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CHINA AEROSPACE STUDIES INSTITUTE

The Real Space Race:
China Will Send a Crew to Orbit Mars by 2050

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Introduction

The People's Republic of China's (PRC's) scientific community established China's broad timelines for crewed Lunar and Mars missions simultaneously in 2009. At that time, the Chinese Academy of Science's (CAS's) 40-year technology forecast called *Space Science & Technology in China: A Roadmap to 2050* was largely seen as unofficial and aspirational.[1] However, the scientists' forecast for a crewed Moon landing "around 2030" has turned out to be an accurate prediction, assuming all goes to plan. [2] This report examines CAS's second prediction for "crewed Mars exploration around 2050." [3]

By applying lessons learned from China's release of information on its timeline for a crewed Lunar landing, this report shows that there is already Chinese top leadership support for a crewed Mars mission, based on statements from many informed individuals, including those from China's Manned Space Engineering Office (CMSE). To shed light on if "around 2050" could end up being "before 2050," as it has in the Lunar case, this report describes the internal and external drivers for why the Chinese Communist Party (CCP) supports a crewed Mars mission to celebrate China's second centennial anniversary in 2049. It also briefly explains that the PRC's founding happens to co-occur with opportune physics enabling at least two excellent Mars launch windows before 2049.

This report considers an initial orbit-only mission, to accurately reflect what the CAS forecast says and to support follow-on studies. The CAS technology forecast specifically distinguished between a "crewed Lunar landing around 2030" and "crewed Mars exploration around 2050," i.e. it does not say Mars landing.[4] Within this scope, this report discusses what Chinese researchers have said about relevant launch windows and highlights select technology milestones for space watchers to track. Last, this report poses three questions policymakers should consider when determining the implications for the United States, as well as flags alternative space missions the PRC could use to celebrate its second centennial.

What did we learn from the Lunar case?

This report applies two lessons learned from China's gradual announcement of its plan to land a crew on the Moon:

1. Chinese statements from informed individuals may be just as authoritative as statements from official CMSE representatives.

2. Limited publicly available information on key technologies to enable the Chinese mission shouldn't be a strong reason to discount statements from informed individuals. In other words, the two types of information are separate but equal indicators.

Generally speaking, when a Chinese official makes an announcement to national Chinese media, outside observers have confidence that those statements reflect top leaders' views. The reason for that is because the CCP manages the media and PRC officials are sensitive to toeing the party line to protect their careers. This fact influenced seasoned Western space watchers to discount State-Owned Enterprise (SOE) statements about a Chinese crewed Lunar landing.[5] To some, it seemed more likely that the SOE rocket engineers' business incentives, rather than CCP support for a Lunar mission, drove the engineers' proposed timelines.[i] For example, just after CAS published its 2009 space technology forecast, two vocal space SOE representatives stated that, "the [crewed Lunar] mission is technically possible in 2025."[6,ii] Those same representatives in 2021 and in 2022 said, "a crewed landing [on the Moon] is entirely possible by 2030."[7] At last, in mid- 2023, CMSE announced that China will attempt to land taikonauts on the Moon "before 2030," and outside observers finally accepted their timeline.[8]

Regarding lesson one, Western space watchers do not fully understand the relationship between China's official messaging and SOE statements, especially in a national strategic industry with a long legacy like the space sector. In the case of assessing China's commitment to a crewed Lunar landing, Western space watchers had less confidence in SOE and China National Space Administration leaders' (CNSA) statements.[9] Instead, space watchers waited for official announcements from CMSE because CMSE is directly in charge of the astronaut program.[10] In this case, some SOE representatives turned out to be well informed. It is still important to be cautious, however, because the rising generation of Chinese space program managers may not have the same access to information.

Regarding lesson two, information on necessary equipment, such as the Lunar spacesuits and the crewed Lunar lander, wasn't publicly available until after CMSE's announcement.[11] Technology readiness is usually a major factor in leaders' willingness to make official announcements, so outside observers naturally looked for other signs in absence of confirmation

[i] SOE economic success, after all, is also a CCP goal.
[ii] Now retired China Academy of Launch Vehicle Technology (CALT) representative Long Lehao and now retired China Aerospace Science and Technology Corporation (CASC) representative Ye Peijian.

from CMSE. However, technological developments take more effort to spot and when observing China, other signals are just as important. For example, in China, aspirational statements indicate leadership intent. When official media repeats high level aspirations, local stakeholders can take action.[12] For example, the CAS 40-year technology forecast was indeed aspirational, but more authoritative than originally expected. The People's Daily in 2013 publicized CAS's timeline with the headline, "CAS: China expects to achieve crewed Lunar landing and build a Lunar base around 2030." [13] The People's Daily article goes on to say that China's Lunar base will enable "crewed Mars voyages."[14] This example illustrates that an organization like CAS can represent top leadership intent and steer technology developers at national and local levels in the leader's desired direction.

The major lesson learned is that repeated statements of aspiration matter. If outside observers wait to confirm technology readiness, they may discount other important signals and fail to examine the relationship between key SOE and CNSA stakeholders and the CCP.[15,iii]

Why does China aspire to conduct crewed Mars exploration by 2050?

China's domestic drivers are just as important, if not more important, that external drivers for its ambition for a crewed Mars mission by 2050. In particular, many signs indicate that the CCP intends a crewed Mars mission as one of many steps to symbolically and materially support China's second centennial goal of achieving national rejuvenation at the 100th anniversary of the founding of the PRC in 2049.[16] In general, Chinese leaders often use space missions as a way to celebrate key events.[17]

In particular, China's first centennial for the 100th anniversary of the CCP was in 2021 and they celebrated with the successful landing of the robotic Tianwen-1 Mars rover. The CCP's 100th anniversary was on July 1, 2021; Tianwen-1 entered Mars orbit in February and successfully landed in May.[18] Xi Jinping's congratulatory message said, "On the occasion of the 100th anniversary of the CCP, the Tianwen-1 mission successfully landed…"[19]

More broadly, Chinese leaders marked the first centennial with achieving what they called "a moderately prosperous society," which included both economic and social components.[20] Even in this regard, the Chinese space sector played a role. The opening of China's commercial space sector in 2014 was one of a slew of policy shifts to widen the social benefits of national strategic industries towards achieving the first centennial goal.[21] Since then, China has continued to expand the benefits of the space industrial base for the crewed space program and deep space exploration across provinces beyond national level organizations.[22] This diversification of Chinese organizations and localities contributing to space technologies makes identifying key developments more complex for outside observers.

[iii] This is now true for the joint China National Space Administration, Anhui Province, and University of Science and Technology of China Deep Space Exploration Lab.
(https://www.cnsa.gov.cn/n6758823/n6758838/c6840504/content.html)

For China's second centennial, Xi Jinping expects "national rejuvenation" by 2049.[23] Space plays an important role in China's plan for national rejuvenation and a global first such as a crewed mission to Mars would be worth celebrating. For example, Xi Jinping recently said, "the spirit of space exploration can further enhance the national confidence and pride of the Chinese people…and [enhance] realizing national rejuvenation.[24] Apart from the symbolism and national pride, the CCP also intends China's space program to materially contribute to the second centennial goal through spurring innovation. Xi Jinping in a 2017 speech said that by 2035 China will become a global leader in innovation. [25] And in particular, a widely cited Chinese space industry report stated that by 2045 China will take the lead in select space technology areas.[26]

From the Chinese perspective, the domestic drivers for the completion of a crewed Mars mission by 2049 are just as strong, if not stronger than the external drivers. That said, achieving a global first for its crewed space program would also cement China's position as a top global space leader, equal to the United States. Competition with the United States is just one aspect of the external drivers. Just as important, leading global space exploration would allow the CCP to demonstrate that China has met its second centennial goal to become "a global leader in terms of composite national strength and international influence" and "a proud and active member of the community of nations."[27] A link between China's national rejuvenation and international influence implies that China will continue to find ways for international participation in its space program, likely to include the missions to Mars.

How committed is China's government to crewed Mars exploration by 2050?

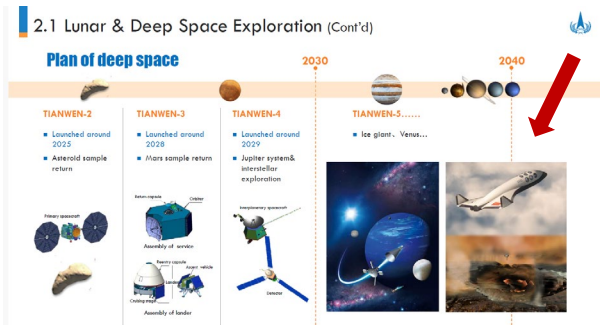
Applying lessons learned, both the authoritative CMSE and informed SOE representatives have already openly discussed that China is planning a crewed Mars mission. For example, in an interview at the annual National People's Congress in 2018 the CMSE Chief Designer Zhang Baoan said the technology for a crewed mission to the Moon can be used to ferry a crew around Mars.[28] The CMSE website published Chief Engineer Zhou Jianping's statements in 2021 and 2022 that, "We will aim for Mars."[29] Even more telling, Chinese official media quoted China's first taikonaut Yang Liwei in 2022 saying that, "China's manned space program will go deeper into space…and there will be crewed exploration of Mars."[30] If space watchers follow the same logic as in the Lunar case, these statements should confirm Chinese leaders' intent.

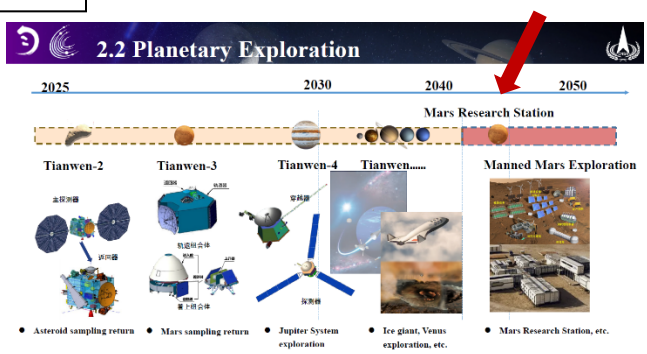
Apart from intent, SOE and CNSA representatives are again leading messaging of possible timelines for a Chinese crewed Mars mission around 2050. For example, as early as 2015, one of the same SOE representatives, Long Lehao, said that the earliest possible crewed Mars mission would be 2035.[31] A different SOE leader, Wang Xiaojun, in 2020 and at the 2021 Global Space Exploration (GLEX) Conference also stated that the earliest date for a crewed mission was around 2035.[32] Even CNSA representatives are publicizing China's crewed Mars mission at international forums. CNSA's 2023 and 2024 presentations at the UN Committee of Peaceful Uses of Outer Space (COPUOS) depicted a crewed deep space orbiting vehicle around

2040.[33] Representatives from China's new Deep Space Exploration Lab (DSEL) showed the crewed vehicle returning atmospheric samples from Venus in 2033 and a Mars research base in 2038.[34] This may very well foreshadow that "around 2050" is shifting to "by 2050."

Wang Xiaojun's 2021 GLEX Presentation

CNSA's 2023 and 2024 COPUOS Presentations





DSEL's 2025 Presentation

SOE and CNSA messaging is also focused on domestic audiences, which strengthens the likelihood that these timelines are sincere projections. In 2019 and 2022 interviews, key CNSA officials discussed how Lunar technology linchpins like the new crewed orbiting vehicle will

also be used for crewed Mars missions.[35] For example, in 2019 the CNSA website published an interview with the ShenZhou spacecraft's Chief Designer, Qi Fayun, who said that "China will go to the Moon and Mars….so [we] need a new crewed vehicle."[36] Representatives from China's new Deep Space Exploration Lab showed the earlier timeline for a deep space crewed vehicle first at a domestic conference.[37] Before SOE representative Wang Xiaojun made his presentation to the 2021 GLEX Conference in Russia, he made the presentation at a domestic conference in 2020. [38]

Mars launch windows[iv] and related Chinese research

Physics primarily determines when a country can feasibly launch a crew to Mars. Mars and Earth are at the closest points in their orbits approximately every 26 months (approximately every two years). Within the 26-month cycle, the best time to launch a crew may be during peak solar activity. While all radiation is a problem for the crew, it may be possible to shield against more severe solar activity. While at the same time, the increase in solar particles can limit the impact of other high energy particles coming from outside the solar system, which are more harmful.[39] The solar cycle peaks approximately every 11 years; a solar maximum is ongoing. Furthermore, the shapes of Earth and Mars' orbits around the Sun create an additional benefit every 15-17 years when Mars is at its closest to the Sun. These beneficial launch conditions will overlap around 2033 and 2048 which would allow countries to launch large equipment with still shorter cruise timelines.[40] (See table)

[iv] Ryan Faith contributed to this section.

Approximations of Crewed Mars Mission Lengths with NASA's Space Launch System (SLS) and SpaceX's Starship*

	Outbound	Stay	Return	Total	Vehicle	
Orbit-only with Venus flyby	200	30	340	570	SLS	
Short stay (landing)	220	30	410	660	SLS	
Long stay (landing)	260	500	260	1020	SLS	
SpaceX proposal (landing)	180	550	180	910	Starship	

* Approximations measured in days. (Hoppy Price, Robert Shishko, Joseph Mrozinski, and Ryan Woolley," Concept for 2033 Crewed Mars Orbital Mission with Venus Flyby," Journal of Spacecraft and Rockets, 2/2023, https://doi.org/10.2514/1.A35437; Bret G. Drake and Kevin D. Watts, editors, "Human Exploration of Mars Design Reference Architecture 5.0. Addendum #2," NASA, 2014, https://ntrs.nasa.gov/api/citations/20160003093/downloads/20160003093.pdf; "Mars Opposition versus Conjunction Primer" NASA presentation at Explore Mars 2021, Washington D.C., https://www.exploremars.org/wp-content/uploads/2021/09/0914_03-15_Bret-Drake_Trajectory.pdf; and MarsMatters, "Mission To Mars: Short Stay VS Long Stay (Opposition VS Conjunction)," 2023, https://www.youtube.com/watch?v=HJO68fD4jJs)

Given these opportune launch windows, Chinese technical research unsurprisingly also considers both a general 2030s and a 2040s timeframe. Based on this report's cursory search for Chinese analysis on an initial orbit-only crewed Mars mission, three different perspectives surfaced, each summarized below. Most of the reports also discussed a crewed Mars landing, but this report only highlights elements related to an orbit-only mission by 2050.

The first perspective is from technologists such as rocket and spacecraft designers, who need to provide the basic systems for transport. In 2014, researchers from a Shanghai municipal key lab and the SOE Shanghai Academy of Spaceflight Technology (SAST) outlined systems for a two person crewed launch in 2033 with a return around 2037, via Venus flyby.[41] They build off of a 2009 National Aeronautical and Space Administration (NASA) study, and similarly proposed multiple launches to assemble and fuel payloads in Earth orbit.[42] The Shanghai team's forecast assumed the rocket capabilities of the Long March 5 (LM-5) and a, at that time, yet to be developed heavy launch vehicle in their proposal. Also assuming the LM-5, in 2015, the Beijing University of Aeronautics and Astronautics and the China Academy of Launch Vehicle Technology (CALT) showed the fuel needed to send a six person crew to Mars, though they did not include details on the launch window.[43]

At a 2020 Chinese domestic conference and again in 2021 at the international GLEX conference in Russia, CALT representative Wang Xiaojun outlined a three-step plan. He proposed starting with robotic missions for site selection in 2033 and the first crewed orbit-only mission occurring around 2035.[44] Also in 2021, Wang Xiaojun and a colleague published a technical article which added more detail to the timeline he presented at GLEX, a timeline which relied on nuclear propulsion. [45] Their article described an ultimate crewed landing on Mars in the 2040s and did not expand on the orbit-only mission described briefly at GLEX.[v] The paper also did not reference using a Venus-flyby.

Other researchers at Beijing University of Aeronautics and Astronautics in 2022 published an English article with a detailed proposal for a crewed launch in 2037 with return in 2040.[46] They specifically considered use of the Long March 9 (LM-9), which is China's non-crew rated heavy launch vehicle that will also be used to launch modules to the Moon.[vi] Most recently, a Chinese presentation at another domestic conference described six LM-9 launches to low Mars orbit to assemble the "62.8 ton astronaut life support payload."[47]

The second perspective which surfaced is regarding radiation and crew safety. Generally speaking, CMSE has actively publicized NASA's radiation studies from the Martian surface and new methods of simulating galactic cosmic radiation to understand human health in deep space.[48] Additionally in 2021, Xinhua's Science and Technology Division published a summary of a study from international and Chinese researchers recommending the mid-2030s for a crewed mission to Mars to co-occur with peak solar activity.[49] A Chinese-led study followed up with radiation data from Tianwen-1's transit and similarly recommended crewed transit during solar maximum.[50] The Chinese-led study also made initial proposals for in-transit shielding during the more active solar eruptions from solar maximum.[51] CMSE's own studies on radiation and human health are usually based on experiments at the Chinese Space Station (CSS). In one interview, however, Li Yinghui, the Director of the National Key Laboratory of Aerospace Medicine at CMSE's Astronaut Research and Training Center generally discussed a crewed Mars mission saying that a "shorter transit time is better."[52]

The third perspective is also related to crew safety, but in terms of navigation and communications. Researchers at the PLA National University of Defense Technology and SOE China Academy of Space Technology (CAST) in 2022 said that there is an "urgent need" to find a solution for enabling "autonomous navigation for a crewed Mars mission."[53] The article's findings were summarized on the CMSE website in 2023 saying that the researchers had determined an "autonomous navigation method to provide an effective guarantee for the implementation of China's crewed Mars exploration program in the future."[54] Regarding the crew's ability to communicate with Earth while in transit, Chinese experts tested a new crewed

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[v] Their paper described a mission that would include a 180-200 day transit both ways, and a 500 day surface stay, for a mission total of approximately 2.5 years using nuclear propulsion.

[vi] Readers should note that the author did not find Chinese researchers discussing the crew-rated Long March 10 (LM-10) in simulations for a Mars mission, which would be a necessary step.

voice system on the CSS and said that it can be a reference case for crewed communications on Mars.[55] Chinese researchers from a Guangdong Province national key lab, the Harbin Institute of Technology, and an international researcher in 2024 proposed a multi-planet backbone relay system between China's ground stations in the PRC and Argentina.[56] They showed how they could have at least the Mars, Venus, and Uranus links launched and interconnected for "a mission between January 1, 2040 to December 31, 2041," but they did not specify it was for a crewed mission.

Milestones to watch

To support follow-on studies, this report focuses on an initial crewed orbit-only Mars mission. At a minimum, two technologies are necessary for an orbit-only mission. Watching for these will help space watchers assess China's progress towards meeting its goal for a mission around 2050, and assessing the likelihood that the PRC could launch in the 2040s.

First, China's LM-10 is the crew-rated rocket that will be used for both the Lunar and Mars missions according to the official statements discussed above. China will first test launch the LM-10A, a single-stage version of the planned three-stage rocket, in 2026.[57] After that test, China will release a date for the test launch for the three-stage LM-10. The Chief Designer of the LM-10 is Zhang Zhi, who has published a technical report on key components of the LM-10, such as the engine, in 2022.[58] Zhang Zhi has not publicly discussed the role of LM-10 and the Mars mission, based on available information. However, in a 2019 Xinhua interview, he said that the LM-9 will enable a crewed Mars landing.[59] He was previously the LM-9 Chief Designer.[60]

The LM-10 is more important than the LM-9 for a crewed orbit-only mission. While Chinese state media in recent months continues to publish CALT representative Long Lehao's statements that the LM-9 will be used for a crewed landing on Mars, readers need to remember that the LM-9 is not crewed rated.[61] The LM-9 would be used to launch the habitat modules for a crewed landing, which is outside the scope of this report. Crew-rated rockets undergo more testing, and take more time.

China would also need its new crewed spaceship, MengZhou, for an orbit-only mission, presumably with modifications. The MengZhou Chief Designer, Ma Xiaobing, is not often in the media, and based on this review, he has not discussed Mars. According to state media and a rare article of Ma Xiaobing's 2023 tour of companies engineering components for MengZhou, the spacecraft development is proceeding as planned.[62] A test flight to Lunar orbit is the next step to watch.

Three questions to determine the implications for the U.S.

There are three questions which U.S. policymakers should consider when determining the implications of this research. The first two questions are: If Chinese taikonauts beat U.S. astronauts to Mars, how much impact will that have on the U.S.-China competition for global

influence? And a second follow on question would be: Is that the only impact?[vii] If the answers to both questions are "yes," it is important to recall China's multipronged rationale. As discussed above, from China's perspective, the domestic drivers are just as strong as the international drivers for its planned crewed exploration of Mars. The domestic drivers include not just important symbolism that China has achieved national rejuvenation, but the domestic drivers are also tied to economic goals intended to widen the benefits of the space industrial base.

The third question policymakers should consider is: Will SpaceX and other commercial companies seek Mars exploration cost-sharing and collaboration with China, if the U.S. is not equally ambitious? Currently, U.S. commercial companies' plans for Mars are not completely contingent on a U.S. government customer. Will that always be the case? Given the nascent international Mars probe data-sharing agreements, there is a basis for deepening international collaboration for future Mars exploration cost-sharing.[63]

Alternative analysis

As detailed above, there is ample evidence to suggest that a major space goal will play a role in the PRC's celebration of its second centennial anniversary in 2049. Based on the research for this report, there are two alternative missions the PRC may pursue depending on how its domestic and international environment develop in the coming decade. A third, more cautious scenario, is also included to stimulate thinking on how international events could hypothetically delay the PRC.

1. Crewed Mars landing by 2050. The Chinese technical papers mentioned in this report also discussed a crewed landing.[64] In addition to Chinese research on Mars habitat modules and spacesuits, it is clear that a crewed Mars landing is among the goals for China's Mars program.[65] They are already messaging a Mar research station.[66] The question is would China attempt a crewed landing before 2049?

2. Crewed asteroid landing by 2050. In China's 2010 era research on crewed missions to Mars, researchers also outlined a crewed mission to an asteroid for space resource utilization.[67] The crewed asteroid mission was likely their attempt to mirror NASA's similarly stated ambitions, which may have also been deprioritized. China's most recent reference to a crewed asteroid mission in a technical report was a 2024 paper about deep space transportation systems.[68] The capabilities China is developing for planned missions such as the robotic planetary defense mission, asteroid sample return mission, and mission to the outer edge of the solar system could potentially enable the PRC to shift to a crewed asteroid mission if desired.[69]

[vii] Another way to ask the latter question is: How confidently can one link a crewed mission to Mars with achieving specific national priorities like the military's ability to fight and win in next-generation warfare, or to significant technology spillovers in the U.S. economy?

3. High risk perception around 2050. The CCP wants to celebrate national rejuvenation, but not at the risk of embarrassment. While China regularly launches a crew to the CSS around its national holidays, China has not recently been involved in a major war or economic crisis. Without such an event, China space watchers have not seen instances where China has delayed its human spaceflight program.[viii] A much more thorough analysis is needed, but based on past ShenZhou launches to the CSS, there are some hiccups in the timeline that might be related to international security events. The longest time between launches was ShenZhou 11 (October 2016) and ShenZhou 12 (June 2021), which was separated by multiple North Korean intercontinental ballistic missile tests, particularly in 2017, some of which passed over Japan leading to additional United Nation sanctions.[70] The second longest spread was between the ShenZhou 6 (October 2005), ShenZhou 7 (September 2008), and ShenZhou 8 (October 2011), separated by China's 2007 anti-satellite missile test and the United States' 2008 Burnt Frost anti-satellite demonstration.[71]

Conclusion

There are ample authoritative signs that the PRC is progressing towards its goal to conduct an orbit-only crewed mission to Mars before 2050. In addition to authoritative statements from CMSE, which had been lacking in the crewed Lunar landing timeline, China's other informed experts are again messaging a timeline that could result in a Chinese crewed Mars launch in the 2040s launch window. To determine the impact of Chinese taikonauts beating U.S. astronauts to Mars, this paper proposed analysts support policymakers by attempting measurable answers to three questions: 1. What would be the impact on the US-China competition for global influence?; 2. While there may be a perception of fading influence in the space sector, but is that the only impact?; and 3. If U.S. commercial space companies stay committed to their ambitions for Mars, would that justify them in collaborating with other countries, even potentially China? Answers to those questions are beyond the scope of this paper. The main aim of this paper is to show that based on lessons learned, the PRC has already officially announced it will celebrate the founding of the PRC with a crewed Mars mission.

Endnotes

[viii] CMSE has delayed launching the CSS telescope, but its delay is related to technology readiness and ongoing internal decisions about the role of the human spaceflight program in Earth observation and space science.

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