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Chinese Military Thinking On Orbits Beyond GEO

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> *"We already regard space, out to at least GEO, as part of our legitimate military theater of operations. Strategic vision compels us to continually expand our perspective. We will soon need to consider all of cislunar space, and we should begin to think about operations throughout the inner solar system."*[1]
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> *The Fairchild Papers, U.S.A.F., 2002*

> *"A base on the Moon can fulfil not only scientific and military tasks. Since science and physics are developing rapidly, new goals appear and we can only contemplate them today… a base can be used for constant monitoring of the Earth's surface."*[2]
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> *Russian Academician Boris Chertok, 2007*

It is impossible to unlink the People's Republic of China's (PRC's) military perspective on orbits beyond the geosynchronous Earth orbit (GEO) from the U.S. and former U.S.S.R.'s Cold War plans for military Moon bases. More recent statements like those above indicating that similar ambitions may persist, even after the Cold War, make it harder. Since the Chinese Communist Party founded the PRC at the opening of the Cold War, the People's Liberation Army's (PLA's) academic institutions writing on space were and continue to be directly responding to the U.S. and Russia's statements and activities. Additionally, as Japan emerged in the 1990s as a lunar actor, the PRC's even deeper historical grievances were an equally strong driver to be prepared for military, economic, and diplomatic competition beyond GEO. Indeed, a Chinese history book covering Beijing's early planning for the lunar program directly states that the successful launch of Japan's lunar orbiter led Chinese technical experts to propose what would become Chang'e 1, over a decade later.[3]

Below is an assessment of PRC military academic writings to include books designed for training military personnel written in Mandarin, and technical research papers published in English and Mandarin. This report analyzes what these documents say about orbits beyond GEO through the lens of what other nations have done. This is an integral perspective to remember. For example, the American authors of the above quote later became, and continue to be, top U.S. leaders, highly likely leading the average Chinese analyst to determine that the U.S. must be serious about expanding the theater of military operations to beyond GEO, and possibly the rest of the solar system, based on the authors' later promotions.

Key Findings

PRC military literature describes a PLA fear since at least 2003 that the United States intends to expand its military operations beyond GEO in order to control access to cislunar and other regions of space, a fear most likely originally based on U.S. and Russian leaders' statements at the time. PRC military academics' definitions of the useful space for military operations have expanded and contracted over time. However, in the most recent iteration of the Science of Military Strategy (SMS), Chinese authors have returned to a more expansive definition, referring not just to "higher orbits" but also "adjacent space and deep space" as the future region useful for military space operations. Together with the first ever SMS reference to the Apollo program having had a mission to "capture Soviet satellites," this is a very troubling trend, potentially indicating the window for tailoring messaging on the U.S. Space Force's intentions in the space beyond GEO for the non-Allied audience is closing.

Importantly, PRC defense-affiliated technical experts writing on beyond GEO orbits, as early as 2021, have not yet started referencing "dual use applications" or "weapons" in their studies, indicating that there may still be an opportunity to adjust U.S. messaging. If they do, these references could indicate that PLA leaders have asked for more concrete ways to respond from their technical experts. This report finds it is significant that defense space technologists are not yet referring to military applications beyond GEO; these references are relatively easy to find in articles describing orbits below 40,00km, i.e. below the graveyard orbit.

Chinese researchers studying orbits beyond GEO have consistently maintained three general goals in their studies, listed here in no particular order: support China's follow-on exploration missions; identify worthy global firsts to achieve; and improve precise orbit determination and spacecraft efficiency. The main difference between defense-affiliated and non-affiliated researchers' articles is that the former are more likely to discuss considerations for crewed missions, such as improved radiation safety, because the PLA continues to manage the human spaceflight program in China.

Chinese technical reports often use foreign mission designs as reference cases, their analysis of which provide useful insights into what space watchers should expect from future Chinese missions beyond GEO. These examples also represent what the PRC likely perceives to be globally acceptable. Of note are the examples where past non-Chinese studies have recommended flying out to beyond GEO to later return to Earth orbit, either to GEO or retrograde GEO. Also of note are former non-Chinese plans to fly through medium Earth orbit (MEO) from cislunar space to use Earth's gravity to redirect the spacecraft to asteroids or comets. All of these strategies have been recommended to increase fuel efficiency.

PRC Military Academic's Strategic Thinking On Orbits Beyond GEO

PLA academic strategists have repeatedly articulated a fear that the U.S. would limit Chinese access to the Moon. One of the first available references in PRC military books is from the PLA National Defense University (PLA NDU) in 2003, which briefly noted that "developed nations" plan for Moon bases.[4] Later in a 2007 article, authors from the Academy of Equipment Command and Technology, responsible for training China's senior engineers and technical

officers for the PLA's space organizations, articulated a fear that, "The U.S. also intends to close off … the space region between the Earth and the Moon."[5,6] A different publisher repeated this fear in a 2010 military training book saying, "According to this [U.S.] plan, near Earth orbits – including the broad space from the Earth to the Moon – will be under the administration of the Americans."[7] It may be significant that a fear first noted by Chinese military space technologists was later published in a book from a national level military publisher. Follow-on research on the specific authors and their careers since 2007 may be instructive.

After 2010, references to potential U.S. control of cislunar space largely disappeared from the available Chinese high level military academic literature. However, it may be reemerging as PLA NDU's most recent 2020 Science of Military Strategy (SMS) referred to a U.S. plan for the Apollo astronauts to "capture Soviet satellites," which is probably a PRC interpretation of the U.S. Manned Orbiting Lab concept, documents about which were declassified in late 2015.[8,9] In the other above mentioned books, authors had referred to the Apollo program as an example of societal interest in space exploration, and focused their contention instead on the Shuttle program, which is widely known to have flow defense and intelligence agency systems.[10] The PLA NDU's 2020 SMS reference is the first time the U.S. military astronauts' role in U.S. lunar exploration has been called out, based on this research.

In addition to general references to other nation's military space ambitions, Chinese military academic literature has also referred to the space beyond GEO when defining regions best suited for different military activities. For example, up until 2003, PLA NDU books parroted Soviet and early Russian military thought by defining "the space battlefield" to be below 930,000km, which is where the Earth's gravity is no longer dominant compared to other celestial bodies.[11,12] However, ten years later in 2013, a non-NDU affiliated military book more operations focused revised the section and noted that military use of space is primarily below 40,000km, i.e. inclusive of everything below the graveyard orbit.[i,13] This book removed the reference to 930,000km and instead made a general distinction between the region up to 384,000km, which is roughly the distance between the Earth and the Moon, and then beyond 384,000km.

Interestingly, also in 2013, the Academy of Military Science's SMS did not include any reference to 384,000km and instead focused on the 40,000km and below regime as well.[14] It may be important that in the same year, two different high level military publications defined the military relevant space beyond GEO in different ways; the academics using a one more expansive definition and the space operators using a more narrow definition. Useful follow-on research could include finding which book published first and the biographies of the various authors.

The more recent SMS books reveal military academic thinking on the definition of military-useful orbits is still under discussion in the PRC. The 2017 PLA NDU SMS removed any reference to beyond GEO distances and only noted military activity takes place in "higher

[i] Based on Chinese military academic writings, China has since at least 2002 worried that satellites were hiding in the graveyard orbit, which is a topic for a different paper.

orbits," which is probably still a reference to the graveyard orbit, not anything around 384,000km, based on the way other reports use the reference to "higher orbits."[15] However, the most recent 2020 SMS reintroduces a more expanded space domain for the PLA, to include not just higher orbits but "adjacent space and deep space" and "diversified orbits," but with no specific references to distances.[16] In this context, the Apollo reference may be telling of a focus back on 384,000km, though this report did not examine this specific question thoroughly. It is also difficult to know if the 2020 expanded definition is the result of internal PRC policy debates or more simply a different editorial chain at PLA NDU.

The reader is advised against interpreting these military academics' references to space beyond GEO as evidence that PRC leaders would approve a mission to hide anti-satellite weapons in the hard to track cislunar space. Instead, the historical lens is very instructive; the Soviets in 1959 launched a "cosmic rocket" beyond 930,000km, the upper stage of which orbits the Sun, and is probably a reason why the Soviets and early Russian military thought specifies this distance.[17] China's close relationship with the Soviets in the early days of the Cold War, in particular regarding the space program, is the most likely reason this distance appears in early PLA academic writings. More recent academic strategic thinking could also justifiably include beyond GEO distances not only because of the quote from the current Deputy Commander of the U.S. Space Command and former Director of NASA Aims Research Center in 2002, but also because even NASA in 2010 considered sending astronauts to a near-Earth asteroid in preparation for a Mars mission, which could have implied within 930,000km.[18]

The above publications are largely reflective of the PRC military's perceived threats and their academic strategic thinking on other countries' activities, in an effort to support broad PLA strategies towards achieving comprehensive national power, specific to military interests. These documents are less reflective of the PRC leadership's plans and intentions. One way to scratch the surface of higher level, concrete proposed plans is to review Chinese academic articles from institutions fully or partially funded by the PLA. The below review of articles focuses on those written by researchers at China's NDU or universities which have labs working on defense projects, as well as personnel working at China's national space tracking facilities which are thought to be primarily managed by the PLA, though the employed personnel may be civilian cadre or even civilian contractors.

PRC Defense Affiliated Technical Writing On Orbits Beyond GEO

A review of Chinese defense affiliated researchers' technical articles over the past 10 years reveals some notable trends, which are apparent in both defense affiliated and non-affiliated authors' articles. Researchers studying orbits beyond GEO have justified the significance of their findings as meeting one or several of the following goals: supporting China's follow-on exploration missions; identifying global firsts to achieve; and/or improving precise orbit determination and spacecraft efficiency. Notable in this review was no explicit reference to "dual-use technology" or "weapons," which is relatively easy to find in articles about space systems below 40,000km. This review did find several references to using a lunar swing-by to place a Chinese GSSAP-like "debris monitor" in retrograde GEO, a circular orbit of almost the same altitude but inclined 180 degrees. These articles cited numerous foreign studies

on the same type of retrograde GEO satellite insertion, and have used the single demonstration of trans-lunar insertion into GEO, conducted by the U.S. Hughes Corporation in 1998 for AsiaSat 3, as a reference case.[19,20]

Other notable findings are that the only difference between the Mandarin and English language articles was the level of detail; there were no differences in stated intent or research topics. For example, the above referenced article on GSSAP was the same in the Mandarin and English versions.[21] In the cases where there was more detail, it could be because the authors intended not to share with a western audience or because it was easier to translate a less complex story. Defense researchers are also more likely than other academics to research orbits especially suited for crewed missions, as the human spaceflight program in China continues to be managed by the military.

Reentry into Earth's orbit from beyond GEO has also been used by international space agencies multiple times, missions which are often used as reference cases for past, present and future Chinese missions. In particular, the defense-affiliated technical articles on the mission extensions of Chang'e 2 (2010), Chang'e 5T1 (2014), and Chang'e 5 (2020) illustrate how defense researchers evaluate what foreign experts have done, or have considered, and apply the lessons learned to China's pursuit for worthy global firsts. Included below are brief introductions to the non-Chinese missions for the purpose of contextualizing PRC activities. These non-Chinese missions also illustrate the types of maneuvers that the Chinese would likely judge to be internationally acceptable and without cause for a high level public announcement.

In preparation to launch Chang'e 2 in 2010, researchers heavily relied on prior foreign mission designs, one of which was the U.S. International Sun Earth Explorer 3 (ISEE-3). ISEE-3 was first launched in 1978 and with its multiple mission extensions achieved global firsts as the first spacecraft to visit a Lagrange Point (Earth-Sun Lagrange Point 2 (E-S L2)) and the first to fly past a comet.[22] It is one of the most frequently referenced foreign missions in the available Chinese technical articles. PLA NDU affiliated authors published an English language article in 2009 detailing their analysis of the ISEE-3, and specifically stated how it helped support future Chinese exploration missions.[23] Chang'e 2 was launched in 2010 and after successfully completing its primary mission in 2013, it headed off to E-S L2, making China the third country/organization behind the U.S. and the European Space Agency (ESA) to visit this Lagrange Point (LP). Chinese researchers readily point out that while only the third to visit E-S L2, they were the first to do so from lunar orbit.[24] The Beijing Aerospace Control Center (BACC), the second main telemetry, tracking and control center in China, further detailed the mission extension in 2013, also in English.[25]

In preparation for the 2014 launch of Chang'e 5T1, researchers leveraged their studies on Japan's 1990 Hiten and the joint NASA-University of California, Berkeley's 2010 Acceleration, Reconnections, Turbulence and Electrodynamics of the Moon's Interaction with the Sun missions (ARTEMIS P1 and P2). A discussion of the Hiten mission is reserved for later. ARTEMIS P1 and P2 was an extension of two of the original five spacecraft from the THEMIS mission, which was in a highly elliptical Earth orbit. ARTEMIS P1 was the first spacecraft to orbit Earth-Moon L2, and P2 was the first spacecraft to orbit Earth-Moon L1 (E-M L1 and L2),

visits after which they traveled to orbit the Moon in opposite directions.[26] China's Chang'e 5T1 after delivering the test return capsule to Earth's orbit, braked like the Hiten mission and headed back out to pass the Moon, leveraging a Lissajous orbit at E-M L2 like ARTEMIS P1. In 2015, Chang'e 5T1 entered lunar orbit where it continues to operate normally. When China launched its lunar relay satellite for the Chang'e 4 lunar far side mission in 2018, it used the E-M L2 again, but in a halo orbit rather than a Lissajous orbit.[27]

As early as 2015 Chinese defense affiliated researchers were publishing on Chang'e 5T1 and mostly in English. Some examples include a 2015 English Beijing Institute of Tracking and Telecommunications Technology, BACC, and Chinese Academy of Sciences paper on China's first test of a GNSS receiver for better orbit determination and automation beyond GEO.[28] In 2016, PLA NDU, and later the BACC in 2018, both published in English different and detailed reviews of other scenarios China considered for the Chang'e 5T1 mission.[29,30] One scheme included a detailed method for visiting 5 LPs in succession. In 2017, PLA NDU compared the efficiency between orbits used in Chang'e 2 and Chang'e 5T1 in English.[31]

To prepare for part of Chang'e 5's mission extension to E-S L1 in late 2020, researchers regularly consulted the ESA-led Solar and Heliospheric Observatory (SOHO) and NASA's Genesis. ESA launched SOHO in 1995 as part of a large multinational effort of multiple spacecraft to study the Sun and was one of three spacecraft sent to E-S L1, and one of two using a Lissajous orbit. While only speculation, the SOHO mission might have gotten more Chinese attention compared with the other spacecraft using a Lissajous orbit for a couple of reasons: first, ESA overcame several challenges with the spacecraft, resolutions of which are publicly available and two, China and ESA have a close working relationship on solar probes; however, the planned late 2024 launch of their joint solar probe will be into Earth sun-synchronous orbit, not E-S L1.[32] NASA's Genesis launched in 2001 and was the first spacecraft to bring back samples from beyond lunar orbit, capturing solar wind particles from E-S L1 and returning them to Earth, mostly successful despite a parachute failure. As the most recent U.S. space sample return mission, this had additional relevance for Chang'e 5.

According to a 2021 Mandarin article describing Chang'e 5's stint at E-S L1 from the Beijing Space Vehicle General Design Department and Shanghai Institute of Aerospace Systems Engineering, China selected the Lissajous orbit over the halo orbit because the former would be more fuel efficient.[33] Another Mandarin article in 2021 but from the Beijing Space Vehicle General Design Department and Beijing Institute of Technology described the usefulness of halo and distant retrograde orbits in the Earth-Moon system for future crewed Martian and asteroid missions.[34] The publication of more articles in English is expected.

Foreign Missions Discussed But Not Yet Tried

Chinese researchers refer to several other foreign missions as reference cases for missions they are likely considering. For example, the 1990 Japanese Hiten mission simulated a trajectory for a joint Japan-NASA spacecraft (Geotail), which used a highly elliptical Earth orbit that intersected with the Moon's orbit. In one lunar pass, Hiten released a lunar orbiter called Hagoromo. After completing its primary mission, Hiten performed the first demonstration of

aerobraking when reentering Earth orbit, after which it executed a novel entry into lunar orbit, and then looped pass E-M L4 and L5, to finally return to lunar orbit. In 1993, Hiten implemented a controlled deorbit into the lunar surface.[35] Such multi-LP missions have been referenced in Chinese articles, such as the one mentioned above regarding alternative scenarios for Chang'e 5T1.

Chinese defense affiliated technical experts have also referenced the 1994 U.S. joint Department of Defense (DOD) and NASA Clementine mission, also known as the Deep Space Program Science Experiment, though much less often based on this study.[36] Clementine was a technology proving mission for the DOD's Brilliant Pebbles program of the Strategic Defense Initiative.[37] It launched into an elliptical polar lunar orbit. After providing the first images of the lunar poles, the U.S. intended Clementine to depart lunar orbit, fly by the Earth to within 19,134km, which is within MEO, an orbit most often used today for navigation satellites, though it has been used for missile warning.[38,39,40] The distance of 19,134km is closer than the first Earth flyby executed by ESA's Giotto mission launched in 1985. Giotto first flew by Haley's comet and then used the first ever Earth flyby at 22,000km to redirect Giotto to another comet in 1991.[41]

Non-technical but defense affiliated research in 2021 reviewing NASA and ESA's DART and Hera kinetic asteroid redirect mission, which launched in late 2021, noted that many asteroid redirect missions have dual use technology applications, but also uniquely enable international collaboration.[42] This author recommended pursuing an asteroid redirect mission to join the international community, including the UN experts working group on planetary defense, to work collaboratively. A different non-technical researcher argued the opposite, saying that the U.S. will highly likely not let anyone cooperate with China on planetary defense because of the technology's dual use applications.[43]

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