 28 launches by mainly launching China's recoverable satellites. The *LM-3*, on the other hand, has just a 77 percent success rate.[48]

As a result, while the success rate of the *Long March* family as a whole may approach international

levels, certain launchers are still far from reaching these standards. (See Table 2.) Because of this, the Great Wall Industry Corporation, the commercial representative for the China Aerospace Science and Technology Corporation, only markets the *LM-2C*, *LM-2D*, *LM-2E*, *LM-3A*, *LM-3B*, *and LM-4B* boosters to international customers. While the *LM-2E* and *LM-3B* have below average success rates (71 percent and 86 percent, respectively), the other four launchers have a 100 percent success rate. It is probable that these two launchers will not achieve international success rates before the next generation of launchers is introduced.

China also does not appear to have the capability to match the launch tempos of the major space powers. (See Table 3.) While China has shown a capability to surge launches, this capability does not compare to the launch rates of Russia and the United States. In fact, examination of the number of launches reveals a huge gap between China and the United States and Russia. Its proximity to the number of European launches, however, reflects just how close China is to being on par with that major space power.

Year	Russia	United States	Europe	China
2005	26	12	5	5
2004	22	16	3	8
2003	21	23	4	6
2002	25	17	12	6
2001	23	22	8	1
Totals	**117**	**90**	**32**	**26**

Table 3. Total Space Launches of Major Space Powers, 2001-05.

China's development of launch vehicles also lags behind the United States and Europe. Development of China's next generation launch vehicle, originally scheduled to take 10 years, may now take 15 years. In contrast, development of the U.S. *Atlas V* and *Delta IV* launchers took approximately 8 years, while the European *Ariane 5* took approximately 11 years.

The only area in which the Chinese have reached international standards is its human spaceflight program. While the United States may operate the more advanced space shuttle, it has recognized the practicality of space capsules for human spaceflight and its next generation of manned spacecraft will adopt the technologies used during the Apollo missions. In this respect, by adopting a "Back to the Future" concept for its *Shenzhou* program, the Chinese are ahead of the United States in manned spaceflight technology.

THE FUTURE[49]

China plans to build on its successes in the Tenth Five-year Plan in the coming years. According to the Commission on Science, Technology, and Industry for National Defense (COSTIND), there are six main space science projects for the Eleventh Five-year Plan:

- Human space flight. This includes increasing the complexity of its human space flight missions with a space walk scheduled for the *Shenzhou*-7 mission in 2008 and docking missions.
- Lunar exploration. The first stage of the lunar mission to send a lunar orbiter to take three-dimensional images of the moon was successfully conducted in 2007. The second stage, landing

a lunar rover on the moon surface to conduct robotic exploration, is scheduled to launch in 2012. The third stage involving a lunar soil return mission is scheduled to be launched by 2020.

- Space science.
  - Indigenously develop a hard x-ray modulating telescope to study black holes to be launched in 2010.
  - Launch the *Shijian-10* recoverable satellite in 2009 to carry out microgravity space biomedicine experiments.
  - Develop a solar telescope to study solar physics.
  - Develop technologies for a three-satellite constellation called *Kua Fu* to study solar activity that will consist of one satellite to monitor solar activity and two others to study the aurora.
- International cooperation. Participate in the Sino-Russian Mars environment exploration plan, the World Space Observatory Ultraviolet Project,[50] and the Sino-French Small Satellite Solar Flare Exploration Project.[51]

In addition, space cooperation will be advanced by the formal establishment of the Convention on Asia-Pacific Space Cooperation Organization and the publication of a second space white paper.[52]

In regards to imaging satellites, China will launch 18 remote sensing satellites; these include earth resources, environmental disaster, meteorological, and oceanographic satellites. These remote sensing satellites are "to form an all-weather, 24-hour, multi-spectral, differential-resolution Earth observation for

stable operation, and achieve stereoscopy and dynamic monitoring of the land, atmosphere, and sea."[53] This will include establishing an environmental and disaster monitoring satellite constellation consisting of four synthetic aperture radar (SAR) and four optical satellites. The first three satellites will be launched in 2007 and will include two optical and one SAR satellite. Another five satellites will be launched in 2010.[54]

China also plans to spend $1.5 billion to develop meteorological satellites, including launching the *FY-2* with a 1.25 kilometer visible and a five kilometer infrared resolution imager; and the *FY-3* with infrared, spectrometer, and microwave imagers; a medium resolution imager; radiometer; and a scanning radiometer. It will also develop the *FY-4*, which will include improved meteorological measurements and one to five kilometer resolution imagers.

In addition to its meteorological satellites, China launched the *HY-1*B oceanography satellite in 2007. This satellite is equipped with a 250-meter resolution imager and an ocean color spectrum scanner with a 1,100 meter resolution. In 2009, China will launch the *HY-2* to monitor ocean waves, ocean wind field, ocean gravity field, ocean currents, and ocean surface temperatures. It will be fitted with a microwave radiometer, microwave spectrometer, and radar altimeter.

A main focus for the Chinese space industry during the Eleventh Five-year Plan will be the development and launch of communication satellites. Multiple large communication satellites having a service life of 15 years and weighing 5,200 kilograms will be launched beginning in 2006.

The Eleventh Five-year Plan thus promises to further China's progress in space technology with

breakthroughs in synthetic aperture radar technology, allowing China to image objects regardless of weather; human spaceflight capabilities allowing for extravehicular activity that will give China the experience necessary to maintain space stations; and continued space weather missions that will provide additional knowledge to protect astronauts from solar activity.

THE BENEFITS OF A SPACE PROGRAM: FITTING SPACE POWER INTO CHINA'S GRAND STRATEGY

China's burgeoning space program provides opportunities for China to use the benefits derived from space power to become a more influential and respected nation. The trappings of a robust space program are one hallmark of the great powers and China appears to be positioning itself as a great power with its space program. Indeed, as a COSTIND press release on its Eleventh Five-year Plan for space science states, "Our country is one of the few major space powers. China's position in the world and the country's security depend on the continued fast development of space technology."[55] This sentiment would be in accordance with some Chinese analysts who have advocated that China adopt a great power mentality in which China's interests mirror those of the major powers.[56] While there is no official Chinese "grand strategy," the Chinese leadership appears to have reached a consensus on the goals of China's foreign policy and how it should go about achieving them.[57] According to Avery Goldstein, China's grand strategy:

> aims to engineer China's rise to great power status within the constraints of a unipolar international system that

> the United States dominates. It is designed to sustain the conditions necessary for continuing China's program of economic and military modernization as well as to minimize the risk that others, most importantly the peerless United States, will view the ongoing increase in China's capabilities as an unacceptably dangerous threat that must be parried or perhaps even forestalled. China's grand strategy, in short, aims to increase the country's international clout without triggering a counterbalancing reaction.[58]

Similarly, Dr. Evan Medeiros writes that China's foreign policy goals are to "[maximize] its influence, leverage, and freedom of action while pursuing economic development to facilitate its reemergence as a great power."[59] China is implementing this strategy by establishing partnerships with other major powers in order to make China an attractive or indispensable actor whose interests must be taken into account. The second component of this strategy is an activist international agenda "designed to establish China's reputation as a responsible member of the international community and mute widespread concerns about how Beijing is likely to employ its growing capabilities, thus reducing the incentives for others to unite in opposition to China."[60] This strategy is also designed to protect China's core national interests against external threats as well as to shape the international system in which it operates. In addition, China's activities are to help usher in a multipolar world in which China would be one of several great powers.[61] In the short term, however, China's foreign policy is concentrated on developing national capabilities and international partners while avoiding the provocative consequences of a more straightforward hegemonic or balancing strategy.[62] This section examines the benefits of space power China uses to pursue these goals.

Space Power's Contribution to China's Comprehensive National Power.

China's space program furthers its grand strategy ambitions by adding to China's comprehensive national power (CNP). Comprehensive national power is defined as the sum of a nation's economic, political, military, scientific and technological, educational, and cultural strength. CNP can be divided into hard power, such as military force, and soft power, such as economic and cultural influence. While space power is not a main contributor to China's CNP, it nevertheless is considered an important component. Space activities increase China's hard power by improving China's military capability and increase its soft power through its economic and political benefits.

China's grand strategy is reflected in its pursuit of space power. China's space program is intended to portray China as a modernizing nation that is committed to the peaceful uses of space while at the same time serving China's political, economic, and military interests. It contributes to China's overall influence and provides capabilities that give China more freedom of action and opportunities for international leadership. With the exception of its ASAT test in January 2007, China has been able to conduct many of these activities without directly challenging the United States in space. Indeed, despite the dual-use nature of space technology, China is loathe to mention the military utility of it space program. China's progress in space technologies, however, has many negative-sum aspects for the United States which may lead to confrontation or competition in space.

Military Benefits. The People's Liberation Army (PLA) is undergoing reforms to transform itself into a military that is increasingly reliant on information for winning wars. According to China's 2006 defense white paper, "informationization" will be the driving force for PLA modernization as well as its major criterion. Moreover, the white paper states that the "PLA pursues a strategy of strengthening itself by means of science and technology, and works to accelerate change in the generating mode of war fighting capabilities by drawing on scientific and technological advances."

Indeed, information superiority is now seen by the PLA as a primary component for winning future wars.[63] The side which can better collect and process information will be better able to detect and exploit battlefield opportunities and counter enemy movements. In analyzing U.S. military operations, PLA writers recognize the role space plays in the collection and transmittal of information. Remote sensing satellites can provide intelligence on the disposition of enemy forces and provide strategic intelligence before a conflict begins. Communication satellites can provide global connectivity and can facilitate communications for forces landing on the island of Taiwan. Navigation and positioning satellites can provide critical information on location and can improve the accuracy of munitions.

In fact, Chinese writers often assert that control of space is a prerequisite for control of the terrestrial domains.[64] According to one source:

> Space power improves battlefield awareness capabilities, strengthens joint operations systems, improves precision strike capabilities, and increasingly strengthens overall battlefield superiority. Integrated joint operations increasingly rely on space power and space is the high point of informationized warfare.[65]

Chinese military authors are also placing increasing emphasis on the use of space. In the past, PLA authors acknowledged that its information systems were incapable of enabling it to act more quickly than the U.S. military and their writings focused more on denying space to potential adversaries. However, as the PLA begins to contemplate using space, it recognizes that it must not only deny the use of information to its opponents but also use space to facilitate its own operations. One source, for example, asserts that "traditional" information collection means cannot meet the requirements of modern war and states that "the collection of targeting information over a wide expanse of territory, the monitoring of the battlefield disposition, and battle damage assessments cannot be separated from space forces for the collection of timely battlefield information."[66]

The establishment of a network of *Ziyuan* satellites is the first step in maintaining a system for this purpose. Moreover, improved imagery resolutions will make it more difficult for the U.S. military to hide its intentions. The improved resolution of the satellite from 20 meters to three meters will permit the Chinese to more accurately collect intelligence, monitor targets, and conduct battle damage assessments. This increase in resolution will enable China to image aircraft, distinguish between warships and commercial ships, and locate clusters of vehicles—all crucial to gaining tactical battlefield intelligence and capabilities they lacked until recently. The addition of SAR satellites in the coming years will increase China's reconnaissance abilities by allowing it to image at night and during inclement weather.

The establishment of meteorological satellites and ocean observation satellites will provide China with a

network of satellites to monitor the weather, provide more timely weather forecasts, and allow more time to prepare for severe weather. These satellites may be especially important during typhoon season when operations would need to be planned around inclement weather. The importance of accurate weather forecasting cannot be underestimated. The invasion of Normandy in World War II was delayed due to inclement weather, and more recently sand storms during the 2003 invasion of Iraq hampered close air support operations.

China's *Beidou* navigation satellite system also has the potential to assist military operations. Because its relative inaccuracy (20 meters) minimizes its use for precision guided munitions, this system appears to be primarily for assisting logistics units with the transportation of supplies. One study, however, argues that the system could improve the accuracy of China's ballistic missiles to 500 meters.[67] Currently, Chinese ballistic missiles primarily use inertial navigation systems, though some also use GPS guidance.[68]

Launchers. Chinese launch activity during the Tenth Five-year Plan can also help facilitate military operations. Chinese launch tempo was more active during this time period than at any other time in its history. Chinese launches were clustered during launch windows of several months, demonstrating an ability to surge launches before a conflict or replace satellites lost to enemy action. Particularly interesting have been the consecutive launches of recoverable satellites from the same launch base to provide continuous reconnaissance capability. In addition, a more robust launch tempo can be used offensively to launch repeated ASAT attacks against adversary satellites.

The introduction of the *Pioneer-1* solid fuel rocket, ostensibly to serve the micro and small satellite market,

also enables China to surge a large number of satellites into orbit during a short period of time. Not only could this rocket supplement China's communication and remote sensing needs, it could also be used to launch ASAT satellites into orbit or provide a direct ascent ASAT capability. Indeed, many observers have speculated that the January 2007 ASAT test was conducted using the *Pioneer-1*.

Because *Pioneer* rockets are presumably based on road-mobile military variants, China could potentially launch satellites or ASAT weapons into orbit even if its three launch bases were destroyed.[69] Locating these launchers would be difficult, and they thus potentially provide China with a persistent ASAT and satellite launch capability.

Economic Benefits. China has embraced its space program as a driver for economic and technological advancement. China's 2006 white paper states: "Since the space industry is an important part of the national overall development strategy, China will maintain long term, steady development in this field."

China's support for its space program lies in its potential to spark innovation. Innovation has been identified as a key factor for economic growth, yet much of China's growth has come through increasing inputs rather than through productivity gains. Moreover, much of China's technological advancement has come through the importation of foreign technology. As James Kynge writes in *China Shakes the World*, China's technological advancement "is driven not so much by research as by commerce. Chinese companies, by and large, derive their technologies by buying them, copying them, or encouraging a foreign partner to transfer them as part of the price of access to a large potential market."[70] A report by the RAND Corporation

notes that the most profitable defense industries, information technology, and shipbuilding are also the ones that have the most access to foreign technology.[71] China's space industry hopes to not only follow in the footsteps of these industries, but also achieve success by indigenously developing technologies that not only spur development within the industry but also have spillover effects for the entire economy.

Despite these hopes, the Chinese government acknowledges that it still has far to go. The vice chair of the Chinese Association for Science and Technology has acknowledged that China's space technology is still in an experimental stage.[72] The space industry is still too immature to make large contributions to China's economic development and makes up less than 1 percent of China's gross domestic product (GDP). China's space technology is also recognized as still developing while other industries in China rely on mature technology. Because of this, the space industry has not been able to realize the spin-off benefits other industries have experienced since Chinese companies favor foreign technologies over domestically produced technologies. Given these challenges, the space industry is expected to have difficulty making a meaningful impact on China's economy in the near term.[73]

Nevertheless, a foundation has been laid for the space program to benefit other sectors of the economy. In regards to human capital, China's space industry keeps large numbers of engineers employed and motivates others to become involved in high technology fields. The Beijing University of Aeronautics and Astronautics (BUAA), for example, has 23,000 students, about one-third of them directly involved in aerospace. In 2001, space-related research and educational programs at BUAA were reported to have increased by 20 percent.[74]

The training of so many highly skilled workers can also benefit the entire economy. It is possible that some of these engineers either directly after graduation or later in their careers may be employed in non-aerospace jobs. In fact, maintaining a large pool of aerospace engineers and scientists presents a strategic advantage for China and a long-term challenge for the United States. China's increasing number of engineers and scientists coincides with the drop in the number of U.S. citizens graduating with advanced technical degrees. If these trends continue, it will become increasingly difficult for the United States to maintain its technical advantage.

In addition, China's human space flight program has instilled an emphasis on quality control needed to safely transfer humans into orbit. These procedures are now conducted for the entire space program and, if effectively implemented, will increase the reliability of China's space technology. These new measures include:

- Increased quality control testing and management oversight of components;
- Adoption of mature technologies;
- Production of surplus subassemblies to provide a better statistical base for quality checking;
- Greater redundancy;
- Modernizing assembly procedures and tooling;
- Improved standards for selecting management personnel and increasing their training;
- A more standardized process to assess incidents.[75]

The emphasis on quality control can also have spillover effects to other industries. The lessons and experience gained in program management and systems engineering can be applied to other areas of China's

economy and enable China to increase the quality of its products with decreasing assistance from foreign sources.

Commercial Services. While China has established foundations in technology, human resource development, and systems engineering, it has also made its first forays into the international satellite market. China's success in signing agreements to export satellites represents a small, but important step to commercialize its space industry. China's satellite exports are not pure commercial transactions, however, and cannot be divorced from its diplomatic agenda. It is no coincidence that China's two satellite export agreements were signed with countries with large oil reserves—Nigeria and Venezuela. While the dollar amount of the Venezuelan satellite is unknown, the price of the Nigerian satellite was reportedly around $300 million. Moreover, China was the only provider willing to sell a satellite to Nigeria and sweetened the deal with $200 million in preferential buyer's credits from the Export-Import Bank of China.[76]

In the short term, the commercial implications of such deals may be limited. Both satellites are scheduled to be launched on *LM-3*B boosters. As we have seen, these launchers have a success rate of just 86 percent, well below industry standards. In fact, it is doubtful that China could have negotiated these deals on purely commercial grounds without substantial discounting to cover the risk of a failed launch. These deals may have also required China to assume the risk of launch failure by ensuring the satellites.

Nevertheless, China's packaging of satellite sales, operations, and launch services may present a new business model. The main impediment to making the satellite industry more cost effective is the inability to lower launch costs. Launch costs during the 1990s

averaged around $12,000 per pound and have only infrequently been able to be lower than $10,000 per pound.[77] By packaging sales, operations, and launches, the Chinese may be able to lower the overall price by reducing costs in satellite manufacturing and operations. In addition, by focusing on customers who may not be able to purchase more advanced, but more expensive western satellites, China can gain valuable experience in the satellite market and draw revenue that can then help them expand into other markets. This model has been used successfully in the telecommunications industry by companies such as Huawei, a manufacturer of networking equipment. Consequently, as its satellite technology and launch rates improve, China could become competitive in the satellite market.

Political Benefits. The Chinese government also uses its space program for domestic and international political gain. China's human spaceflight and lunar exploration missions present a peaceful image of China's space program and are intended to counteract concerns over China's use of space for military purposes. Diplomatically, China's expanding international cooperation on space activities portends a more influential foreign policy. Headquartering the Asia-Pacific Space Cooperation Organization in Beijing demonstrates China's determination to take a regional leadership role in space.

The success of China's program also has internal political benefits. The Chinese Communist Party (CCP) is now communist in name only, and its continued legitimacy is predicated on delivering economic and nationalistic benefits in an informal social contract with its citizens: The CCP agrees to increase the standard of living and develop China into an internationally respected country, and the people agree not to rebel.

By developing a robust space program and participating in high-profile activities such as human space flight and lunar exploration, the Communist Party can demonstrate that it is the best provider of material benefits to the Chinese people and the best organization to propel China to its rightful place in world affairs. The October 2007 launch of its lunar orbiter, for example, received nearly continuous all-day coverage on Chinese state-run television.

Anecdotal evidence appears to confirm public support for the program. According to one *National Public Radio* report, the *Shenzhou* program receives widespread support among the Chinese populace. Quoting one man, "If China wants to be powerful, we need to be able to compete in space. It's like having the atom bomb. If we want to have a voice that is heard in the world, we must have this space program."[78] Anecdotal evidence from author interviews with Chinese shortly after the launch of the first manned mission also indicates that the program receives widespread support, with a number of the interlocutors specifically stating that they were proud that the human space flight program used indigenous technology.

Such support does not appear to be universal, however. Statements by Chinese officials comparing the cost of the lunar program to the cost of constructing two kilometers of subway line in Beijing suggest efforts to justify parts of the space program to its detractors.[79] Moreover, the depth of public support for the space program is unclear, and it is unknown to what extent the public is willing to support space activities, particularly if China is subjected to a national crisis or severe economic downturn.

THE IMPLICATIONS OF THE RISE OF CHINA'S SPACE PROGRAM FOR U.S. INTERESTS

China's pursuit of space power is a reflection of its grand strategy. It has established partnerships with the major space powers of Europe and Russia as well as numerous smaller space powers, and it has sought leadership positions in the international space community, which promotes an image of China as a responsible member of the international community. By striving to be a major space power, China increases the multipolarity of world politics. China's progress in space capabilities has also increased China's comprehensive national power. None of these capabilities, however, have yet tipped the scale in China's favor militarily, economically, or politically. While China must be considered a major space power in terms of number of launches, satellites, and missions, the ability to use its space program for military applications, and economic and political benefit remains limited in relation to the other major space powers. China has, however, laid the foundation to begin using space power as an instrument of its national power. China's increase in space power, whether in relative or absolute terms, has implications for U.S. national security.

Military Interests.

A 1997 report by the U.S. National Defense Panel called space power "an integral part of the revolution in military affairs and a key asset in achieving military advantage in information operations." It asserted that "space is the information battle's high ground," and that "the United States cannot afford to lose the edge it now holds in military-related space operations."[80]

It also warned that "greater accessibility to space by our competitors will strongly influence the struggle for advantage in military operations."[81]

China's improving space capabilities appear to have negative-sum consequences for U.S. military security and the potential for armed conflict between the United States and China requires the United States to prepare to confront an adversary possessing space technologies. Chinese remote sensing satellites can provide critical intelligence on the disposition of U.S. forces. For example, the U.S. Defense Department revealed in its 2006 *Military Power of the People's Republic of China* that China is researching the use of ballistic and cruise missiles to attack aircraft carriers.[82] Such a capability would require the Chinese military to first locate and track the aircraft carrier, most likely through the use of space-based means. Aircraft carriers would play a critical role in a conflict over Taiwan due to the lack of nearby airfields, and the loss of even one carrier could seriously degrade U.S. operations.

Commercial Interests.

A surgent Chinese space program would also appear to have negative-sum consequences for U.S. commercial interests, mainly due to the slow growth of key sectors of the international space market. According to data collected by Futron Corporation, global revenue for members of the Satellite Industry Association grew by 63 percent between 2001 and 2005. (See Table 4.) Most of this increase occurred in the area of satellite services, such as satellite television and radio, which constituted 60 percent of total satellite industry revenue.

Year	Amount
2001	64.4
2002	71.3
2003	74.3
2004	82.7
2005	88.8

Table 4. World Satellite Industry Revenues in Billions U.S.$.[83]

Other sectors did not fare so well. Global satellite manufacturing revenues decreased from $9.5 billion in 2001 to $7.8 billion on 2005. U.S. revenue decreased from $3.8 billion to $3.2 billion for the same time period. (See Table 5.) Global launch industry revenues remained stagnant at $3 billion from 2001 to 2005, while U.S. launch revenues increased from $1.1 billion to $1.5 billion.[84] (See Table 6.) These numbers illustrate that while the entire satellite industry market may have increased dramatically during the Tenth Five-year Plan, revenue from critical sectors such as satellite manufacturing and launch services either decreased or remained unchanged. Under these conditions, a Chinese space industry that becomes more active in international commercial activities will negatively affect existing market players. When this may occur is uncertain. The poor success rate of certain Chinese launchers and China's catering to low-end satellite customers indicates that it could be some time before China's commercial space activities dramatically affect the global market.

Year	World Amount	U.S. Amount
2001	9.5	3.8
2002	11.0	4.4
2003	9.8	4.6
2004	10.2	3.9
2005	7.8	3.2

Table 5. World and U.S. Satellite Manufacturing Revenues in Billions U.S.$.

Year	World Amount	U.S. Amount
2001	3.0	1.1
2002	3.7	1.0
2003	3.2	2.1
2004	2.8	1.5
2005	3.0	1.5

Table 6. World and U.S. Launch Industry Revenues in Billions U.S.$.

The potential over the long term of a strong Chinese presence in the international space market, however, may require the U.S. Government to assist the U.S. space industry to remain competitive due to its reliance on government contracts for the majority of its business. The government, while a customer, must also assume some responsibility for the health of the industry if the United States is to maintain its lead in space technology. According to one report, "the federal government provided over 95 percent of funding for basic research, 85 percent for technology development,

and 70 percent for concept demonstration in the space sector."[85] It also found that the United States led in 39 space technologies, was equal in 13, and lagged in three; and that U.S. space technology was most advanced in areas which received more government support.[86]

Demographic changes occurring in the aerospace engineering profession also remain a critical challenge for the U.S. space industry. According to the Aerospace Industry Association, "The United States has lost 750,000 scientific, technical, production, and administrative workers in the past 14 years."[87] Many aerospace professionals will also be eligible to retire. In 2005, 55 percent of the aerospace industry workforce was over age 45, and in 2008, 25 percent of the U.S. aerospace workforce will be eligible to retire.[88] In addition, the number of U.S. citizens graduating with degrees in math and sciences continues to decline and of those, many choose careers in more lucrative fields such as computer science. One potential source of human capital may come from other countries, but that option is limited for military contractors whose workers require security clearances. The result is that the U.S. space industry may only be able to replace half of the 57,000 to 68,000 military engineers expected to retire by 2010.[89]

This is in contrast to the Chinese space program where a large percentage of the workforce is under age 45, and where China continues to graduate increasing numbers of students educated in math and sciences. China is widely reported to graduate 600,000 engineers per year while the United States graduates just 70,000. These numbers, however, are subject to debate. According to research done by Duke University, the United States graduates 137,000 students with 4-year degrees in engineering. This same research concluded

that China actually graduates 351,000 engineers.[90] Even if China is not graduating the number of engineers once believed, the Duke University numbers demonstrate that China is producing more than 12 times the number of engineers as the United States when the size of the two countries' economies are compared.[91]

U.S. demographic and educational challenges may be exacerbated by Chinese mercantilist policies that support the space industry, in contrast to the U.S. space industry which is more subject to market considerations. Indeed, the U.S. space industry is contracting at a time when the Chinese industry is expanding. In response to market concerns two major restructurings of the U.S. space industry occurred in 2006. On October 11, 2006, Lockheed Martin announced that it had:

> completed the sale of its interests in Lockheed Khrunichev Energia International, Inc. (LKEI) and ILS International Launch Services, Inc. (ILS) to Space Transport Inc. The two companies had provided sales, marketing and mission management support for launches of both the Lockheed Martin-built Atlas and Khrunichev-built Proton and Angara rockets to commercial customers.[92]

Also in October 2006, the U.S. Federal Trade Commission approved the merger of Lockheed Martin's and Boeing's rocket manufacturing and launch services into a joint venture called United Launch Alliance. The merger was approved due to the fears of the U.S. Defense Department that one of the rocket manufacturers would drop out of the business due to a weak launch market.[93]

Diplomatic Interests.

The importance of China's space diplomacy should not be overstated, but is nevertheless noteworthy.

Good relations in space do not drive good relations on Earth. International cooperation on space activities usually follows progress in the overall relationship and is more of an indicator of the state of a relationship than a critical component. It is more likely that China's penchant to offer aid and investment to developing countries without conditions will increase its influence more than cooperation on space activities.

Nevertheless, China's space program does play a role in advancing China's diplomatic agenda and China's leadership in this area may contribute to its overall increase in diplomatic influence. China's cooperative space activities present another avenue for countries to participate in space without the United States and increases multipolarity. The failed attempt by China to become a major player in the Galileo project is just one example of how attempts by China to promote a more multipolar world can impinge on U.S. security interests.

China's cooperation with the European Union (EU) and Russia also provide additional opportunities for technology transfer. While China's participation in Galileo has been diminished, future activities may result in closer cooperation between the EU and China. The Sino-Russian cooperation on a Mars exploration mission will certainly result in some form of technical cooperation. Moreover, the likelihood of cooperation with China has prompted some countries to develop space technologies independent of the United States in order to avoid U.S. International Traffic in Arms Regulations (ITAR). For example, the *Apstar 6* satellite launched by China in April 2005 was Acatel's first ITAR-free satellite. Consequently, cooperation with China is making Europe more technologically independent of U.S. industry, which could increase competition and

result in the loss of market share for U.S. aerospace companies.

THE U.S. RESPONSE: CONTAIN, COMPETE, COOPERATE, OR DO NOTHING?

The difficulty in deciding an appropriate response to China's rise as a major space power arises from the inability of both sides to determine whether their relationship will be friendly or hostile. The United States views a more capable China as potentially coming into conflict with its interests. China, for its part, views the U.S. hedging strategy as possibly thwarting its ambitions to become a major power. The uncertainty of the U.S.-China relationship is reflected in the rise of China's space program, which appears to hold more negative-sum outcomes than positive-sum outcomes for the United States. Indeed, the focus on the negative-sum outcomes of China's space program and possible U.S. responses has increased with the renewed emphasis in both countries on human space flight and lunar exploration. The United States is thus presented with four policy options to meet the changing dynamics presented by China's space program: contain, compete, cooperate, and do nothing.

Contain.

Containment is the least viable of the four options, and as China becomes more integrated with the world, it will become even less practical. As Avery Goldstein writes, China's grand strategy of integrating itself into international politics and the world economy "undermines the feasibility and desirability of a U.S. policy of containment."[94] Nations without the security

concerns of the United States will increasingly look upon space as another venue for interacting with China. China has stable and positive working relationships with its neighbors and other major powers, and these relationships, for the most part, are improving. China cooperates with many nations in space and looks to Europe in particular for access to technology and expertise that is denied by the United States.[95] It maintains important cooperative activities with Russia in which Russia sells technology or expertise, especially in regards to China's human spaceflight program. It also maintains important cooperative relationships with organizations based in the EU, including with Surrey Satellite Technology, Ltd. with which China developed two microsatellites.

China's heading of the Asia Pacific Space Cooperation Organization also demonstrates just how difficult it would be to isolate China as it takes a leadership role in international space forums. China will benefit from international space cooperation with or without the United States and trying to contain China's space cooperation with other countries, except when U.S. interests are directly threatened as with the *Galileo* project, may only undermine its position with other space powers.

Compete.

The similarities of the two countries' human spaceflight programs in terms of technology and lunar programs in terms of timelines has raised the prospect of a new space race in which the two countries compete to send humans to the moon. Accelerating the U.S. return to the moon, however, would require devoting increased resources to the U.S. space program at time

when the federal budget has come under greater scrutiny. Since the *Apollo* program, the American public has been unwilling to fund the National Aeronautics and Space Administration (NASA) much beyond a 1 percent share of the federal budget and at a time of deepening budget deficits and ongoing wars in Iraq and Afghanistan, it appears unlikely that NASA can garner the support needed for greater budgets. Indeed, in February 2007 the U.S. Congress passed a continuing resolution which froze NASA's budget at the level for 2005-06, which was a $545 million reduction in the amount requested by the Bush administration. The action resulted in $677 million less for the human space flight program due to funding required for the construction of the International Space Station and will delay development of the new Crew Exploration Vehicle until 2015.

Support for another space race faces an additional hurdle. The American public is not as emotionally invested in its space program as during the 1950s and 1960s. The historical conditions that created the space race were unique and pitted rival superpowers in a contest of economic systems and global support. While many Americans recognize China as a potential threat, most do not regard it as inimical to U.S. interests as the Soviet Union. U.S.-China relations may be ambivalent, but they are also ones in which extensive cooperation takes place, and it is not apparent how defining China as a competitor in a space race will further relations. It is also not apparent whether the American public will support a race which it has already won. The United States first landed men on the moon in 1969 and may be in no rush to return.

Cooperate.

Alternatively, the similarities of the two space programs have prompted calls for cooperation. Supporters of cooperation argue that cooperation in space has the potential to increase transparency and trust and to lessen competitive aspects that may lead to armed conflict.[96] Supporters of cooperation also argue that cooperation can produce dependencies on the United States for technologies that could be used as leverage to influence the Chinese space program in ways advantageous to the United States and can increase the transparency of the Chinese space program.[97]

A policy that treats China as a friend, however, has its own shortcomings. Because China's strategy is designed to further its own national interests and because its interests are often not aligned with U.S. interests, it is unlikely that assisting China in increasing its space power will eliminate these differences and may, in fact, exacerbate them. Moreover, cooperation in space is of limited value in advancing U.S.-China ties considering the secondary role of space diplomacy, and cooperation in space will not help resolve differences over Taiwan, human rights, or Chinese economic practices.

The most important argument against cooperation is the possibility of the transfer of sensitive technology. Most space technology is dual-use in nature and could assist the Chinese in developing advanced weaponry that could be used against U.S. forces. Nearly any transfer of space technology directly improves China's military capabilities not just because space technology is inherently dual-use, but also because China's space program is inherently military in nature. While cooperation does exist between NASA and the

U.S. military, the Chinese space program lacks the bureaucratic walls which make NASA a predominantly civilian organization in both focus and culture. Indeed, China's space program is a military-civilian joint venture in which the military develops and operates its satellites and runs its infrastructure, including China's launch sites and satellite operations center. The China National Space Administration, often incorrectly referred to as China's NASA, mainly functions as a civilian front for international cooperation and as a liaison between the military and the defense industry. In fact, CNSA does not even manage important space cooperative activities like cooperation with Europe on *Galileo*, which is run by the Ministry of Science and Technology.

While technology transfer appears out of the question, another possible avenue of cooperation would be for China to contribute funding to gain access to a program. However, with a total annual space budget averaging just 1 billion RMB per year (approximately $125 million),[98] it is unlikely that China can provide meaningful funding. While China agreed to contribute $250 million to the *Galileo* project, that amount is insignificant considering the multi-billion dollar price tag of most space projects. Cost estimates to return U.S. astronauts to the moon reach to $104 billion and do not include funding for robotic missions or the $20 billion to use the Crew Exploration Vehicle to service the International Space Station.[99]

Moreover, using cooperative activities to increase transparency and trust is likely to be very difficult. China's ASAT test in January 2007, and its refusal to admit the test until well after the event, demonstrated China's intransigence and lack of transparency involving space matters even when provided with incontrovertible evidence.

Increasing trust in regards to space activities appears to be difficult when space operations, in particular counterspace operations, may figure prominently in Chinese efforts to strike asymmetrically at the United States in the event of an armed conflict.[100] In the past, cooperative efforts with China's military have been difficult. The Military Maritime Consultative Agreement (MMCA), designed to reduce the risk of accidents and miscommunication in the air and on the sea, has been bogged down since the collision of a Chinese fighter with a U.S. reconnaissance plane due to Chinese insistence on using the venue to claim sovereignty over its exclusive economic zone. Even when the United States transferred military technology to China during the 1980s, the Chinese were reluctant to provide the United States with the basic motivations for certain technologies.[101] Secrecy surrounding the Chinese space program is similarly tight, and Chinese space experts appear to be under strict guidelines and normally only divulge information that has already come out in the Chinese press. China's space experts also appear to function as a conduit for disinformation. One prominent Chinese space expert concludes in an English language publication that "It is obvious that assertions judging China's manned spacecraft program as a military threat are baseless."[102] Yet, in an internal military publication the same author argues that human spaceflight technology "can carry a large amount of effective military payload" and can be used for information support missions as well as function as a weapon or as a weapons platform.[103]

Do Nothing.

Since the mid-1990s, the United States has had little cooperation with China in space. Convictions

of U.S. aerospace companies for illegally transferring technology to China put a halt to most cooperation between the two countries. In addition, NASA Administrator Michael Griffin traveled to China in September 2006 to explore the possibilities of cooperative activities, but little came of the trip.

Inaction is a safe option that does not risk the transfer of technology or expertise. A policy of inaction does risk ignoring the possible benefits of cooperation, however. As Clay Moltz writes, "It is self-defeating for the United States to be trapped into sending signals about the *impossibility* of space cooperation to emerging powers, such as China, where threat reduction should instead be a high U.S. security priority."[104] Refusal to participate in multilateral space activities involving China, for example, will unnecessarily put the United States at a disadvantage since it will have little leverage to address its concerns.

SEEKING TANGIBLE RESULTS

Deciding an appropriate response to China's rise as a major space power is made difficult by the fact that the nature of China's rise is uncertain. All four options discussed above assume the future nature of China's role in the world. Containment and competition not only take China as a future adversary but also are impractical in that they do not take into account China's integration into world affairs or the cost to the United States. Cooperation, on the other hand, treats China as a friend but has the potential of transferring technology and expertise that could improve China's military and appears to promise too much in regards to acculturating China to the norms of international space behavior. Inaction, while not fully treating China

as an adversary, appears unable to offer opportunities to deal with China's rise as a major space power that could benefit the United States.

U.S. space policy in regards to China requires an approach in which China is treated as both a potential friend and enemy and provides opportunities for both countries to learn and become comfortable with their respective roles in the world. Such a policy would demonstrate the benefits of cooperation while downplaying the potential of increasing China's space power at the expense of U.S. interests. Pursuant to this, China's increasing space capabilities do present opportunities for collaboration that can provide tangible benefits to both countries in the form of cost savings, scientific research, and safety that do not risk U.S. national security. For example, China and the United States could coordinate space science missions to derive scientific benefits and to share costs. Coordinating space science missions with separately developed, but complementary space assets, removes the chance of sensitive technology transfer and allows the two countries to combine their resources to achieve the same effects as jointly developed missions. The findings from these missions would be shared equally. This approach is being used by the Europeans and Chinese on the Double Star project to research the sun. Such cooperation is not unprecedented when it comes to the United States and China. The United States and China serve as co-chairs of the 68 member Group on Earth Observations (GEO), an intergovernmental organization leading a worldwide effort to build a Global Earth Observation System of Systems (GEOSS) over the next 10 years. This group stresses coordination rather than integration in pooling together international resources for environmental monitoring.

Financial considerations may make organizations such as GEO more commonplace in the future and make the United States more receptive to cooperative activities. NASA's renewed commitment to human spaceflight has resulted in static funding for space science missions. NASA projects that funding for its Exploration Systems Mission Directorate, which is responsible for its human spaceflight program, will increase from $1.733 billion in 2006 to $7.993 billion in 2012. At the same time, funding for the Science Mission Directorate will remain relatively stable, with $1.325 billion allocated in 2006 and $1.353 billion in 2012.

NASA is currently involved with scientific missions that could benefit from international cooperation with China. The most notable scientific missions are the two countries' lunar programs. Both the United States and China are planning robotic missions to the moon involving surveying by orbiting satellites and landings on the moon surface. Another possible opportunity for cooperation could be planned missions to study black holes. The United States is teaming with other countries to launch in 2008 the Gamma-ray Large Area Telescope to study how black holes eject jets of gas at extreme speeds. China is also planning to launch in 2010 an X-ray telescope to research black holes. Similarly, the United States and Canada are cooperating on a new Mars lander to study the habitability of the red planet. Such exploration could be done in conjunction with the Russian-Chinese effort to send a Mars rover-type vehicle to Mars.

Cooperation could also have benefits in the realm of human space flight by increasing safety in space.[105] The United States and China already have an agreement to assist stranded astronauts on the earth; this agreement could be extended to space. Having the option to use

Chinese spacecraft to rescue astronauts or cosmonauts manning the Space Shuttle, International Space Station, or the future Orion spacecraft seems to be a pragmatic goal.[106] In these situations, only the Russians could provide rescue, and even that could be threatened if political unrest in Kazakhstan were to prevent launches from Baikonur. Developing a code of conduct for space travel, similar to those governing travel on the high seas obligating assistance to crews in peril, would increase the safety of one of the most dangerous occupations. Such a code of conduct would require the Chinese to practice docking with the International Space Station and U.S. spacecraft to ensure safety and reliability. It would also require U.S. spacecraft to dock with the planned Chinese space station. A side benefit of a code of conduct to assist endangered astronauts in space may be an increase in the transparency of the Chinese space program. Cooperation would necessarily entail discussions over technology, policies, and intent that would otherwise be difficult to obtain.

CONCLUSION

The rise of a peer competitor in space raises important concerns for the United States. China has made great progress in space technologies in absolute terms, but when compared to the other space powers, it continues to lag behind. Much of the attention on China's progress in space technologies is due to it starting from a low base. While progress of the more advanced U.S. space program is largely incremental, China's progress is more rapid due to the addition of new systems.

Nevertheless, China's progress in the space arena cannot be discounted. China is probably truthful when it says that it is not in a space race. It neither has a sufficient foundation nor the resources to conduct one. Yet, China's rise as a space power will most likely have a net negative-sum effect for the United States over the long term. It has clearly laid a foundation to become a peer. Moreover, while Chinese technology and operations tempo may not equal those of the major space powers, as China's space technology improves and becomes more reliable, whether China's space technology matches the major space powers may become irrelevant. At some point, its technology may simply be good enough to support modern war and be competitive in the marketplace. Taking satellite imagery as an example, one-meter resolution satellite imagery, now widely available commercially, is considered the threshold for widespread military utility. China does not need to develop technologies with capabilities on a par with U.S. satellite capabilities to achieve desired effects.

Because of this, it is doubtful that merely staying one generation ahead of the competition, as advocated by the *Report of the Commission to Assess United States National Security Space Management and Organization*, will be enough to maintain effective leadership in this area. Even if U.S. space power does not decline in absolute terms, China's advance in space technologies will result in relative gains that challenge the U.S. position in space.

While relative decline for the United States in space technologies is unavoidable, it need not lead to a loss of leadership. The rise of a new space power requires two responses from the United States: domestic and international. Domestically, the reliance of the space

industry on government clients requires a broad-based response by both the U.S. Government and industry. Without a stable, adequately funded, organized, and staffed space industry, it will be difficult to master the technologies needed to meet the military, commercial, and political challenges of a Chinese space program. This will not only require better program management on the part of industry and government, but will also require both actors to think innovatively about how to attract and maintain a competent workforce.

As China's space power grows, space diplomacy will also have a role in meeting the challenges of China's space program. This monograph argues that a program of limited cooperation with China that focuses on tangible benefits for both countries is best suited to meet those challenges. Space activities are multifaceted, and the U.S.-China space relationship need not be solely defined by military considerations. Nevertheless, the inherently military nature of the Chinese space program and its lack of transparency and tendency towards disinformation preclude most forms of cooperation. By focusing cooperation on the safety of space travel and improving science, however, NASA can contribute to its mission while meeting the challenges of a growing space power.

APPENDIX

CHINESE SPACE LAUNCHES BY SPACECRAFT

2001-05

YEAR	DATE	NAME	Description
2001	9 January	*Shenzhou*-2	Unmanned Space Capsule
2002	25 March	*Shenzhou*-3	Unmanned Space Capsule
2002	15 May	*Fengyun*-1D	Meteorological
2002	15 May	*Haiyang-1*	Oceanography
2002	15 September	*Pioneer*-1	Rocket test (failure)
2002	27 October	*Ziyuan*-2	Remote Sensing
2002	20 December	*Shenzhou*-4	Unmanned Space Capsule
2003	24 May	*Beidou*-2A	Navigation and Positioning
2003	16 September	*Pioneer*-1	Rocket Test
2003	15 October	*Shenzhou*-5	Manned Space Capsule
2003	21 October	*Ziyuan*-1B	Remote Sensing
2003	21 October	Innovation-1	Communications
2003	2 November	Return Satellite-18	Remote sensing/scientific
2003	14 November	Chinasat-20	Communications
2003	30 December	Explorer-1	Double Star solar wind study
2004	18 April	Satel Experimental lite-1	Remote Sensing
2004	18 April	Nanosatellite-1	Experimental test
2004	25 July	Explorer-2	Double Star solar wind study
2004	29 August	Return Satellite-19	Remote Sensing
2004	9 September	Shijian-6A	Space environment study
2004	9 September	Shijian-6B	Space environment study

2004	27 September	Return Satellite-20	Remote Sensing
2004	19 October	*Fengyun*-2C	Meteorological
2004	6 November	*Ziyuan*-2 03	Remote Sensing
2004	18 November	Experiment-2	Technology demonstration
2005	12 April	Apstar-6	Commercial Communications
2005	5 July	Shijian-7	Space environment
2005	2 August	Return Satellite-21	Remote sensing/scientific
2005	29 August	Return Satellite-22	Remote sensing/scientific
2005	12 October	*Shenzhou*-6	Manned Space Capsule

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