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China's Space Policy: Prospects for Collaboration between the EU and China

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Background Briefing: China's Space Policy: Prospects for Collaboration between the EU and China

Executive Summary

- The Chinese space industry is state-owned, extensive, and closed. All the space programs are dual-use in nature.

- With painstaking efforts to learn by doing, China has become a key player in competitive launch vehicles, navigation systems, space station programs, and lunar and Mars explorations in international space markets.

- The achievement lies in a combination of factors--growing knowledge spillovers, open sources, and proactive engagement with the business community--that offer China an opportunity to divulge the results of European and North American innovation, thereby offsetting lack of access to state-of-the-art technologies, a critical bottleneck of space programs, and facilitating its innovation at a fast rate.

- As the desire to access knowledge and resources is a driver for collaboration among firms and countries, it is in the interests of the EU and China that collaboration in the space industry reduces its research, production, and management costs, while increasing program efficiency and benefits.

- To minimise potential risks, the incremental approach to collaboration will benefit both parties, starting with setting up space legal frameworks, providing management training programs, working on the civilian aspect of the navigation system, building joint platforms for research on space stations and lunar and Mars explorations, capitalising on the Chinese launch services, and developing a new generation of more efficient, cheaper, and faster heavy boosters.

- A primary concern for any possible collaboration with China is that the spillover of European patents, know-how, management skills, and state-of-the-art technologies might give the Chinese military a competitive edge, thus undermining regional and international security.

1. Introduction

The space industry is a symbol of China's technological sophistication. Through following a rationale of 'learning by doing', the development of China's prominent launch vehicles (missile program), COMPASS navigation system, space docking and walking, and lunar and Mars explorations are indicators of its rise as a serious contender in international space markets. The shift in its technological capability shows that China's space industry, a latecomer to this business, has enabled a radical transformation in innovation, the critical component of its competitiveness, allowing it to gradually bridge the gap with leading industrialised countries.

At the heart of its success, are knowledge creation and knowledge application as tools of innovation, which have institutionalised nation-wide cooperation mechanisms to optimise knowledge and resources for the programs. This has produced the equilibrium of affordable technologies and cost-benefit efficiency that makes other choices less attractive and less competitive. Suffering a deficit of state-of-the-art technologies and cooperative arrangements with industrialised countries, China's space industry accepts the contingent lock-in of inferior technologies as the rational path to help its programs get further ahead.

The purpose of this policy paper is to assess the potential for collaboration between the EU and China. It starts with reviewing the evolution of Chinese space programs and policies in an effort to pinpoint the bottlenecks inherent in the industry as the starting point for building platforms for joint programs. Then, it measures the costs and benefits of collaboration for meeting challenges faced by both parties in the post-financial crisis era. Finally, the paper suggests a number of policy recommendations designed to develop and enhance joint programs between the EU and China in the space industry.

2. Chinese Space Industry and Policy

China bets big on the space industry, which is vital to innovation, national security, and its power status in the world. Throughout its multifaceted programs, organisational emphasis on flows of knowledge, and the capabilities to leverage such knowledge, serves as a means to achieve national security and pride. Despite increasing knowledge spillovers across the globe and efforts to learn by doing, technology remains a critical bottleneck for space programs, although this opens the door for potential collaboration with industrialised countries.

2.1 Missile Technology

The Chinese ballistic missile (launch vehicle) program, introduced in 1956, sparked a dynamic organisational process of knowledge-creation and knowledge-application, through which ideas are tested, modified, and incorporated into the practice of innovation and production. This program initiated by chance, rather than through systematic designs and rational deliberations. As a driving force, the organisational context (centralised governance, formal structures, and informal rules) defined the program boundaries, in which knowledge operated and attributed to the contingent lock-in of missile technology.

The knowledge-based path of the missile program was motivated by both high hopes of fostering the creative destruction of the traditional technological system and nationalist desires to build lethal weapons for defence. This knowledge depended on the insights and values of defence scientists and engineers into the project management process to target technical challenges despite ubiquitous uncertainties and inertia that might undermine the program as a result of red tape and bureaucracy.

This approach to technological management gave the space industry a comparative advantage to build missiles through 'learning by doing', but also through accumulating US tacit knowledge and Soviet explicit knowledge. Put simply, defence scientists and engineers vigorously monitored and digested technological developments outside of China in order to upgrade their own knowledge, to modify research and manufacturing priorities, and to manage testing. However, despite these efforts, China faced severe exogenous challenges. The economic sanctions imposed on China by the West in the 1950s pushed China to depend on Soviet technologies and later on self-reliance. The fear of insecurity and isolation that developed during the Cold War taught China that such technologies were critical for survival. As a result of technological constraints, the program was forced to focus on a single weapon, not on the weapon system that justified program and priority choices and stood unchallenged until the mid-1980s.

The value and utility of China's missile program was maximized in order to demonstrate China's technological leadership. Regarding organisational mechanisms, China concentrated almost all of its available resources on missiles, but also vertically integrated research, manufacturing, testing, logistical support, and human resources. This nation-wide cooperation provided the program frameworks, rules, and management methods to absorb foreign knowledge and adapt it to local conditions for in-house knowledge-creation and knowledge-application. Although the Chinese missile program was far behind those of the United States and the Soviet Union (Russia), it laid a foundation for future development. The political utility of technology and the technological utility of politics embedded in the organization made this choice of a knowledge-based path functional and dominant.

2.2 Dual-use technology

The impasses hit by the lock-in of missile technology called into question the rationale of multifaceted knowledge-creation and knowledge-application aimed at increasing efficiency, competence, and returns. The approach, coupled with the top secret nature of the program, decreased the willingness for knowledge and resource exchange with the civilian sector, while attempts to adopt civilian technologies would increase reconfiguration, organisation, and production costs. In reality, the continued bottlenecks in the areas of materials, engines, command and control, and the guidance system forced the space industry to scale back the missile program, rather than to leapfrog into the ambitious spacecraft program introduced in the 1970s. The question was how to adopt new knowledge and resources in order to escape from the inferior lock-in without breaking the mechanism of nation-wide cooperation. In response to endogenous reform and to the exogenous shocks of the revolution in high technologies, the space industry gave unusual emphasis on dual-use knowledge as the critical junction for a new lock-in. In order to adjust to this desired fit, defense scientists and engineers increasingly sought to incorporate civilian input into a military organizational context, which contributed to what later became known as Project 863, the national high-tech program. This push for military and civilian conversion in order to secure access to knowledge and resources revealed that little consideration had been made in this direction during Mao's time. The unlocking of the inefficient missile technology moved forward doggedly.

In response to the US Strategic Defense Initiatives (SDI) of Star Wars and the European Eureka Plan, as well as the technological impasses of the missile and spacecraft programs, Project 863 introduced the new policy of incorporating dual-use or, more precisely, spin-on high-technology into the defense industry. Many defence scientists and engineers at the time expressed frustration that economic reform had made bureaucrats insensitive to threats from the West to China. This insensitivity meant that the interlocking mechanism of nation-wide cooperation, at the core of the Chinese missile program, could fall apart, as the utility of the defense industry was no longer appreciated. One of the indicators of this was when the assertive civilian sector tried to take a share of the resources traditionally enjoyed by the defense industry. The loss of the resources to the civilian sector would have ended any hope for technological modernisation. Given these considerations, Project 863 indicated that Mao's missile technology lock-in was no longer working and in fact needed to be unlocked. Dual-use technology was seen as a solution for the defence industry to achieve a revolution in technology.

Project 863 institutionalized sub-projects 863-204 and 863-205, which were devoted to building launch vehicles, spacecraft, and a space station as a continuation of the missile and satellite programs. To unlock the missile technology lock-in, dual-use technologies gave the industry an opportunity to collect, digest, and disseminate the latest achievements in the civilian sector that were critical to current and future programs. The most pressing issue was to pinpoint the best system of technology that could strengthen the Chinese missile and spacecraft program's deterrence capabilities, rather than to fight war.

The dual-use approach, taken by the West as a guide to absorb new technologies for developing new products, provided choices for renewal. In the face of result-focused practices, the space industry was able to actively identify the options for breakthroughs. In pursuit of emerging technologies, it recognised the utility of 'small' developed countries, such as Britain, France, and Germany, as promising insurance against the monopoly of technologies by the United States.

Dual-use technology also raised the question about the scope of action at home. On an organisational front, there was the management of technology spillovers, namely, the spin-off and the spin-on that had split the industries since the 1950s. Project 863 advocated spin-on from the civilian sector, which enjoyed direct access to advanced foreign technologies, especially in the area of supercomputers, information technology, and factory automation, which could add significant value to military products. However, the opposition to this favoured the spin-off method, which downplayed the relevance of civilian technologies. The compromise was a policy that endorsed the integration of civilian and the military elements, with attention to the civilian sector as the new version of nation-wide cooperation. The resulting spillovers of dual-use technology through the self-reinforcing dynamics of nation-wide cooperation were able to enhance the process of learning, adapting, and assimilating advanced technologies to build China's core competence.

2.3 Spacecraft technology management

Dual-use technology exacerbated spacecraft Project 921, a core focus for China's catching-up priorities. Despite high expectations, its underperformance lay in rapidly shifting business and economic environments, which threatened the sustainability of the program. With the exogenous shocks of development in space and information technologies in the 1990s, increasingly resilient and expansive dual-use knowledge cast doubt on the poorly defined spacecraft program. The constraints on choices were also associated with the endogenous shocks of the needs to identify specific dual-use technologies before the program could advance along the path to reconfiguring core competences. Regardless of the endeavours to overcome organisational inertia and routines, the anomaly of locking in a dual-use technology continued to hinder the progress of the spacecraft program.

As China deepened its reform, competition for efficiency, profits, and markets was the primary indicator by which to measure programs. In the space industry, there was increasing resistance to ill-designed programs that would undermine organisational efforts to optimise knowledge and resources for developing quality products. Having set up the State Spacecraft Program Team for managing the program, however, many of the issues related to the vital technologies remained undecided. The consensus among the team members favoured proceeding with the spacecraft program, though they agreed to disagree on the program purposes, the technical designs, and the technologies to be used.

What mattered most was the organisational determination to improve program efficiency by incorporating foreign technologies and designs into the Chinese spacecraft. In technical and economic terms, efficiency helped to reduce research and production costs, but the bottom line required that the program became affordable. To encourage the defence scientists and engineers to debate product designs and project management, the technical committees then introduced a competitive mechanism, devoted to creating a synergy of civilian and military technologies, rules, and practices; a mechanism that prompted the presentation of six models based on the US, European, and Russian designs by the institutes under the Ministry of Space Industry (MSI) for further assessment. Because of different technical requirements, the designs were plagued with enormous program costs and logistical demands, namely, global communication, observation, meteorology, remote control networks, and fleets required to be deployed in the Atlantic and the Pacific to monitor the spacecraft. Acting strategically, as the defence scientists and engineers saw, a solution for the technological and logistic challenges was to team up with the industrialized countries and, in so doing, partners could engage in mutual organisational learning and share knowledge and resources.

During the feasibility study, there were heated debates tht pitted advanced against inferior technologies for spacecraft. The conceptual terms advanced and inferior forced the management team to maintain a subtle balance between ideal and reality as a justification for its position. The true story behind this frustration to define the terms was to build a Chinese, not a Russian or US, spacecraft, a goal that polarised defense scientists, engineers and the bureaucrats. Of course, China favoured its own design for national pride, but the US space shuttle represented cuttingedge technologies, the command of which would definitely give China a solid membership in the space club. Nevertheless, the technical challenges and the financial costs would have been beyond reach in the 1990s. The Russian spacecraft, by comparison, seemed outdated, but it was affordable and reliable with a simple structure. The low-cost, less-risky manned spacecraft would fit into the Chinese mentality of doing more with less in order to catch up with the technological leaders, at an acceptable price. The concern over the technologies reflected that the purpose of the expensive program was unclear. If cost was a primary issue, there were other ways to build a meaningful program by conducting unmanned spacecraft missions in the context of military and civilian conversion. If the purpose was to gain membership to the exclusive global 'space club', it was a rational choice to use the spacecraft as a short cut to send astronauts into space.

The trouble with the program was the spacecraft design, the symbol of catching-up. When building the manned spacecraft, every step of the design was contested and taken with reluctance. Finally, the compromised vote of 3 to 2 favored China's Soyuz-TM-style three-section spacecraft, which would give enough living and working space to a crew of three astronauts.

There was one inferior technology that kept on bedeviling the spacecraft program. During this organisational process, foreign technologies, a positive mechanism, were able to affect the course of action and, in turn, attempts to digest and diffuse them across the board enabled the space industry to adapt to market power considerations and liberalization. With the objective of increasing returns, the shift in interests and capabilities indicated a departure from the mindset of self-reliance towards potential cooperation with the industrialized countries. The targeting of advanced foreign technologies for indigenous space products remained at the core of space technology management.

2.4 Lunar and Mars Explorations

With the implementation of Project 921, dual-use technologies became a standard format for knowledge-creation and knowledge-application that made the space programs viable and sustainable. The breakthroughs in spacecraft research and flights surely strengthened the determination to push for the lunar and Mars explorations as the showcase of its leadership in the 21st century. Since the costs of replicating knowledge was lower than original innovation, China tried to seize every opportunity for potential cooperation with industrialised countries in order to share their knowledge. Though uncertainty remained, efforts made by the scientists from the Academy of Sciences enabled the prioritisation of the lunar and Mars explorations as an extension of the space programs in 2000. Like the spacecraft program, the explorations were aimed at integrating civilian and military technologies for conducting scientific research and joining the club of powerful countries.

According to the white paper of China's Space Activities in 2011, the lunar program has three distinct phases: orbiting the moon, soft-landing, and returning with lunar samples. *Chang'e* 1, the pioneering mission of the program, was launched in October 2007; the lunar rover named *Yutu* had a soft landing on the moon in December 2013; and during the final phase, there will be a manned mission for collecting samples and returning to the Earth. By contrast, the Mars exploration aims to conduct basic research, with the assumption of 'early development, early benefit'. China initiated the program in the 11th five-year plan (2006-2010), the first unmanned mission would be launched between 2014 and 2033, and the manned mission will be in 2040 and 2060, during which the crew will land on Mars and return home.

Central to the explorations is the institutionalisation of the program, which once again reflects the ideal of nation-wide cooperation involving leading civilian and military agencies and research institutes. But knowledge and technical barriers continue to frustrate the programs despite ttheir institutionalisation and their increased access to dual-use technologies. The lunar rover, for example, suffered serious mechanical and control circuit problems after landing on the moon, suggesting that to some extent, the Chinese technologies were unable to deal with the sticky lunar dust and low temperatures. In other words, China had or has no access to the EU and US technologies in this field.

In the same way, China's Mars exploration program marks its determination to fly out of the Earth-Moon system. According to the white paper, it is designed to conduct the 'detailed investigation of the plasma environment and magnetic field', the 'Martian ion escape process and their possible mechanisms', 'ionosphere occultation measurements', and 'sandstorm on the Martian surface', rather than to have immediate military purposes. The best example of seeking international cooperation is that China and Russia signed the agreement on a joint Mars exploration, which allowed the Russian booster to send the Chinese satellite into the Mars orbit and to conduct joint exploration research. Yinghuo-1, the Chinese Mars exploration space probe, along with the Russian Fobos-Grunt sample return spacecraft, was launched in November 2011. Unfortunately, the launch failed.

The lunar and Mars explorations are the long-term priority programs of the space industry. The programs remain promising, but the scientists and engineers face enormous challenges in monitoring and communications, automation, thermal control, degaussing, and data acquisition technologies. With increasing knowledge spillovers across the globe and efforts to seek cooperation, China will take time to learn, share, and disseminate technological knowledge for solving such challenges.

3. Assessments

Throughout the space programs, China has proactively sought access to knowledge and technologies. The path it has constructed over the decades in essence is product-driven to adapt foreign knowledge and technologies to local environments, in order to position China as a competitor in space. During this process, debates on knowledge-creation and knowledge-application attribute to the pattern of practice for technological progress. At the core of this practice is new knowledge that, once accepted, shapes the path along which the programs are pushed forward. Knowledge becomes the sole criterion to measure the technology that the defense scientists and engineers choose to use and the degree of their commitment to it in order to make the programs viable. This approach to organisation learning and innovation highlights the nature of the path in the space industry.

First, China's space policy and programs are product-driven. Due to deficiencies in and the absence of access to technologies, the programs pay special attention to learning by doing as an option to enhance product innovation in order to maintain the optimal equilibrium of available technologies and cost-benefit efficiency. This distinct approach indicates that foreign knowledge serves as the key to the space programs and leaves a heavy imprint on them. Yet, its collaboration with industrialised countries is limited.

Second, catching-up is central to the space programs. Weaving the ideal of catching-up through knowledge-creation and knowledge-application into the fabric of R&D agendas and management gives defence scientists and engineers a role to play. The mechanism of nation-wide cooperation legitimises their ideals across sectors for increasing returns. When confronted with the monopoly of technologies by industrialised countries, they gradually modify the inferior lock-ins that threaten program survival.

Third, technology management is increasingly transparent in the space industry, where the defense scientists and engineers debate technical issues, choices, and priorities to pinpoint advanced but affordable technologies. Since all the space programs are approved by the top political leaders, this implies that the space programs, a symbol of national pride, are personal and centralised in nature. The encouraging news is that reform has shown signs of rendering the space programs rational and cost-effective.

China's rise as a serious contender in space will drive industrialised countries to become more innovative in order to maintain their dominant position. As a result of knowledge spillovers, their innovative ideas and technologies are shared, digested, and imitated by Chinese scientists and engineers for adding significant value to knowledge-creation and knowledge-application and for producing cheap products to compete in the markets. Following this logic, Chinese scientists and engineers proactively seek short cuts by optimising knowledge and resources for the breakthroughs in the critical areas of the space programs.

3.1 Benefits of Collaboration

- Cost Reduction: the space programs, however defined, are costly. With increasing economic power, China is committed to the space programs and its investment in space, compared to other programs, remains competitive. On the other hand, the EU faces the budget constraints due to the devastated financial crisis of 2008. For both, cost-sharing makes the space programs focused, viable, and affordable.
- Technology Supply-Demand: the EU is the powerhouse of state-of-the-art technology in the world. This valuable asset is in contrast to Chinese deficiencies in technology. Collaboration as a vehicle for organizational learning allows China to access EU knowledge and technologies, while helping the EU to invest in core activities, access resources outside their boundaries, and market their knowledge and technologies in China. Technology supply and demand accelerate innovation, which gives both a competitive advantage in different ways.
- Program Transparency: the Chinese space industry remains closed, rather than open. Collaboration through organizational arrangements to pool resources for committed areas

improves the mutual understanding of the nature of the programs and reconciles the benefits and costs of knowledge specialisation with those of political and security concerns.

3.2 Costs of Collaboration

- Embargoes and Controls: arms embargoes and export controls are the legal barrier to collaboration, although there is 'no EU common ground on what items are covered under the law.' Imposed by the EU and the US on China immediately after 4 July 1989, arms embargoes and export controls govern technology and knowledge transfers. Lifting the embargoes and controls will be a large challenge, because of the uncertain nature of the Chinese space programs and due to different interests and priorities among the EU member states and the United States regarding China.
- Knowledge Spillovers: China's knowledge-based path follows a pattern of learning, copying, and innovating, with the aim of accessing and acquiring knowledge. Though critical technologies are the bottleneck of its space programs, there is no doubt that knowledge spillovers over time lead to the development of indigenous technologies and low-cost capabilities. This scenario of knowledge-creation and innovation makes China independent of EU specialisation, while jeopardising the EU's interest in the dynamic Chinese markets.
- Intellectual Property Protection: a large concern for any space collaboration with China is that it has no effective mechanisms (administrative, judicial, or cultural) to enforce its protection of patents, trademarks, know-how, and copy rights. Lack of efforts to enforce regulations can translate to bad faith in collaboration, unless Chinese partners also face similar problems in the EU.

4. Conclusion: Policy Recommendations

China’s competitive space programs show both its technological sophistication and deficiencies. At the working level, building collaboration between the EU and China is complementary to both parties. Yet, the success of collaboration requires strong political support in order to balance, strategic and economic interests as a result of different political and value systems.

- Space Legal Frameworks: Chinese legal scholars make efforts to grasp critical issues in space, such as, debris management, environment, and navigation. Since the EU has expertise in this field, as a first step amendments to legal frameworks to enable closer collaboration will lay a foundation for policy dialogue and joint space programs.
- Project Management Training: Chinese project managers are scientists and engineers who have a special role to play in identifying program priorities, setting agendas, and implementing them. It is essential to enhance communication at the working level in order to understand the concerns and intentions of both parties. Management training programs will help to pinpoint common interests and develop the code of conduct.
- Space Station, Lunar, and Mars Programs: both China and the EU have great interests in space station, lunar, and <Mars programs. As an alternative to uncertainty over EU-Russian ties, creating a joint platform with China will allow EU scientists to continue research without disruption, while sharing results and benefits.
- Launch services: Chinese low-cost launch services attract a lot of attention across the globe. Regardless of long-term or mission-based cooperation on launches, there is a strong business

argument for taking advantage of Chinese services, which will substantially reduce the launch and management costs of satellites.

- Boosters: These represent a weak link in the Chinese space program. Joint research will accelerate the development of a new generation of more efficient, cheaper, and faster heavy boosters for multiple space missions in the 21st century.

Appendix

Table 1 Policy Goals

Agency	Core Mission	Strategic Goal
Manned spacecraft	Space docking and walking and a manned space lab	Space station
Moon exploration	Moon landing and returning samples to Earth	Manned missions
Imaging	High-definition imaging and land-based support systems	High definition imaging
Booster	Non-toxic, non-pollution, low-cost, high-reliability boosters	Boosters

Sources: National mid and long-term S&T development plan (2006-2020); China National Space Agency (2014); White paper (2006); space project development plan (2006-2010).

Table 2 Project Budgets

Year	Project	Budget (RMB billion)
1956	Missile	Unknown
1986-2005	863	3.3
1992-2012	Manned spacecraft	2
2004	Moon exploration	1.4

Sources: Ministry of Science and Technology (December 2006); Wu Ping, spokesman of China's manned spacecraft project office (28 June 2012); Moon exploration office (23 January 2004).

Table 3 Legal Research Priorities

Type	Issue
International space law	Debris warning and reduction, Spacecraft protection, Space environment protection, Satellite navigation, Conflict resolution mechanisms, Chinese space station and international cooperation
Domestic regulations	Space law, Space industry and products, Pricing, Import and export, Ownership reform

Sources: China National Space Agency (2014); and Space project development plan (2006-2010)

Table 4 Selected international cooperation

Region	Country	Project
Europe	EU	Information exchange on Copernicus remote sensing data and Galileo/COMPASS Information exchange in earth observation, geo-science, space science, and exploration
	Russia	Spacecraft, Moon/ Mars exploration, GLONASS/COMPASS,
	Belorussia	Satellites
	Ukraine	A joint system for Earth observation, A joint ionospheric satellite, Rocket and space technology
North America	Canada	Limited cooperation as a result of the US International Traffic in Arms Regulations (ITAR)
	United States	
Asia	Pakistan	PakSat-1R
	Sri Lankan	COMPASS, Satellite launch and application
	Indonesia	Space tracking and control Satellite launch and application
Latin America	Venezuela	Venesat-1, 2, 3 and

	Brazil	technology transfer Joint earth imaging satellite, earth resources satellites,
Africa	Nigeria Congo	Nigcomsat-1 and 1R 'East-Is-Red' 4 Satellite

Source: China National Space Agency (2014).