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# PLA On-Orbit Satellite Logistics

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The People's Liberation Army (PLA) is preparing its satellite operators to perform on-orbit satellite refueling, for peacetime and wartime space logistics. They are also already integrating lessons learned into corresponding military doctrine and training tools. To further ready a PLA in-space logistics force, a Chinese defense contractor has indicated, for the last six years, that it has a mission ready satellite refueler for geosynchronous Earth orbit (GEO). With more clarity on the PLA's requirements for satellite logistics, the Chinese Communist Party (CCP) has approved new commercial players to enter the field to provide, not only technology, but also frameworks to shape international norms. These developments have largely gone unnoticed, perhaps because of an overemphasis on a low probability satellite grappling event.

## Readying the PLA in-space logistics force

In 2018, a Beijing based Strategic Support Force (SSF) unit under the Space Systems Department (SSD) published a comprehensive article on the PLA's requirements for a simulation tool to train military satellite operators in space-based refueling. [1] The unit requested a computer program to simulate the space environment and on-orbit service satellites to enable training and evaluation, mission scheduling, and technology testing. The software had to accurately simulate at least four different types of on-orbit servicing equipment, one type of which had already been tested in space, according to the authors. The authors could be referring to China's earlier LEO or GEO successes between 2013-2018, which tested refueling and debris removal. [2] Note that this request for a training simulator is before the launch of ShiJian-21 (SJ-21), which moved a defunct Beidou navigation satellite to the graveyard orbit in early January 2021.[3]

The simulation tool is in use, but probably still in development. The PLA's National University for Defense Technology (NUDT) in 2022 criticized existing development efforts for not examining how much fuel is required to carry out particular servicing missions, after the servicing satellite reached the customer.[4] There are many Chinese military and academic studies evaluating the most fuel-efficient way to service multiple customer satellites. However, the NUDT recommended adding specific fuel and time requirements for five anticipated mission sets: 1) on-orbit refueling and repair; 2) auxiliary position maintenance; 3) adjusting inclination; 4) deorbiting a defunct satellite; and 5) rescuing a failed satellite. A satellite service tailored for inclination adjustment, normally a highly fuel intensive maneuver, is significant.

Developing doctrine and normalizing the mission

Even prior to successful technology development, the PLA's organizations in charge of researching and writing doctrine have mentioned nascent planning for space-based logistics. These early signals have probably enabled the PLA theorists and technologists to engrain an acceptance of on-orbit satellite refueling and debris removal missions among PLA satellite operators.

At the same time that the PLA was testing debris removal and refueling in LEO, the PLA's doctrinal textbooks began including robotic space-based logistics. The PLA's Academy of Military Sciences (AMS) published the *Lectures on the Science of Space Operations* in 2013, which described the importance of having a military unit capable of supporting space equipment sustainment with on-orbit logistics. The book specifically mentions refueling and repair. It the section covering space support and logistics, the text stated,

> *"Two forms of maintenance will usually be used for space equipment that has been damaged: maintenance in orbit and maintenance on the ground. Regarding repairs in orbit, it will be necessary to establish technological support strengths that are extremely mobile and that can enter space at any time and carry out support for space equipment."*[5]

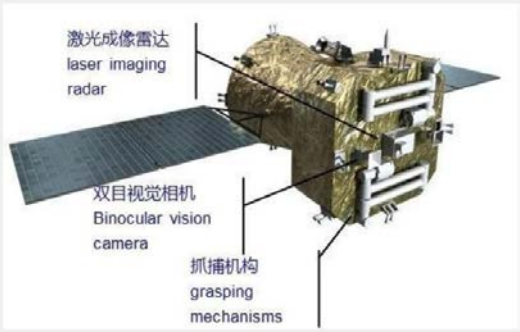
The textbook then described that on-orbit military logistics "primarily mean[s] replacing parts and refueling spacecraft in orbit."

Significantly, even the PLA's broader doctrine covering all military operations, not just space operations, mentions in-space servicing. The PLA National Defense University's 2020 *Science of Military Strategy* stated that "orbital services" are an important development trend, and that the PLA needs to play a role in the international legal debates on debris disposal.[6] References to international norms are becoming more frequent in PLA books on space. If the PLA can gain early clarity on the types of space-based logistics they want, Chinese diplomats can play a leading role in influencing international discussions.

In addition, PLA experts are writing books to deepen operational planning. In 2021, key PLA satellite servicing experts from the SSF SSD, together with the AMS Joint Operations Experimental Center wrote a dedicated textbook on scheduling satellite servicing and related mission planning.[7] To integrate lessons learned into the book, the authors jointly conducted several technical studies in advance, covering satellite refueling and rendezvousing with uncooperative satellites.[8] The two SSF SSD on-orbit servicing experts are from two different units, Unit 32032 in Beijing and Unit 32027 in Henan province. Liu Bingyan of Unit 32032 "plans and researches on-orbit servicing" at AMS's War Research Institute. Gao Yong of Unit 32027 has a PhD from Tsinghua University, and, at the time of publishing the book, was "the director and researcher of a department of the Strategic Support Force." Gao had successfully led troops in on-orbit servicing missions, according to the description.[9]

Existing PRC on-orbit refueling capabilities

A Chinese defense contractor has since at least 2018 advertised "orbital mission extension vehicles" for use in GEO. The advertisements state that the vehicle is capable of refueling satellites and extending their mission approximately five years.[10] The Eighth Institute of the China Aerospace Science and Technology Corporation (CASC), known as the Shanghai Academy of Spaceflight Technology (SAST), at the 2018 Zhuhai Air Show displayed its "on-orbit gas station," with the below images also on its website:





According to SAST's website, the extension vehicle has a launch mass of 600kg, is equipped with two robotic arms, and can extend the life of a GEO satellite with a mass of 2500kg for at least five years.[11] The extension vehicle is launched connected to the rocket's final stage. More research is needed to determine if Chinese GEO missions, which begin with a rendezvous with an "apogee kick motor" or AKM, are examples of mission checkout for the extension vehicle. [12] It is possible that the above images may be a copy of Northrup Grumman's Mission Extension Vehicle concept. However, there is just as much evidence, if not more, that SAST's capabilities are real.

More information on the servicing satellite's capabilities surfaced after the 2021 Zhuhai Airshow.[13,14] According to participants at the show, SAST's service vehicle holds 1.3tons of fuel and can, in an emergency, replenish a minimum of 50kg to extend a satellite's life for one year. It also requires a two-meter rendezvous with the customer satellite for the robotic arms to connect. Additionally, to receive fuel, the customer satellite must have been equipped with SAST's refueling docking port, an early version of which was first demonstrated with the Tianzhou resupply vehicle to the Tiangong Space Station in 2017.

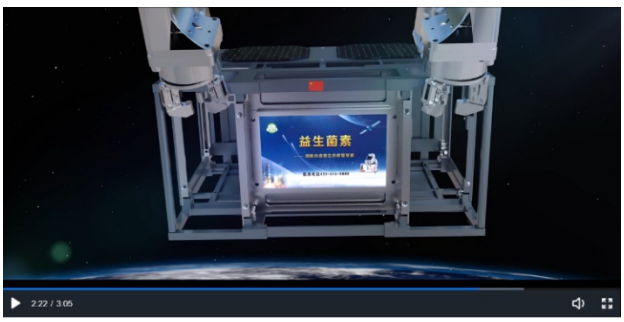
As of 2022, SAST has indicated that it may have developed a similar LEO system compatible with the final stage of the Long March 4C rocket, used for sun-synchronous orbit launches. In March 2022, SAST publicized that it had installed "independent energy, communication and control modules" on the Long March 4C final stage so that the rocket body could take on a different function in orbit.[15,16] According to SAST, the rocket body would become a "complete payload platform, and [it would be] used to carry out environmental adaptability verification and related detection." At the 2022 Zhuhai Air show, SAST included the new final stage capability as part of its proposal for a "space environmental governance system," that would integrate SAST's various debris mitigation technologies as a package solution to the growing on-orbit debris problem.[17] This is just one sign that the Chinese are potentially preparing their own consortia of industry and academics to influence international norms.[18]

A role for Chinese new space companies?

The PLA has led on-orbit servicing capabilities in China, primarily because of its role building the Chinese Space Station. To build a space-based satellite refueling sector, AMS together with NUDT in 2022 published a separate book detailing the key technologies for refueling in space, and related lessons learned.[19,20] Some of the authors have been active in popularizing on-orbit logistics at Chinese universities.[21] Additionally, since at least 2016, China's civilian Ministry of Science and Technology has included on-orbit servicing it is technology development plans. Like other Chinese government five-year plans, they signal research support, and encourage Chinese universities and companies to apply for related funds.

Potentially one of the first Chinese commercial attempts to demonstrate the ability to launch, track, and command an on-orbit satellite service, failed at liftoff. In 2020, a Chinese company in the satellite development and applications field called Intersteller Walk (星际漫步) signed a launch deal with Chinese commercial launch company iSpace and Chinese commercial satellite telemetry, tracking, and control (TT&C) company Satellite Heard, or Emposat (航天驭星).[22] Intersteller Walk planned to launch a satellite with two robotic arms to demonstrate its patented satellite-to-satellite docking port. A demonstrated docking port, separate from SAST's, would probably accelerate the diversification of players. However, the iSpace launch was delayed to February 2021, and ultimately failed.[23]

Probably in an attempt to recoup some of the costs, Intersteller Walk's website displays a video of what may be the originally intended test, to at least display the advertisements for investors.[24] The below images show advertisements for a Chinese liquor company and a Chinese probiotics company. Given that on-orbit servicing has been in a Chinese civilian ministry development plan since 2016, it is likely Intersteller Walk is not the only company to have attempted a demonstration.


China's new space companies are increasingly gaining access to the spacecraft servicing sector. At the time of writing, one Chinese province and two Chinese cities had published 14th Five Year Plans (2021-2025) including technology development support for on-orbit servicing.[25,26,27,28] They include Heilongjiang province in China's northeast, which is the home to the Harbin Institute of Technology, which tested China's 2013 robotic arm and tether debris removal technologies in LEO.[29] The cities include Chengdu in Sichuan province, and Xian in Sha'an Xi province. Sichuan province is home to China's Xichang Satellite Launch Center, and

Xian is the hub for China's TT&C. China's announcement that commercial companies can resupply the Chinese Space Station did not explicitly include refueling, but that might be on the horizon.[30,31]

Readying the U.S. force

The U.S. Office of the Director for National Intelligence's Annual Threat Assessment in 2023 stated that China had, "conducted orbital technology demonstrations, *which while not counterspace weapons tests*, prove China's ability to operate future space-based counterspace weapons."[32] The U.S. Space Force's National Space Intelligence Center in January this year reiterated that, "China is developing satellite inspection and repair systems that *could* function as weapons and it has launched multiple satellites *to test orbital maintenance and debris mitigation*."[33] In other words, the U.S. intelligence community (IC) is saying with high confidence that the PLA has on-orbit servicing capabilities—full stop.

With the PLA already adopting and iterating on lessons learned in space-based logistics, the U.S. Space Systems Command (SSC) should not wait to have its own on-orbit servicing equipment before it starts training future operators. In October 2022, the new SSC leader of the Assured Access to Space Directorate shared that on-orbit logistics has long been an interest, but not a military mission. At the time of the interview, he stated that there were no U.S. military operational units to do on-orbit logistics.[34]

Indeed, the Defense Advanced Research Projects Agency's trailblazing LEO refueling experiment largely relied on NASA mission control to execute commands. More recent U.S. commercial refueling services in GEO have been operated by commercial mission control centers. While elements of the U.S. Department of Defense (DoD) were the first to conceptualize autonomous military on-orbit logistics in the early 2000s, the space component of logistics lost ground to responsive launch initiatives in "Operationally Responsive Space" and "Assured Access to Space" plans.[35,36,37] Unfortunately for the U.S., the PLA has more consistently pursued the on-orbit segment.

The higher probability event of a trained PLA unit ready to sustain on-orbit space operations in wartime is getting overlooked. In order to dislodge the anchored, lower probability event of a surprise satellite grappling, the rest of this article will examine key assumptions. Readers are encouraged to provide corrections and counterarguments to the below rebuttals. The intention is to strengthen U.S. readiness.

1. Assumption: The PLA's GEO satellites with robotic arms are a threat to "juicy targets" like U.S. satellites that are not equipped with enough fuel to maneuver.
   Rebuttal: Many of the satellites can move enough to diminish the risk, while potentially staying on mission. Since at least 2010, the U.S. has equipped the military's GEO communications satellites (SATCOM) like the Advanced Extremely High Frequency (AEHF) satellites with Hall thrusters that use some on-board gas, but mostly rely on solar power for collision avoidance.[38] At least since the start of this decade, U.S. missile early warning satellites in GEO such as the Space Based Infrared System (SBIRS) satellites have also included Hall thrusters for position

adjustment.[39,40] Hall thrusters enable slight maneuvers with much lower mass and fuel requirements. Given that rendezvous and proximity operations (RPOs) require precise calculations, even the minor and slow adjustments of a Hall thruster would complicate any adversaries' approach.

2. Assumption: Even if the U.S. could use a fuel-efficient maneuver to avoid a RPO with a Chinese grappling satellite, the Chinese might be able to sneak up on the U.S. satellite.
   Rebuttal: The Chinese satellites with robotic arms are currently easily trackable with ground-based telescopes because they are very large. The SJ-17 satellite is approximately 4,000kg—larger than Milstar and just smaller than AEHF.[41] The launch vehicle that carried SJ-21 to geostationary transfer orbit (GTO) has a launch capacity of approximately 5,000kg, indicating that SJ-21 may be as large, if not larger than SJ-17.[42] When the Chinese have successfully miniaturize satellites with robotic arms, they may have more counterspace applications, as argued in a recent report. [43]

3. Assumption: The PLA may not have malicious intent, but under the stress of war, they will use their on-orbit grappling satellites as counterspace weapons. The intention is demonstrated in their lack of transparency.
   Rebuttal: Perceptions of transparency are well established as cultural and subjective. The best way to strengthen understanding, even without reaching agreement, is through regular discussion. At the time of each Chinese launch of known LEO and GEO satellites with robotic arms, Chinese official media stated that the satellite would test debris observation and mitigation technology.[44,45] Another way the Chinese communicate about their plans is by publishing their national space plan in English. The last and most recent versions have included debris mitigation.[46] The 2021 version significantly expanded the section listing on-orbit servicing plans, to include goals for international cooperation and influencing international norms.[47] To foot stomp, a Chinese official document in English describing their plans for international cooperation and negotiation on in-space servicing is a strong signal they are interested in discussing their plans.

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