China's Order of Battle:
Dual-Use Rendezvous Spacecraft in 2027 and 2029

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Overview

Dual-use rendezvous spacecraft (hereinafter, "R spacecraft") have many unique characteristics. Accurately predicting the order of battle (OOB) for R spacecraft by 2027 and 2029 is difficult because it depends on a number of underlying judgements, and any specific estimate can be characterized as tipping the scale in favor of a preconceived agenda. While there is substantial uncertainty regarding the exact number of R spacecraft China will produce, we assess with high confidence that China will be capable of producing a quantity more than sufficient to achieve the strategic effects outlined in the briefing.

To ensure a methodologically sound—and useful—estimate, this note examines several crucial factors underpinning the R spacecraft OOB. It also considers both 1.) how many R spacecraft China is likely to be theoretically *capable* of producing and launching into orbit by 2027 and 2029 and 2.) how many R spacecraft China is likely to *actually* produce and launch. Both estimates are important: the latter serves as a useful high-confidence OOB to maximize accuracy and utility of the wargame, while the former is an important referent for ensuring that the defenses selected would hold even under conditions of a higher-than-expected quantity of R spacecraft (this is critical given the high degree of uncertainty regarding exact number).

Assumptions

1. *China is highly likely to pursue R spacecraft for ASAT use in the status quo.*

As laid out in prior communications, both written and oral, there is clear evidence that China is actively pursuing co-orbital ASAT development and testing. As also laid out in the briefing, the most potent use of R spacecraft by China as antisatellite weapons (ASATs) is at the opening of a conflict because prepositioning R spacecraft in close proximity to critical satellites could potentially deter U.S. and/or its allies (especially Japan) from intervening without firing a shot, or could enable sudden simultaneous strikes on the entirety of one or more strategically vital constellation(s).

2. *The OOB is likely to heavily depend on whether effective countermeasures are adopted and clearly communicated by the U.S. and its allies in advance.*

The quantity of R spacecraft produced and launched by China is likely to be highly elastic. If the U.S. possesses an effective response and China is aware of this, then R spacecraft are likely to be relatively unattractive for use in an ASAT role. Under such circumstances, China would likely produce few R spacecraft despite ample production capacity. This is because China's counterspace development appears strategically motivated, other ASAT weapons are preferable for most other missions, and a much smaller number of more capable R spacecraft are necessary and sufficient to fulfill civil and commercial RPO missions. In contrast, if the U.S. and/or its allies lacks an effective response, or such countermeasures are not adopted and clearly communicated in advance, then there is a moderate to high probability that China's OOB for R spacecraft will be large. This is a function of both capability and will. First, as outlined below, the R spacecraft on which China is focusing are cheap and China has the capacity to produce many in short order. Second, China is well aware of the unique strategic opportunities such prepositioning would afford and has demonstrated interest in such operations.

3. *China is likely to have the ability to dock with another satellite by ~2025, or at least prior to 2027.*

The latest edition of Secure World Foundation's *Global Counterspace Capabilities: An Open-Source Assessment* (eds. Brian Weeden and Victoria Samson, Apr. 2021) states that in the summer of 2010 the Chinese SJ-12 "initiated a series of deliberate changes in its orbital trajectory to approach and rendezvous with the SJ-06F satellite" (p. 1-2). Then, "the two satellites may have bumped into each other, although at a very slow relative speed of a few meters per second. There were no external indications of damage to either satellite, nor any debris created by the incident. The incident appears to have been similar to the bumping that occurred during the autonomous rendezvous attempt between NASA's Demonstration for Autonomous Rendezvous Technology (DART) satellite and the U.S. Navy's Multiple Path Beyond Line of Site Communication (MUBLCOM) satellite in April 2005." (p. 1-2) The report further stated that although both the DART and MUBLCOM "were apparently unharmed, the public version of NASA's mishap report lacks details as to why the collision happened." (p. 3-4)

The "very slow relative speed of a few meters per second" (while the normal speed of a satellite is more than seven thousand meters per second), without "any debris created" and similar to the U.S. "bumping that occurred during the autonomous rendezvous attempt" were telling: this Chinese bumping signified that its two satellites did get very close to each and "may have bumped into each other" during the testing of rendezvous and proximity operations (RPO). No one can say with certainty exactly how many years China's RPO capability lags that of the U.S. However, given the high stakes, clear interest, and steadily growing history of Chinese success in space endeavors (see e.g., Dr. Goswami's briefing), it would be imprudent to dismiss the risk. Based on incidents such as that outlined above, we adopt the working assumption that China will be able to conduct a given set of RPOs approximately 5 years after the U.S. attains such capability.

In Feb. 2020, Northrop Grumman's commercial R spacecraft, Mission Extension Vehicle-1 (MEV-1) for the first time in history autonomously docked with Intelsat-901. A 5-year lag would see China achieve a similar autonomous docking capability by approximately 2025. It is important to note that MEV docked with a satellite that was not pre-designed with docking in mind. "MEV-1 autonomously reached out with its docking probe, that entered the nozzle of the liquid apogee engine on Intelsat 901. The docking probe was inserted into the engine nozzle and through the "throat" — narrowest part of the engine nozzle. Once the top of the probe was beyond the throat, it deployed a series of "fingers" to expand its size — like a wall anchor once inserted into a wall." This means that if China attains the same capability, it could "dock" with a U.S. satellite and take it to a useless orbit. Once U.S. complied with China's demand (e.g., no intervention), China could bring the captured satellite back to its original orbit unharmed. Alternatively, once "docked," the Chinese R spacecraft could use its robotic arm to bend antennas, dent solar panels, etc. to disable our satellites without creating much space debris.

4. *Satellites suitable for co-orbital ASAT use can be substantially smaller and cheaper than the MEVs.*

Whereas MEV-1 has a mass of 2,326 kg and MEV-2, 2,875 kg for commercial applications, China appears to optimize its R spacecraft for ASAT use. Both Shiyan and Aolong-1, used as Chinese experimental spacecraft, as well as similar Russian spacecraft (e.g. Kosmos 2499 and Luch), are small satellites, not exceeding 200 kg each. As for the SJ-12 and SJ-06F discussed above, there is no data on their masses. However, they belong to the Shi Jian class and six of them have open data, showing their masses ranging from 221 kg to 480 kg. Therefore, it is likely that both SJ-12 and SJ-06F would be in this mass range.

For context, it is reasonable to assume that the cost of a small satellite (i.e. less than 200 kg) is on the order of $10 million or less, depending on the payload. This is far less expensive than their potential targets—traditional U.S. satellites such as such as early warning satellite ($1.7 billion), satellite for communication under nuclear-disrupted environment ($1.7 billion), or GPS satellite ($577 million) cost approximately 50-150x more.

5. *China is highly likely to have the technological prowess to produce and launch R spacecraft in numbers sufficient to threaten critical assets in GEO and GPS.*

The most important question is whether China is *capable of producing and launching a sufficient number* of ASAT-capable R spacecraft by 2027 and 2029 to achieve the strategic effects outlined above. We assess that they are.

There are indications that China is showing significant progress in producing a large number of small satellites, including R spacecraft. In January 2021, Global Times reported that China's first intelligent mass production line is set to produce 240 small satellites per year. It took only 429 days to complete the line. This line has increased production efficiency by over 40 percent, and has begun trial operations. If one Chinese company has already completed this level of mass production line in 2021, it is very conservative to assume that, by 2029, China can produce half of 240 or 120 R spacecraft.

This is unsurprising, and part of a broader trend. In 2014, Beijing opened its space industry to private companies, emphasizing small satellites. In September 2019, the Science & Technology Policy Institute at IDA released a major report on *Evaluation of China's Commercial Space Sector* (Irina Liu, et al). Their analysis included a high-level overview of the 78 commercial space companies, 28 of which are in the sector of satellite and component manufacturing and 5 more in satellite navigation. According to the Space Foundation, the Chinese military and government have an $8 billion annual budget. We should expect that if China assesses R spacecraft to be important for their asymmetric counterspace and military strategy, they will dedicate the resources necessary to ensure that the private companies can produce the number of R spacecraft they need. Once China has demonstrated its rendezvous and proximity capability, including docking and robotic arm operations, these companies are likely to enable mass-production of payloads and satellites. As demonstrated by the China's use of small satellites for R spacecraft and for promoting commercial manufacturing and applications in small satellites, it appears that China is undertaking the preliminary work necessary to enable mass-production of payloads and satellites for R spacecraft prior to 2025, the approximate year given above for demonstration of more advanced RPO capability.

As prior communications on April 14 China Space Wargame Preparatory Meeting discussed, even 100 Chinese rendezvous attackers would be twice the number necessary to carry out all of the most high-impact co-orbital operations simultaneously. Namely: close approaches to our half-dozen early warning satellites, another half-dozen satellites for communications in case of nuclear-disruption, and our three dozen GPS satellites. Each of these constellations are critical and will remain highly vulnerable in 2027 and 2029.

Order of Battle

Table 1: # of Chinese Rendezvous Spacecraft for Peaceful Use

Year of Conflict	# of Rendezvous Spacecraft
2027	8
2029	15

Basis for Projection:

1. As outlined above, we assume that China's RPO capability lags that of the U.S. by approximately 5 years, which would imply an operational Chinese R spacecraft analogous to the MEV-1 by about 2025.
2. Northern Sky Research (NSR) recently forecast that demand for GEO life extension missions will grow to 75 satellites by 2030, representing a $3.2 billion market. We assume that life extension missions will include refueling, repairing, upgrading and relocating services. We assume that the number of space debris removal missions is also 75 by 2030. This produces an estimate of 150 missions annually by 2030 for rendezvous spacecraft worldwide to perform for satellite servicing and debris removal. We also assume that by 2030 the current practice of attaching a rendezvous spacecraft to a satellite for 5 years in order to provide fuel will be replaced by simply refueling. Additionally, we assume that it takes 6 months for a mission, meaning these 150 annual missions will require a minimum of 75 rendezvous spacecraft worldwide to provide. Finally, we assume that the global market for satellite servicing and debris removal splits 4 ways: U.S., European Union (EU), China, and the rest of the world each get 25% of the 150-mission demand and provide 25% of the 75 rendezvous spacecraft required. This would mean that China would have or require on the order of 19 rendezvous spacecraft by 2030.
3. We assume that China will add linearly from 1 capable R spacecraft they have in 2025 to the 19 spacecraft they possess in 2030. This produces the following estimates: 8 spacecraft by 2017, 15 spacecraft by 2029.

Table 2: # of Chinese Rendezvous Spacecraft Intended for ASAT Purposes

Year of Conflict	Low # of Rendezvous Spacecraft	High # of Rendezvous Spacecraft
2027	0	10
2029	0	100

Basis for Projection:

1. The lower-bound estimate assumes that the U.S. and its allies adopt clearly effective countermeasures in the near future, thereby rendering prepositioning of R spacecraft ineffective and undesirable. As mentioned above, under such a scenario it is moderately likely that China would lose any desire to employ R spacecraft for counterspace operations in the timeframe discussed.
2. The upper-end estimate, in contrast, assumes that U.S. responses to the rendezvous threat follow the current trend of pursuing some necessary measures in all three arenas (i.e., international, multilateral and unilateral responses) but far from sufficient and timely. All assumptions laid out above are adopted, and a conservative estimate derived for an upper-bound of production capacity assuming motivation. We assume initial operational capability (IOC) in 2025, and that from 2025-2027 China is developing the production

line such that it can only produce 18 R spacecraft over this period (i.e., 8 for peaceful use plus 10 for ASAT purposes). However, even 10 such satellites (or even only the 8 "peaceful" spacecraft assumed in Table 1), China would be able to threaten our early-warning satellites. By 2029, we conservatively assume that China would be able to produce 115. This would be more than twice the number necessary to simultaneously preposition near all of our half-dozen early warning satellites, half-dozen nuclear communications satellites, and three dozen GPS satellites.