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Innovations in Space:

Chinese satellite mega-constellations

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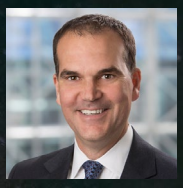

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A Series on Innovation and Space

This next installment of the Innovations in Space series provides an overview of the current development of Chinese mega-constellations. We specifically examine the status quo, anticipated future developments, and necessary steps for co-existence with other constellations.

Our team has written previously about the U.S., UK, and EU-based mega-constellations, most of which are targeted to launch in low-earth orbits (LEO). These constellations are subject to regulation both by the International Telecommunication Union (ITU) and domestically by the country and regulatory agency that licenses each operator.

But regardless of the licensing jurisdiction, mega-constellations in LEO orbit have extensive global implications. Spectrum demands and potential interference between mega-constellations present major challenges, with orbital debris caused by these structures also a shared concern among operators of satellites, space stations, and other activities in space. The need to build and operate constellations in a manner to mitigate orbital debris and pollutants is a shared, global concern. Other issues of space and earth sustainability, including light pollution and aluminum re-entering earth's atmosphere, are by definition global issues.

Three of the largest world powers – the United States, China, and Russia— are part of the mega-constellation race. As the United States continues to distance itself from Russia (through use of economic sanctions and other legislation) it may be pushing the Chinese and Russian space capabilities to further collaborate, marrying Russian operational knowledge with Chinese technology and funding.

The coming Chinese mega-constellations

Mega-constellations —satellite systems comprised of more than 150 non-geostationary orbit satellites — promise to deliver broadband internet interconnectivity on a global scale. Leading systems in the United States and Europe, including SpaceX's 4,408 satellite Starlink System and Amazon's 3,232 satellite Kuiper System, have received much attention in Western media but China is not standing still and has recently taken meaningful steps to launch mega-constellations of its own.

Four publicly-known Chinese mega-constellation projects are currently underway: (1) Galaxy Constellation(银河星座), (2) Hongyan(鸿雁), (3) Hongyun(虹云), and (4) Guowang(国网). All of these projects are backed, at least in part, by state agencies or state-owned enterprises. China's National Development and Reform Commission (NDRC国家发展改革委员会) recently added "satellite internet" to a list of "new infrastructures" in April 2020, suggesting additional funding opportunities for mega-constellation developers.[1]

China also appears intent on pursuing joint ventures for satellite-based broadband internet services. As reported by the *Süddeutsche Zeitung* and *Liechtensteiner Vaterland*, for example, state-backed Chinese investment has flooded into the "micro company" (*Kleinstgesellschaft*) Trion Space AG. Lichtenstein-based Trion has only a handful of employees, but ambitious plans – and the halo of a number of favorable Lichtenstein international satellite filings – to construct, launch, and operate 288 satellites for delivering satellite internet services. Although ultimate control of Trion is the source of much speculation, *Süddeutsche Zeitung* asserts that most of Trion's funding can be traced back to the People's Liberation Army and the state-controlled Shanghai Alliance Investment (SAIL), which holds a 42 percent stake in Shanghai Spacecom Satellite Technology (SSSI).

New Chinese investment

The significant growth of China's commercial aerospace sector is at least partially responsible for the development of Chinese space technology in recent years. In 2020, private investment in China's commercial space industry reached US$933 million, more than tripling since 2019.[2] Although Chinese mega-constellation projects remain in their early stages, developers have made notable headway in recent years. The developers of Hongyan, Hongyun, and Galaxy Space have successfully launched technology demonstrations.[3] Furthermore, recent reports suggest that the Hongyan and Hongyun constellations may be consolidated to form the single Guowang constellation. Chinese ITU filings in September 2020 may confirm this rumor. Chinese administrative filings with the ITU also reveal plans to construct two similarly named "GW" low Earth orbit constellations totaling 12,992 satellites, which range from 500-1,145 kilometers in altitude with inclinations between 30-85 degrees.[4] December 2020 filings for "GW-2" and "GW-A59" list a wide range of frequency bands.

What has prompted the sudden surge in Chinese mega-constellation activity?

Innovative new services

Economic opportunity surely plays a part. According to ABI Research, satellite broadband services might reach up to 5.2 million users in 2026 and generate US$4.1 billion service revenue. Moreover, while several companies including Globalstar, Iridium, Odyssey, and Teledesic scaled back or scraped their plans to provide broadband service in the 1990s due to high cost and low demand, the technology needed to support

1. Andrew Jones, *China is developing plans for a 13,000 satellite communications megaconstellation*, SpaceNews (21 Apr. 2021), https://bit.ly/3iczDpx.
2. *See* Andrew Jones, *China's commercial sector finds funding and direction*, SpaceNews (25 Apr. 2021), https://bit.ly/3ic3sXi.
3. *See* Gideo Gautel, *Coordination Failure: Risks of US-China competition in space*, Medium (29 Apr. 2021), https://bit.ly/3ocDqHl.
4. Andrew Jones, *China is developing plans for a 13,000 satellite communications megaconstellation*, SpaceNews (21 Apr. 2021), https://bit.ly/3AOv5gb.

high-capacity communications has improved considerably. As just one example, LEO systems can deploy subscriber earth stations that use phased array antennas with excellent gain and sidelobe performance.[5] These antennas support advanced antenna techniques, like beamforming and beamsteering, to narrowly control energy at desired locations. Thanks to SpaceX, Lockheed Martin, and other launch service innovators, the cost of accessing space has also fallen dramatically. More reliable access, lower costs, better technology, and growing addressable markets no doubt make the space-borne distribution of internet services more feasible – and financially rewarding – than ever.

Finite global resources

The fear of missing out likely enters the calculus, too. Spectrum and orbital resources are in preciously short supply. Only so many radio frequencies for satellite use are available to support the user uplinks and downlinks needed to offer broadband internet service from orbit. And while the geography of space is vast, the useful orbits around Earth are not unlimited. For broadband services, perhaps the most prized orbital altitudes are those in the 400 to 600 kilometer range where the distances from users on Earth are short enough to keep latency, or lag, low enough to support real-time broadband communications comparable to that received from terrestrial services.

Proponents of the new Chinese mega-constellations have pressed to gain their fair share of access to international spectrum and orbital resources as soon as possible. If China hopes to keep pace with its Western rivals, these efforts cannot start soon enough because the allocation of both critical assets is driven by a decades-old process of international collaboration that has begun to show its age as more and more entrepreneurs and state actors set their eyes on the start. The ITU, a United Nations agency, promotes shared, cross-border use of telecommunications technologies.[6] More than 5,000 delegates from up to 193 ITU-R Member States support ITU progress by preparing technical studies, settling interference concerns, and negotiating spectrum rights.[7] Operators deploying global radiofrequency-based services, therefore, must comply with ITU-R requirements derived from the multilateral negotiations. These include the ITU-R Radio Regulations, resolutions, and recommendations.[8] Radio Regulations and resolutions dictate radiofrequency usage, including available frequency bands for each service, operational restrictions, and frequency-sharing criteria.[9] Changes to the Radio Regulations and resolutions occur slowly – typically every four years and only after the ITU-R working groups have studied the consequences of potential modifications and all ITU-R member states agree to revisions at an ITU-R World Radiocommunication Conference.[10]

Dual-use technologies

One additional factor undoubtedly plays a role in the surge of Chinese companies planning global mega-constellation deployments: national security. Mega-constellations are marvels of engineering that demand the seamless integration of some of most advanced aerospace and chipset engineering on the planet. The technology to launch and operate such a large number of broadband satellites supports its logical complement: the technology to de-orbit and eavesdrop on those same satellite assets. While China has announced the ultimate aim of closing the digital divide both domestically and abroad, the constellations' early customers are likely to be national entities such as airlines, maritime users, and militaries.[11]

Like most other space-faring nations, China has signed the 1967 Outer Space Treaty, which

5. LEO is any orbital height below roughly 2000 kilometers.
6. *See* About International Telecommunication Union (ITU), ITU, https://bit.ly/33RZJri (last visited 28 Sept. 2021).
7. *See ITU Radiocommunication Sector*, ITU, https://bit.ly/373tyag (last visited 28 Sept. 2021).
8. *See, e.g., Radio Regulations, ITU*, https://bit.ly/2H342GX *(last visited 28 Sept. 2021).*
9. *See, e.g., Radio Regulations, ITU* (last visited 28 Sept. 2021), https://bit.ly/3iVJxt4; *ITU-R Preparatory Studies for WRC-23*, ITU, https://bit.ly/3nHntGn (last visited 28 Sept. 2021).
10. *See World Radiocommunication Conferences (WRC)*, ITU, https://bit.ly/2FmHosK (last visited 28 Sept. 2021).
11. *See* Gideo Gautel, *Coordination Failure: Risks of U.S.-China competition in space*, Medium (29 Apr. 2021), https://bit.ly/3zPlTH8.

limits the use of outer space for "peaceful purposes" and commits countries not to launch nuclear weapons or other weapons of mass destruction in orbit around the Earth, on the moon, or toward any other celestial body.[12] But even if advanced aerospace technology is never used for waging war, investing in space means investing in the core technologies necessary to keep pace with global and national security rivals on airplanes, missiles, missile defense, and advanced electronics. China's potential pursuit of dual-use technologies is hardly unique, with the U.S. and Europe both benefitting from the practice for years.[13] Like China, both the U.S. and Europe have offered financial support to cultivate their respective space industries. SpaceX, for example, has received numerous lucrative launch contracts from the U.S. government and recently secured nearly US$1 billion in subsidies to deploy broadband internet service in ostensibly unserved and underserved areas. In this sense, the latest Chinese mega-constellations are as much about keeping China pace with Western development as about surging ahead.[14]

The Long March

Whatever the impetus behind enlisting multiple enterprises to design and deploy a satellite mega-constellation, China seems to have a made a long-term strategic bet that the nation's future on Earth depends on a future in space. The state-owned Assets Supervision and Administration Commission (SASAC国务院国有资产监督管理委员会), a government body overseeing state-owned enterprises, issued a press release[15] on 29 April 2021 announcing the creation of the China Satellite Network Group Co. Ltd. (中国卫星网络集团有限公司).[16] The China Satellite Network Group will exist independent from and parallel to China's main space contractors, the China Aerospace Science and Technology Corp. (CASC中国航天科技集团有限公司), and the China Aerospace Science and Industry Corporation (CASIC中国航天科工集团有限公司). The apparent independence of China Satellite Network Group from CASC and CASIC indicates that other actors, such as state-owned enterprises and commercial sector space companies, could be involved in the construction of the constellation.

Looking to the future

As Chinese, European, and American mega-constellations continue to mature and increasingly pursue access to the same kinds of extremely limited resources, the well-established organizations and international rules that have helped ensure a safe and equitable distribution of spectrum and orbital resources will face new challenges. Western leaders have come to view China as a strategic competitor intent on upending the post–World War II international order established by the U.S. and its allies. Aggressive Chinese moves into the leading edge of satellite development suggest private satellite ventures will increasingly have to contend with an array of new competitive, and geopolitical, threats from around the globe.

12. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty), 18 U.S.T. 2410, 610 U.N.T.S. 205, 61 I.L.M. 386 (1967).

13. *See generally The Dual-Use Technology Conundrum: The Role of Dual-Use Goods in the Modernisation of the EU Armed Forces and Export Control Initiatives*, Finabel (31 Aug. 2021), https://bit.ly/2XZSs8I; *Governance of Dual-Use Technologies: Theory and Practice, American Academy of Arts & Sciences* (Elisa Harris, ed., 2016), https://bit.ly/3CUfexn.

14. *See e.g.*, Matt Henry & Matthew Carney, *China and the US are locked in a superpower tech war to 'win the 21st century'*, ABC News (7 Jul. 2021), https://ab.co/3oheluK; Jonathan Liebenau, *How the West can respond to China's technology surge*, London School of Economics (26 Feb. 2021), https://bit.ly/3m5E3jh.

15. *See* Notice of Establishing the China Satellite Network Group Co. Ltd. of SASAC (28 Apr. 2021), https://bit.ly/3o7rypY.

16. The company is wholly owned by SASAC with a registered capital of RMB¥1,000,000. Its business scope includes demonstration and design, research and testing, engineering design, engineering construction, engineering services, operation control, operation management of satellite networks, standard formulation of software, hardware and system derivative products, testing and appraisal, product certification, network and information security, system protection, and related technical services of satellite network system etc. According to public media, the company is set up for the purpose of promoting the development of satellite networks. Currently, its technology, preferred deployment, and whether it has established any subsidiary in the EU or U.S. are unavailable to the public.

Constellation	Developer	Number of satellites	Orbital altitude (kilometers) Satellites	Frequency bands	ITU filing date/ submission type	Status	Notes
Galaxy Constellation	Galaxy Space	**Phase 1:** 144; **Phase 2:** 1,000+	1,200	Ka/V/Q-Band		Launched satellite Yinhe-1 in January 2020 to test Ka/V/Q-band communications; only 1 satellite in orbit as of April 2021[17]	Reported to consist of thousands of communications satellites with the potential to form a larger national network.
Hongyan	China Aerospace Science and Technology Corporation (CASC)	300+	1,100	L/Ka-Band		Successful technology demonstrator launched; only 1 satellite in orbit as of April 2021[18]	Although both Hongyan and Hongyun were originally intended to serve the PLA, rural customers within China, and overseas Chinese assets, recent statements indicate that the constellations may be slated to rival those of SpaceX and OneWeb. According to some reports[19] original plans associated with the two satellite systems will likely change given their projected consolidation into the larger mega-constellation Guowang.
Hongyun	China Aerospace Science and Industry Corporation (CASIC)	156[20]	1040/1048/1175	L/Ka-Band		Successful technology demonstrator launched; only 1 satellite in orbit as of April 2021[21]	
Guowang	China Satellite Network Group	Two similarly named "GW" low Earth orbit constellations totaling 12,992 satellites[22]	500-1,145	Ka/V-Band (Reports note a wide range of possible bands)	ITU received two advance publication information submissions 19 Dec. 2020 for satellite systems "GW-A59" and "GW-2."		Statements from CASC and CASIC suggest that Hongyun and Hongyan may be combined to form a mega-constellation Guowang; China Satellite Network will be independent from CASC and CASIC.[23]

17. *See* 全球首颗Q和V频段通信能力达10Gbps (16 Jan. 2020), https://bit.ly/2XPCWvu.
18. *See* "鸿雁"首发星成功发射 中国全球空间互联网系统全面启动 (29 Dec. 2018), https://bit.ly/3CPekC9.
19. *See* 12992颗卫星！中国的"GW"巨型星座计划确认！全面技术解读, https://bit.ly/3EXAEeH (last visited 28 Sept. 2021).
20. *See* 卫星互联网产业链解析：战火早已熊熊燃烧 (10 Dec. 2020), https://bit.ly/3oh5mJZ.
21. *See* Gideo Gautel, Coordination Failure: *Risks of US-China competition in space*, Medium (29 Apr. 2021), https://bit.ly/3ocDqHl.
22. *See* Andrew Jones, *China is developing plans for a 13,000 satellite communications megaconstellation*, SpaceNews (21 Apr. 2021), https://bit.ly/3iczDpx.
23. *See* 中国卫星：国家相关部门正统筹规划鸿雁、虹云在内的星座计划, (19 Apr. 2021), https://bit.ly/3m5zDc8.

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