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The Chinese Chang'e Lunar Exploration Project and Its Management Structure

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Summary

China is progressing steadily since the late 1990s in its space megaproject, which includes the Shenzhou manned spaceships and Chang'e lunar probe program. Amid worldwide attention, China's ambition to make a presence in space is moving towards the target of a moon landing in the next one to two decades. By looking at the management structure and key features of the lunar exploration project, the paper decodes the Chinese system designed to reach its space goals and its implications for the capabilities to build up indigenous innovation that China desires.

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BACKGROUND ON THE CHINESE SPACE MEGAPROJECT

China's two major space programs, the manned space exploration (Shenzhou) and the lunar probe (Chang'e) program, are grouped into one single megaproject that was launched in the Medium- to Long-Term Science and Technology Development Plan (MLP) in 2006. The Shenzhou manned space program was initiated in the early 1990s and later migrated into the space megaproject umbrella, while the Chang'e program was established with the approval from the State Council on January 23, 2004, in line with the development time line of the MLP.¹ Both Shenzhou and Chang'e are ongoing programs. The Chang'e I lunar probe was launched in 2007 and Chang'e II in 2010. Chang'e III is scheduled in 2013 and Chang'e IV and V are under study.²

Shenzhou is a military program under the direct administration of the General Armament Department (GAD) of the PLA (People's Liberation Army). The GAD director serves as the general commander of the manned space program. Chang'e is a defense-related program although not managed by the PLA. It is under the leadership of the State Administration of Science, Technology, and Industry of National Defense (SASTIND), with the SASTIND director as the head of the leading group office. The latter is one level lower than the Shenzhou general commander in administrative ranking.³ The ranking difference doesn't necessarily indicate a difference in importance between the two projects; however, it might have some implications on the resources that each project can mobilize and utilize.

MANAGEMENT STRUCTURE

The Chinese space projects follow a top-down approach with the state having the dominant control

1. *Woguo Raoyue Tance Gongcheng Dashiji* [Several Key Events in China's Lunar Exploration Program], Xinhuanet.com, October 24, 2007 <http://news.xinhuanet.com/news-center/2007-10/24/content_6933859.htm.

2. Zhang Qiaoling, *Ouyang Ziyuan Yuanshi Miaohui Chang'e Gongcheng Houxu Lantu* [Future Plans of the Chang'e Program Introduced by Academician OuYang Ziyuan], Keji Shibao, December 9, 2011.

3. Administrative ranking is the ranking system of government officials in China. The GAD director is at the minister level and the SASTIND director is at the vice minister level.

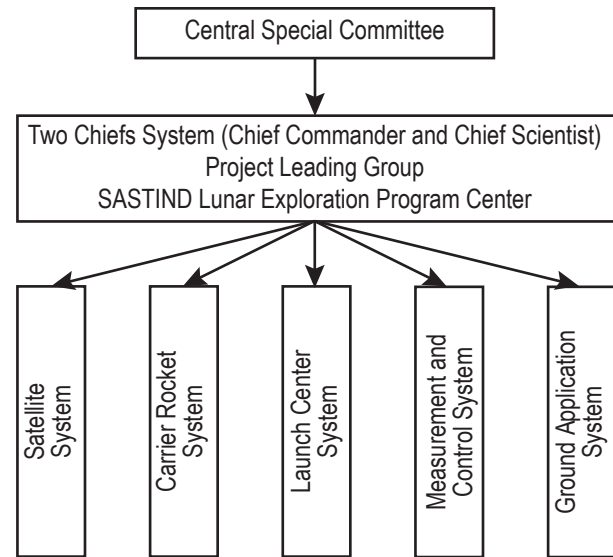


Figure 1. The Chang'e lunar probe project.

in the management structure. The project's organizational chart is shown in Figure 1.

The central leaders are the key decision-makers and most important supporters of the project. The Chang'e program attracted the attention of President Hu Jintao and Premier Wen Jiabao at the beginning of its preparatory period in 2003. Both commented on the project plan multiple times and the final approval came from the State Council executive meeting in 2004 with Wen Jiabao giving the final yes.⁴ Throughout the implementation stage there has been attention from Politburo Standing Committee members, who have visited the project sites, participated in launch events, and hosted celebrations of achievements.

The Chinese space projects have inherited the management system developed in the "Two Bombs One Satellite" era in the 1960s. The Central Special Committee (CSC) led by the premier and established to make the major decisions during "Two Bombs One Satellite" is still the top institutional organ that commands and monitors the overall flow of the space projects today. It is a tradition for the premier to host a CSC meeting to hear a progress report before any launch events.⁵ At the operational level, SASTIND plays the major role of organizing and coordinating. Key sup-

4. *Woguo Raoyue Tance Gongcheng Dashiji*.

5. Li Mingsheng, *Qianggu Yimeng* [A Dream Through Ages] (Jiangxi Renmin Chubanshe, 2009).

porting ministries include the Ministry of Finance, Ministry of Science and Technology, and GAD.

For daily operations, a project leading group was formed for each of the Chang'e I and II projects, with the SASTIND director the head of the office and mainly responsible for coordination and administrative decisions, followed by a project center (工程中心) and a Two-Chief system (两总系统). The leading office and the program center serve more of the role of project coordinator and facilitator among the different research units, manufacturing and launching infrastructures, enterprises, and universities during the operation of the plan. The Two-Chief system consists of one chief commander and one chief scientist, who are mainly responsible for the actual R&D operation.

The Two-Chief system is also a legacy from "Two Bombs One Satellite." Both the chief commander and chief scientist are leading engineers and/or scientists in aerospace industry. For example, Sun Jiadong, the chief designer of the Chang'e I probe, is an expert in carrier rockets. Luan Enjie, the chief commander of the Chang'e I probe, is an expert in missile control technology and aerospace project engineering. Both of them participated in the "Two Bombs, One Satellite" program in the 1960s.

In the Two-Chief system there are two lines directing R&D activities: the chief commander is responsible for the economic, technological, and quality control portions of the project; while the chief scientist, following the instructions of the chief commander, is in charge of model design, testing, and other scientific and technological responsibilities.⁶ This management system allows for flexibility and close collaboration, linking political and operational domains and in turn producing more efficient management characteristics, including channels of communication, reporting requirements, and testing R&D and production systems.⁷

The Chang'e program has five R&D subunits (see Figure 1): Satellite System, Carrier Rocket System, Launch Center System, Measurement and

6. Guo Baozhu, "System Opinions and Methodologies in Space Project Management," *China Engineering Science* 13, 4 (2011): 45

7. John Wilson Lewis and Litai Xue, *China Builds the Bomb* (Stanford, CA: Stanford University Press, 1988), 253.

Control System, and Group Application System, and each of these has its own Two-Chief system.

Overall, decisions flow vertically from the top leader group (central authorities) to the executive team (the leading group), and then to the project operators (the two chiefs). The project operators then break the research goals into five parts and assign them to the R&D subunits. Each subsystem will further divide the research goals into detailed research objectives and give them to the corresponding research unit underneath.

Many of the research institutes and infrastructures that carry out the detailed R&D objectives in the subunits are affiliates of the two space conglomerates of China: the China Aerospace Science and Technology Corporation (CASTC) and the China Aerospace Science and Industry Corporation (CASIC). They play important roles in R&D activities at the operations level. Because of the involvement of the two conglomerates, there are questions as to whether there are market elements to the Chang'e program. However, because this is a system that doesn't work on competition but on assigned tasks, the market impact, if any, can barely be seen. Each unit is presumably the best institute in the assigned area, so there is no competition to win contracts. However, strict quality controls are in place because the projects are linked to national prestige. A project that affects China's prestige negatively will lead to serious consequences for the project personnel. Therefore, even without a competition mechanism, the research team works extremely hard to make sure everything goes right. Research units, including industrial conglomerates, are gathered for the purpose of fulfilling the research tasks associated with each model.⁸

FUNDING AND PERSONNEL

As a national priority, the Chang'e megaproject is able to mobilize the best resources available in the Chinese space industry. It enjoys funding from the central government S&T budget, and can gather the highest quality research teams. The official spending figure published by the Chinese government is 1.4 billion RMB (222 million USD) for

8. Guo Baozhu, "System Opinions and Methodologies in Space Project Management."

Lunar Project	Country	Cost	Year
Chang'e Megaproject	China	364 million USD	2004–2010
Apollo	United States	20 billion USD excluding the infrastructure and support ¹	1959–1973
N1–N3 Lunar Spacecraft	Russia	4.5 billion USD ²	1970s
C919 Large Passenger Airplane Megaproject	China	31 billion USD ³	2008–2020
Shenzhou I to Shenzhou X Projects	China	6.14 billion USD ⁴	1996–2013

Data sources:

1. "Project Apollo: A Retrospective Analysis," NASA History, <<http://history.nasa.gov/Apollomon/Apollo.html>>.
2. Brian Harvey, *The New Russian Space Programme: From Competition to Collaboration* (Wiley, 1996).
3. "Zhongguo Dafeiji Xiangmu Zongtouzi Jiangda 2000 Yi [Budget Reaching 200 Billion RMB for the Chinese Large Passenger Aircraft Project]," *People's Daily*, May 8, 2009.
4. Jiang Jianke, "Zhongguo Zairen Hangtian Gongcheng Muqian Zonghuafei Yue 390yi Yuan [China Manned Space Program budget 39 Billion RMB So Far]," *People's Daily*, June 25, 2012. Calculated based on the exchange rate of 1 USD = 6.35 yuan on June 27, 2012.

Table 1. Reported costs of space programs.

the Chang'e I project and 0.9 billion RMB (142.9 million USD) for the Chang'e II project.⁹

There are suspicions that the reported figures on China's space projects are inaccurate. Table 1 compares Chang'e reported spending to the U.S. Apollo project, the Russian N1–N3 Lunar Craft, the C919 Large Passenger Airplane Megaproject, and the reported budget of the Shenzhou program.

It is clear that both United States and Russia spent billions of dollars in the 1970s in carrying out lunar exploration projects. The Chinese aircraft megaproject alone has a calculated funding of 31 billion USD. These projects have similar scale and complexity, and it is difficult to find explanations of why the Chinese reported spending figures for its space projects are so low. It is possible that the Chinese government is underreporting the actual spending for reasons of its own. First, the space projects are defense or military in nature, and in the Chinese defense system there is little transparency in the budgeting mechanism. Due to the authoritarian nature of the political system, the government is not required to release the figures. Second, considering the significant

9. Zhou Haibin, Lu Tao, and Guo Cunju, "Tanyue Huafei Xiangdangyu Xiu Lianggongli Ditie [The Cost of Lunar Program is Similar to Building Two Miles of Subway]," *China Economic Weekly* 39 (2010). Calculated based on the exchange rate of 1 USD = 6.3 yuan on April 26, 2012.

amount of the budget devoted to the space projects, mainly for the purpose of enhancing national prestige, publishing the real spending figures will probably make the Chinese public unhappy about government spending habits, especially when the money could be spent in other ways to improve the standard of living.

Despite the vague spending figures, the Chang'e Megaproject is more honest in reporting the large scale of S&T personnel and research facilities involved in the program. The development of Chang'e incorporates more than 200 research institutes, laboratories, and universities, all of which are leading R&D centers in China. The Chinese Academy of Sciences and its affiliated institutes have done the major research work, including high-precision camera design, space observation, and ground applications. The National Observatory, Center for Space Science and Applied Research, Shanghai Observatory, Xi'an Institute of Optics and Precision Mechanics, and the Purple Mountain Observatory, all under CAS, are acknowledged as having made major contributions to the project. CASTC, CASIC, and the China Electronics Technology Group Corporation have been the major corporate players in organizing and carrying out R&D work.

Highly-skilled personnel with graduate degrees make up a large portion of the R&D team,

and many of the participants hold degrees in STEM-related subjects. Here are examples of the high-level scientists and engineers on the team:

- 70.7 percent of the major project leaders of the Chang'e II project (deputy and chief deputy scientists/engineers) have a master's degree and higher; 36.2 percent have a doctorate.¹⁰
- In the launch vehicle system, 70 percent of the director designers are senior engineers and above and they are trained according to the vehicle series they are working on.¹¹
- In the satellite system, 63 percent of the director-level scientists have a master's degree and above.¹² Many of them are from the top-tier institutions such as Tsinghua University, Peking University, Beijing University of Aeronautics and Astronautics, and Northwestern Polytechnic University.

The Chang'e project has encompassed a high-quality workforce that has been working extremely hard in developing China's lunar exploration capabilities. As noted by Wu Weiren, the chief designer of the Chang'e II project, the highly skilled workforce, which has strong abilities in conquering technological difficulties and making breakthroughs, has been a major driving force to create indigenous innovation in the Chang'e project.¹³

BUILDING INNOVATION CAPACITIES IN THE SPACE INDUSTRY

There are debates within China on whether it is worthwhile to have such a large-scale S&T project with massive investments that has limited impact on the civilian living standard. However, looking at the U.S. Apollo program, it has been generally concluded that Apollo was an endeavor

10. Cai Jinma, "Chang'e Visits Guanghan Palace Again," *Defense Science and Technology Industry* 12 (2010): 25.

11. Sun Yang, "Zhezhi Duiwu Yiding Nengda Piaoliangzhang [The Team Must be Able to Win the Combat]," *Defense Science and Technology Industry* 10 (2010): 61.

12. *Ibid.*, 26.

13. Xu Ling, "Jizhongliliang, Zizhugongguan [Concentrate the Power to Make Breakthroughs]," *Defense Science and Technology Industry* 10 (2010): 46.

or that demonstrated both the technological and economic virtuosity of the United States and established its technological preeminence.¹⁴ The Chang'e project has been serving a similar role for China in demonstrating its technological advancement. China claims that the ideological excitement that the Chang'e success has brought to the S&T world is a strong motivator for catching-up activities in other S&T fields. To better send this signal, the project's propaganda office has organized intensive media reports to ensure that the success is broadcast nationwide in a way to build up patriotism. The media team has been dubbed the "sixth system" beside the five official R&D units in the project and was praised by the project leading group.¹⁵

Aside from its political purposes, the experience accumulated from the Chang'e program has the following implications for China's innovation competence:

- It sustains and promotes the development of Chinese expertise in basic sciences such as astronomy, celestial mechanics, and other space exploration subjects that were shrinking due to lack of practical application, and also improves interdisciplinary cooperation among different subject areas.¹⁶
- It helps to nurture a high-quality S&T workforce and the passing on of space technology knowledge from old to new generations. Many of the leading scientists and engineers on the Chang'e R&D team are already in their late 30s. The space industry has increased participation of younger scientists through graduate entry schemes, and provides more advanced apprenticeships to attract high-quality entrants from universities. For example, CASIC recruited 4,221 college graduates in 2010, among which 68 percent have a master's degree or higher. CASIC's recruitment plan for

14. "Project Apollo: A Retrospective Analysis," NASA History <<http://history.nasa.gov/Apollomon/Apollo.html>>.

15. Cai Jinman, "Media and Propaganda is the 'Sixth System'," *Defense Science and Technology Industry*, 1(2011).

16. Zhang Tao, "Chengqianqihou Wenbutuijin [To Build the Bridge from the Past to the Future, to Progress Steadily]," *Defense Science and Technology Industry* 10 (2010).

2011 has a quota of 4,900 students, with a target of 74 percent master's and doctoral students.¹⁷ It has become a popular trend for Chinese college graduates to seek positions in the defense conglomerates, especially the space and aviation ones which have large allocations of government funding.

- National acknowledgement of the Chang'e team creates better scientific environment for the S&T personnel. Not only do they have societal respect, they also receive financial rewards from the civilian enterprises. For example, China Minsheng Banking Group donated 90 million

17. "CASTC Plans to Recruit More Than 4900 College Graduates," *SASAC News* <<http://www.sasac.gov.cn/n1180/n1226/n2410/n314244/11286642.html>>.

RMB to those who had made significant contributions to the Chang'e project.¹⁸

- Successes in organizing and implementing the Chang'e project have increased the store of megaproject management experience in general. However, the impact on the development on "non-mega" innovation projects might be limited.

18. "Minsheng Bank Donates 3 Million RMB as Bonus to Personnel Who Made Great Contribution in the Chang'e II Program," *People's Daily Online News* <<http://scitech.people.com.cn/GB/13533853.html>>.

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