DEFENSE INTELLIGENCE AGENCY

CHALLENGES TO SECURITY IN SPACE

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EXECUTIVE SUMMARY

Space-based capabilities provide integral support to military, commercial, and civilian applications. Longstanding technological and cost barriers to space are falling, enabling more countries and commercial firms to participate in satellite construction, space launch, space exploration, and human spaceflight. Although these advancements are creating new opportunities, new risks for space-enabled services have emerged. Having seen the benefits of space-enabled operations, some foreign governments are developing capabilities that threaten others' ability to use space. China and Russia, in particular, have taken steps to challenge the United States:

- Chinese and Russian military doctrines indicate that they view space as important to modern warfare and view counterspace capabilities as a means to reduce U.S. and allied military effectiveness. Both reorganized their militaries in 2015, emphasizing the importance of space operations.
- Both have developed robust and capable space services, including space-based intelligence, surveillance, and reconnaissance. Moreover, they are making improvements to existing systems, including space launch vehicles and satellite navigation constellations. These capabilities provide their militaries with the ability to command and control their forces worldwide and also with enhanced situational awareness, enabling them to monitor, track, and target U.S. and allied forces.
- Chinese and Russian space surveillance networks are capable of searching, tracking, and characterizing satellites in all earth orbits. This capability supports both space operations and counterspace systems.
- Both states are developing jamming and cyberspace capabilities, directed energy weapons, on-orbit capabilities, and ground-based antisatellite missiles that can achieve a range of reversible to nonreversible effects.

Iran and North Korea also pose a challenge to militaries using space-enabled services, as each has demonstrated jamming capabilities. Iran and North Korea maintain independent space launch capabilities, which can serve as avenues for testing ballistic missile technologies.

The advantage the United States holds in space—and its perceived dependence on it—will drive actors to improve their abilities to access and operate in and through space. These improvements can pose a threat to space-based services across the military, commercial, and civil space sectors.

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INTRODUCTION

Although the United States and the former Soviet Union dominated early space activities, space capabilities have proliferated over the past six decades as technological and cost barriers have fallen. These capabilities provide important support to many of society's daily activities, including communications, navigation, financial transactions, and weather monitoring. As of 2018, over 1,800 active satellites are on orbit, which are owned and operated by over 50 countries and multinational organizations.[1] Nine countries and one international organization can independently launch spacecraft: China, India, Iran, Israel, Japan, Russia, North Korea, South Korea, the United States, and the European Space Agency (from French Guiana).[2]

Space has also become more commercialized. The commercial space sector is involved in space launch, communications, space situational awareness, remote sensing, and even human spaceflight. These firms not only supply products to governments, but they also compete commercially.[3]

The number of objects on orbit—both active satellites and orbital debris—will continue to increase rapidly with the wider availability of lower cost, small satellites and with the prospect of large constellations consisting of thousands of satellites. The challenge of space congestion will grow, and actors will need better capabilities to track and identify objects and prevent collisions in space.[4,5]

Space capabilities have become central to many military operations, including missile warning, geolocation and navigation, target identification, and tracking of adversary activities. The military and intelligence collection capabilities that government and commercial remote sensing satellites provide is reducing the ability of all countries to remain undetected while performing sensitive testing and evaluation activities or military exercises and operations.[6,7]

Some actors are seeking ways to deny the effectiveness of the United States, having witnessed more than 25 years of U.S. military successes enabled by space capabilities.[8] China and Russia, in particular, are developing a variety of means to exploit perceived U.S. reliance on space-based systems and challenge the U.S. position in space.[9] Iran and North Korea also have demonstrated some counterspace capabilities that could pose a threat to militaries using space-based services.

While China and Russia are developing counterspace weapons systems, they are promoting agreements at the United Nations that limit weaponization of space. Their proposals do not address many space warfare capabilities, and they lack verification mechanisms, which provides room for China and Russia to continue to develop counterspace weapons.[10,11] The 1967 Outer Space Treaty prohibits placing weapons of mass destruction on orbit and on any celestial body and it prohibits using celestial bodies for military bases, testing, or maneuvers. 107 states have ratified the treaty, including the United States, China, North Korea, and Russia. Iran is one of 23 states that have signed, but not ratified, the treaty.[12]

Key Space Concepts

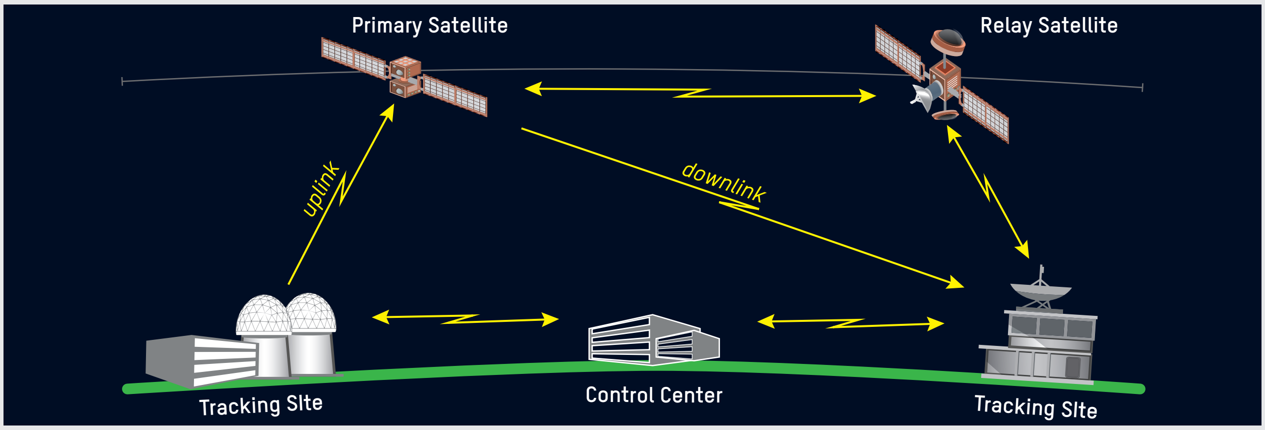
Communication Satellites: Communication satellites provide voice communications, television broadcasts, broadband internet, mobile services, and data transfer services for civil, military, and commercial users worldwide.[13]

Intelligence, Surveillance, and Reconnaissance (ISR): ISR satellites support civil, commercial, and military purposes. Civil and commercial ISR satellites provide remote sensing data, which includes data on the Earth's land, sea, and atmosphere. ISR satellites support a variety of military activities by providing signals intelligence, warning (including of ballistic missile activity), battle damage assessments, and military force disposition.[14,15]

Missile Warning: Missile warning uses space-based and terrestrial sensors to notify countries of missile attacks and can enable defensive or offensive operations in response. Space-based sensors usually provide the first indication of a launch and ground-based radars provide follow-on information and confirm the attack.

Positioning, Navigation, and Timing (PNT): Satellite navigation constellations provide PNT data that enable civilian, commercial, and military users to determine their precise location and local time. The European Union, Russia, and the United States' satellite navigation constellations offer global coverage, and Japan and India operate regional systems. China operates both a regional and worldwide satellite navigation system.[16]

Satellite Command and Control (C2) Architecture: The satellite C2 architecture is how users control and communicate with satellites. The control center uses the uplink to the spacecraft to deliver commands. The spacecraft downlink is how data is sent from the spacecraft to a ground station that has the necessary antennas, transmitters, and receivers to receive the data. Some satellite constellations use relay satellites, which enable communication between satellites outside the reception area of a ground station.[17] Any component of the architecture is vulnerable to attack, ranging from physical vulnerabilities of a ground site to electronic warfare (EW) disrupting the connection between the space segment and the operator.



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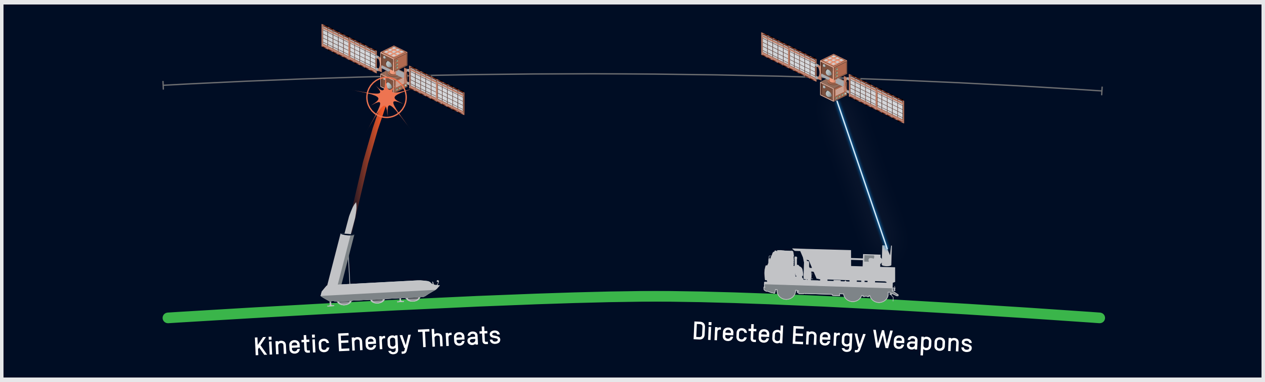
Space Launch: Space launch is the ability to deliver payloads into space. Space launch vehicles (SLV) can deploy, sustain, augment, or reconstitute satellite constellations in support of military, civilian, or commercial customers.[18]

Key Counterspace Concepts

Cyberspace Threats: Cyberspace pervades all other warfighting domains, including space, and many space operations depend on cyberspace and vice versa.[19] With sophisticated knowledge of satellite C2 and data distribution networks, actors can use offensive cyberspace capabilities to enable a range of reversible to nonreversible effects against space systems, associated ground infrastructure, users, and the links connecting them.

Directed Energy Weapons (DEW): DEW use directed energy to disrupt, damage, or destroy enemy equipment and facilities.[20] These weapons, which can have effects ranging from temporary to permanent, include lasers, high-power microwaves, and other types of radiofrequency weapons. It can be difficult to attribute the origin of a DEW attack, depending on the type.



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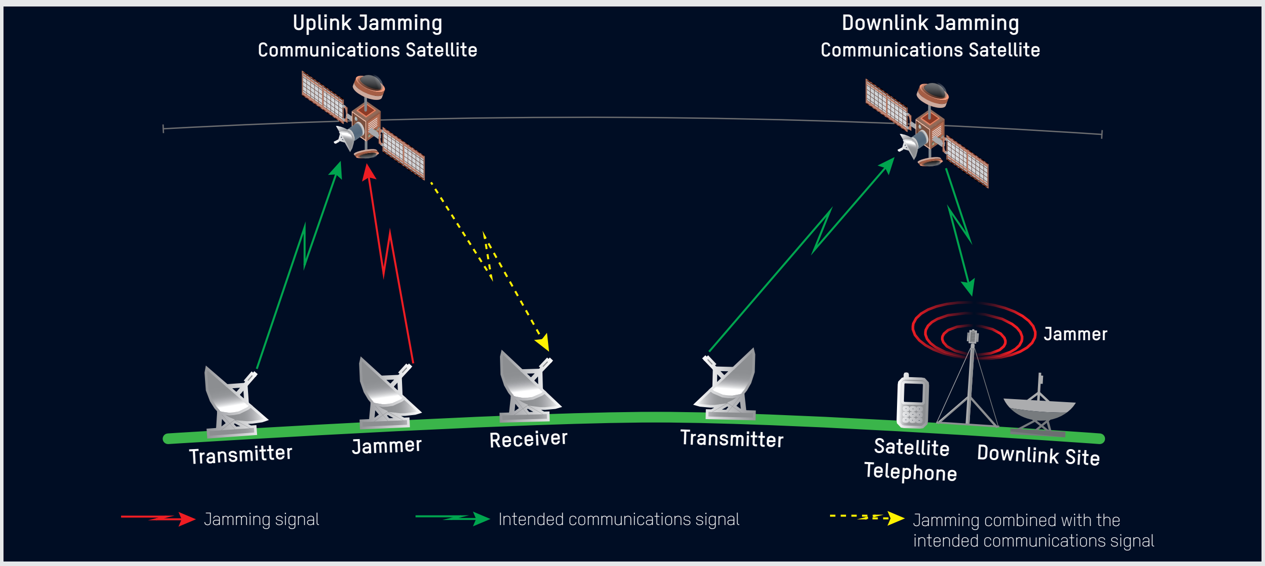
Electronic Warfare: EW includes using jamming and spoofing techniques to control the electromagnetic spectrum.[21] EW can be challenging to attribute and distinguish from unintentional interference. Uplink jamming is directed toward the satellite and impairs services for all users in the satellite reception area. Downlink jamming has a localized effect because it is directed at ground users, such as a ground forces unit using satellite navigation to determine their location. Spoofing deceives the receiver by introducing a fake signal with erroneous information.



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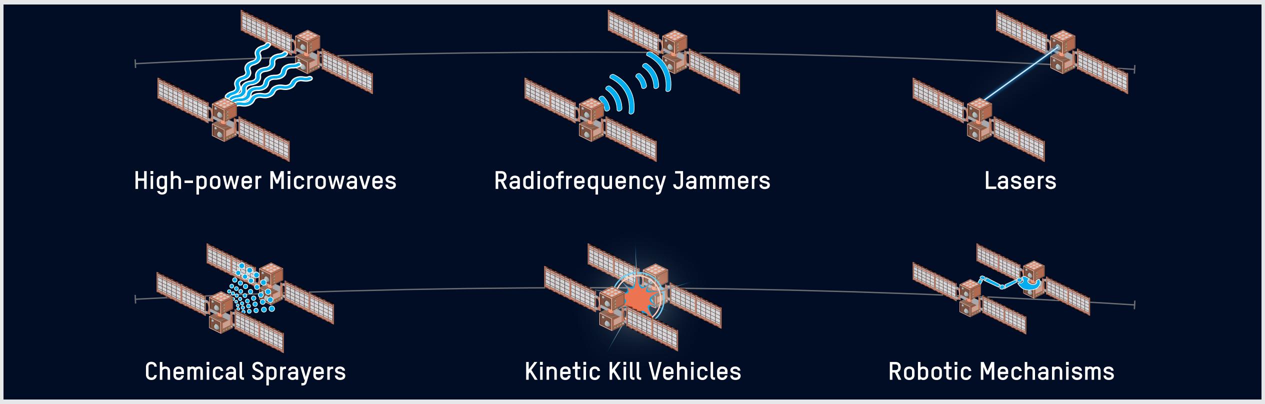
Kinetic Energy Threats: Kinetic energy threats, or antisatellite (ASAT) missiles, are designed to destroy satellites without placing the weapon system or any of its components into orbit. These systems typically consist of a fixed or mobile launch system, a missile, and a kinetic kill vehicle. These weapons could also be launched from aircraft. Once released, the kinetic kill vehicle uses an onboard seeker to intercept the target satellite. Ground-based ASAT missile attacks are more easily attributed than some other counterspace weapons, such as DEW, and their effects can create orbital debris.

Orbital Threats: Orbital or space-based systems are satellites that can deliver temporary or permanent effects against other spacecraft. These systems could include payloads such as kinetic kill vehicles, radiofrequency jammers, lasers, chemical sprayers, high-power microwaves, and robotic mechanisms. Some of these systems, such as robotic technology for satellite servicing and repair and debris removal, have peaceful uses but can also be used for military purposes.



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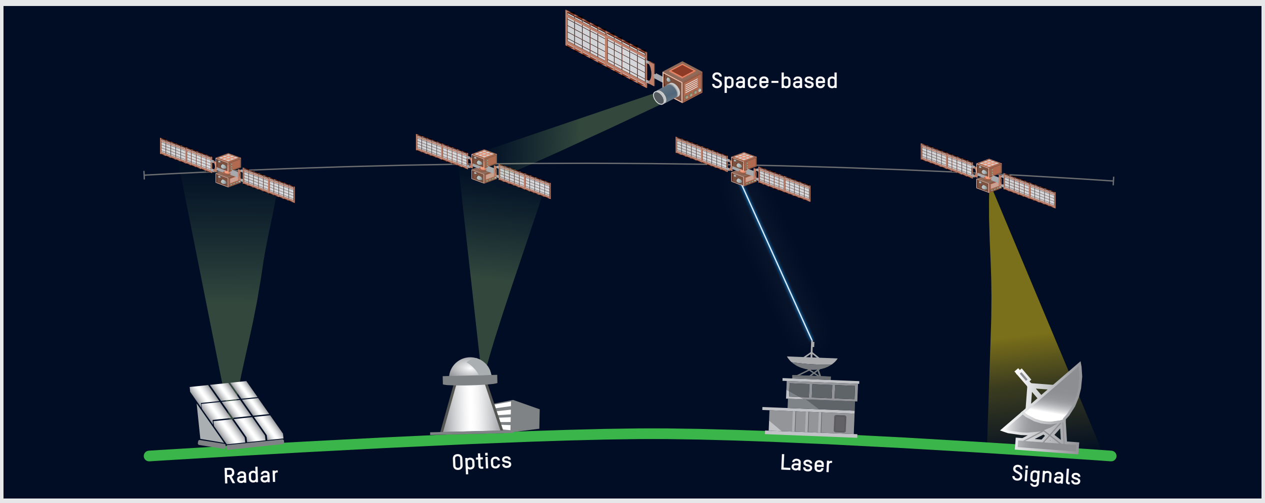
Space Situational Awareness (SSA): SSA is having current knowledge of a space object's location and the ability to track and predict its future location; it also incorporates understanding of an actor's intent for their spacecraft.[22] SSA is necessary for space operations, including the ability to successfully target space objects and assess the effectiveness of an attack. Space object surveillance and identification sensors, which can include telescopes, radars, and space-based sensors, provide the data for SSA.[23]



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Space-based Services

Since the late 1950s, space-enabled technologies have come to provide critical, yet often unrecognized, support to many of modern society's daily activities. Technological advancement and lower-cost barriers mean society is increasingly reliant on these technologies, and losing access to space-based services would have far-reaching effects.

Space-enabled applications heavily impact our daily lives in four areas: navigation, communications, remote sensing, and science and exploration.[24]

Space-based PNT services, such as GPS, provide position and navigation data that enables the use of satellite navigation for directions for routine activities. Positioning and navigation services support sea, ground, and air transportation services, such as by helping plan more efficient routes and managing route congestion. For militaries, PNT data, among other things, allows for the precise targeting for munitions and air, land, and sea navigation.

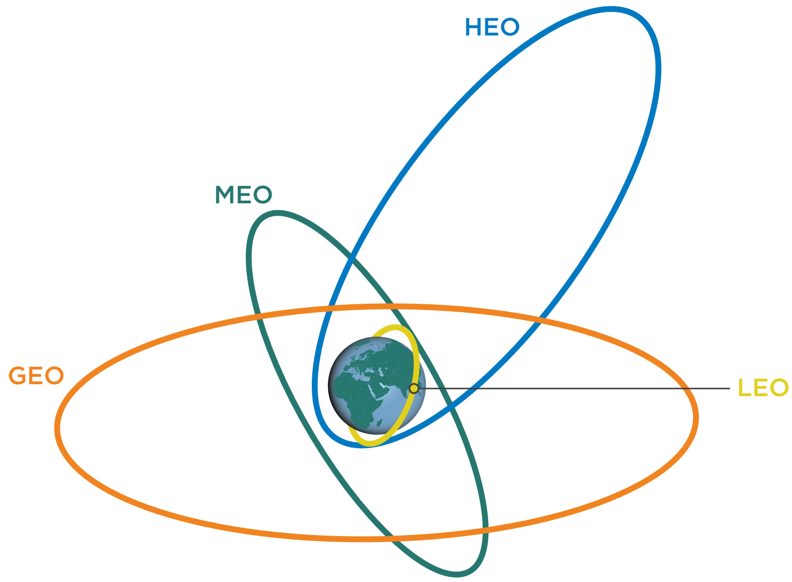
PNT signals, especially precise timing, also provide critical support to modern infrastructure. Without precise timing, financial institutions would be unable to create timestamps for transactions, impacting the public's ability to use ATMs and credit cards, and utility companies would be unable to efficiently transmit power.[25]

Communications satellites—which comprise the majority of satellites on orbit—support global communications and complement terrestrial communications networks.[26] Losing these satellites can have wide-ranging impacts, which was illustrated in 1998 when a U.S. communications satellite suffered a computer failure—people were unable to pay for gas, hospitals were unable to contact physicians who relied on pagers, and television stations were unable to deliver programming.[27] For militaries, satellite communications improve situational awareness and allow forces greater mobility by eliminating the need for ground-based infrastructure.[28]

Without remote sensing satellites—which provide data on the Earth's land, sea, and atmosphere—society would be unable to benefit from weather forecasting, including preparing for weather emergencies. These satellites provide data about the terrain and environment, which range from assisting businesses in determining areas with mineral resources to assisting farmers in identifying potential agricultural disasters. These satellites also support the military by providing ISR data that enables militaries to identify adversary capabilities, track troop movements, and locate potential targets.[29]

An inability to access space for scientific purposes could impact technological innovation. In addition to providing insights into the nature of Earth and the universe, society has benefitted from technological advances enabled by space research and space exploration activities. These advancements include cell phone cameras, better metal alloys for jet engine turbines, solar panels, memory foam, portable computers, and compact water purification systems.[30,31]

Orbit Types and Uses[32,33]



Orbits are notional and for illustrative purposes only.

ORBIT	ALTITUDE*	USES
Low Earth Orbit (LEO)	Up to 2,000 km	- Communications - ISR - Human Spaceflight†
Medium Earth Orbit (MEO)	Approx. 2,000 to 35,000 km	- Communications - Position, Navigation, and Timing
Highly Elliptical Orbit (HEO)	LEO altitudes at perigee (nearest to Earth) Approx. 40,000 km at apogee (farthest from Earth)	- Communications - ISR - Missile Warning
Geosynchronous Earth Orbit (GEO)	Approx. 36,000 km	- Communications - ISR - Missile Warning

** The advantages of higher orbits for communications and ISR are near-persistent coverage of most of the Earth in view of the satellite, but limited access to polar regions. LEO satellites cover all parts of the world, including the poles, but for shorter periods based on the speed of the satellite.*

† With the exception of nine U.S. Apollo missions to the Moon, all human spaceflight has been completed in LEO.

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CHINA

> "To explore the vast cosmos, develop the space industry, and build China into a space power is a dream we pursue unremittingly."
>
> —China's Space White Paper, December 26, 2016[34]

China has devoted significant economic and political resources to growing all aspects of its space program, from improving military space applications to developing human spaceflight and lunar exploration programs. China's journey toward a space capability began in 1958, less than 9 months after the launch of Sputnik-1. However, China's aspirations to match the Soviet Union and the United States soon faced self-imposed delays due to internal political dynamics that lasted until the late 1960s. China did not launch its first satellite until April 1970. In the early 1980s, China's space program began moving with purpose.[35]

Beijing now has a goal of "[building] China into a space power in all respects."[36] Its rapidly growing space program—China is second only to the United States in the number of operational satellites—is a source of national pride and part of President Xi Jinping's "China Dream" to establish a powerful and prosperous China. The space program supports both civil and military interests, including strengthening its science and technology sector, international relationships, and military modernization efforts. China seeks to achieve these goals rapidly through advances in the research and development of space systems and space-related technology.[37,38,39,40,41]

China officially advocates for peaceful use of space, and it is pursuing agreements at the United Nations on the nonweaponization of space.[42] Nonetheless, China continues to improve its counterspace weapons capabilities and has enacted military reforms to better integrate cyberspace, space, and EW into joint military operations.

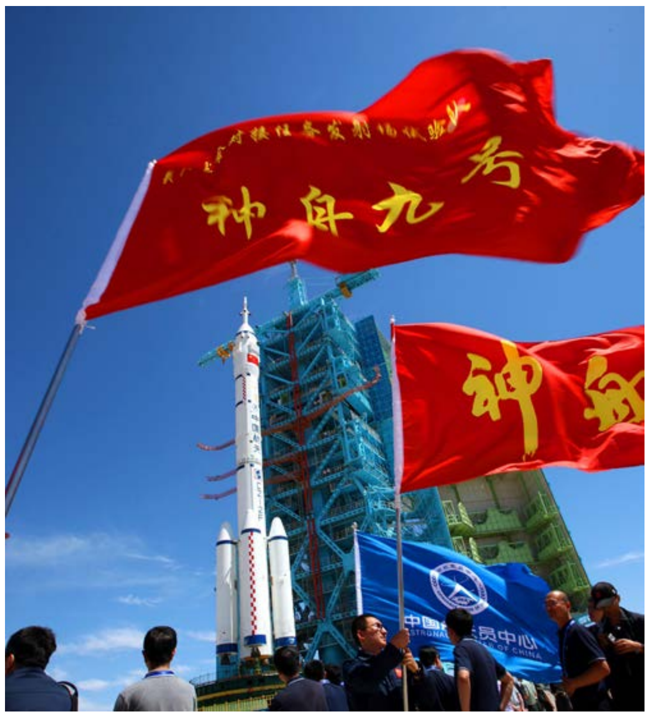


Image Source: AFP

China launched the Shenzhou-9 in June 2012, which was the first crewed spacecraft to dock with the Tiangong-1 space laboratory.

Strategy, Doctrine, and Intent

China's Military Strategy

In 2015, Beijing directed the People's Liberation Army (PLA) to be able to win "informatized local wars" with an emphasis on "maritime military struggle." Chinese military strategy documents also emphasize the growing importance of offensive air, long-distance mobility, and space and cyberspace operations. China expects that its future wars mostly will be fought outside its borders and will involve conflict in the maritime domain. China promulgated this through its most recent update to its "military strategic guidelines," the top-level directives that Beijing uses to define concepts, assess threats, and set priorities for planning, force posture, and modernization.

The PLA uses "informatized" warfare to describe the process of acquiring, transmitting, processing, and using information to conduct joint military operations across the domains of land, sea, air, space, cyberspace, and the electromagnetic spectrum during a conflict. PLA writings highlight the benefit of near-real-time shared awareness of the battlefield in enabling quick, unified effort to seize tactical opportunities.[43]

The PLA views space superiority, the ability to control the information sphere, and denying adversaries the same as key components of conducting modern "informatized" wars.[44,45,46,47,48,49] Since observing the U.S. military's performance during the 1991 Gulf War, the PLA embarked on an effort to modernize weapon systems and update doctrine to place the focus on using and countering adversary information-enabled warfare.

Space and counterspace operations will form integral components of PLA campaigns, given China's perceptions of the importance of space-enabled operations to U.S. and allied forces and the growing importance of space to enable beyond-line-of-sight operations for deployed Chinese forces. The PLA also sees counterspace operations as a means to deter and counter a possible U.S. intervention during a regional military conflict.[50,51] PLA analysis of U.S. and allied military operations states that "destroying or capturing satellites and other sensors" would make it difficult to use precision guided weapons.[52] Moreover, PLA writings suggest that reconnaissance, communications, navigation, and early warning satellites could be among the targets of attacks designed to "blind and deafen the enemy."[53]

Key Space and Counterspace Organizations

China's space program has a complex structure and comprises organizations in the military, political, defense-industrial, and commercial sectors. The PLA historically has managed China's space program, and it continues to invest in improving China's capabilities in space-based ISR, satellite communication, and satellite navigation, as well as human spaceflight and robotic space exploration.[54] State-owned enterprises are China's primary civilian and military space contractors, but China is placing greater emphasis on decentralizing and diversifying its space industry to increase competition.[55]

As part of the military reforms announced in 2015, China established the Strategic Support Force (SSF) to integrate cyberspace, space, and EW capabilities into joint military operations.[56,57,58] The SSF forms the core of China's information warfare force, supports the entire PLA, and reports directly to the Central Military Commission. The SSF likely is responsible for research and development of certain space and counterspace capabilities. The SSF's space function is focused primarily on satellite launch and operations to support PLA ISR, navigation, and communication requirements.[59]

Image Source: XINHUA/AFP

In December 2015, President Xi conferred a military flag to the new Strategic Support Force Commander Lt. Gen. Gao Jin (left), who was later promoted to general.[60] Gen. Gao previously served as the head of the PLA think tank, the Academy of Military Sciences, which publishes documents on PLA doctrine.[61]

Currently, the State Council's State Administration for Science, Technology, and Industry for National Defense (SASTIND) is the primary civil organization that coordinates and manages China's space activities, including allocating space research and development funds.[62] It also maintains a working relationship with the PLA organization that oversees China's military acquisitions. SASTIND guides and establishes policies for state-owned entities conducting China's space activities, whereas the State-owned Assets Supervision and Administration Commission provides day-to-day management.[63,64]

The China National Space Administration (CNSA) serves as the public face of China's civil space efforts.[65] China is increasingly using these efforts to bolster relationships with countries around the world, providing opportunities to lead the space community.[66,67,68] In April 2018, CNSA stated that China had signed 21 civil space cooperation agreements with 37 countries and four international organizations.[69]

In the commercial space sector, mixed-ownership enterprises such as Zhuhai Orbita, Expace, and OK-Space offer remote sensing, launch, and communication services.[70,71,72] Many of these space technologies can serve a civilian and military purpose and China emphasizes "civil-military integration"—a phrase used, in part, to refer to the leveraging of dual-use technologies, policies, and organizations for military benefit.[73]

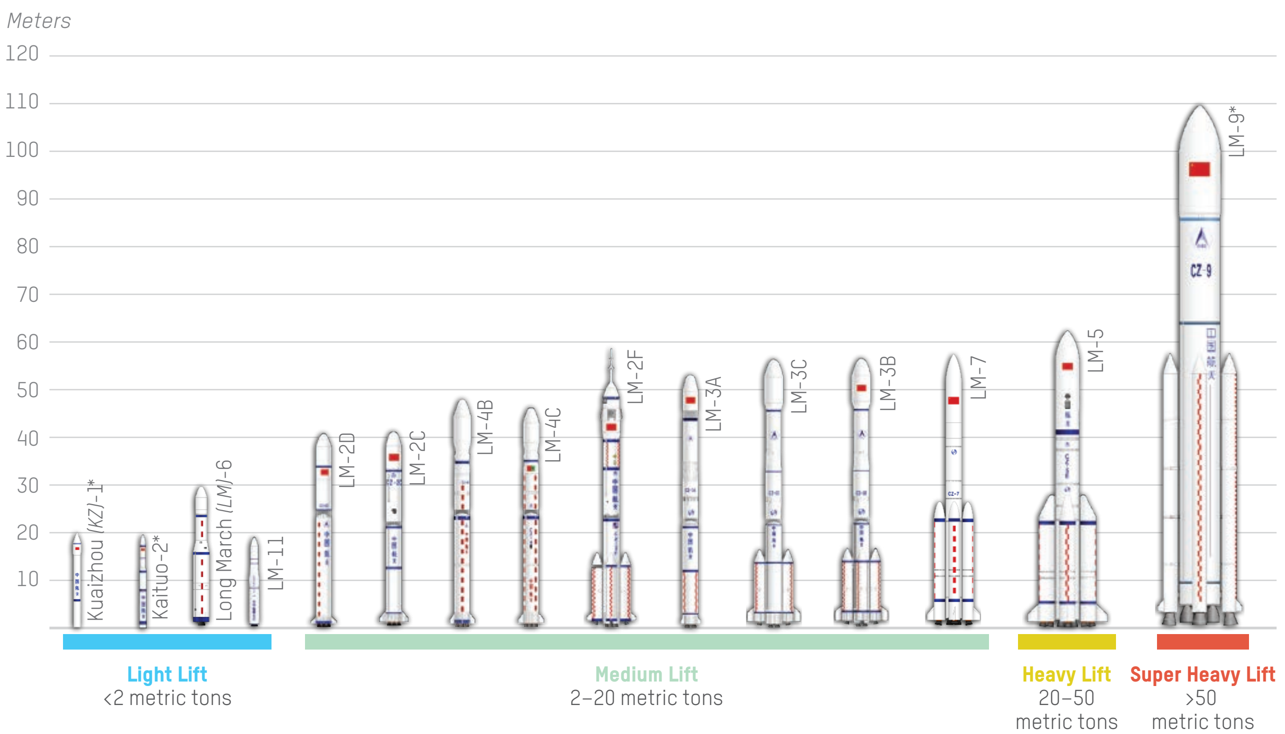
Space and Counter-space Capabilities

Space Launch Capabilities

China is improving its space launch capabilities to ensure it has an independent, reliable means to access space and to compete in the international space launch market. Recent improvements reduce launch timelines, increase manufacturing efficiencies, and support human spaceflight and deep-space exploration missions.[74] These improvements include new, modular SLVs that allow China to tailor an SLV to the specific configuration required for each customer. Using modular SLVs can lead to increases in manufacturing efficiency, launch vehicle reliability, and overall cost savings for launch campaigns.[75] China is also in the early stages of developing a super heavy-lift SLV similar to the U.S. Saturn-V or the newer Space Launch System to support proposed crewed lunar and Mars exploration missions.[76]

China has developed a "quick response" SLV to increase its attractiveness as a commercial small satellite launch provider and to rapidly reconstitute LEO space capabilities, which could support

Chinese Space Launch Vehicles



* *Developmental*

Depicted payload capacity is approximate and varies depending on planned orbit.

The launch vehicles depicted are representative of China's launch capabilities. Additional light-, medium-, and heavy-lift vehicles are in development. China uses its light-lift vehicles to place small payloads into LEO and its medium lift to place larger satellites in MEO and smaller satellites in GEO. The LM-5 heavy-lift SLV supports launching crewed space station components to LEO and heavy payloads to GEO. The developmental LM-9 primarily will support missions to the Moon and Mars.

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Chinese Space Launch Sites and Key Satellite Control Centers

China has four launch sites. The newest, Wenchang on Hainan Island, has a launch latitude closer to the Equator, which provides a more efficient path to launch satellites into GEO. China's main satellite control center is in Xian and its primary control center for human spaceflight and lunar missions is in Beijing.[77]

Visualization: DIA, D3 Design • 1811-19969

military operations during a conflict or civilian response to disasters. Compared to medium- and heavy-lift SLVs, these quick response SLVs are capable of expedited launch campaigns because they are transportable via road or rail and can be stored launch-ready for longer periods. Currently, due to their limited size, quick response SLVs such as the KZ-1, LM-6, and LM-11 are only capable of launching relatively small payloads into LEO.[78,79,80]

Human Spaceflight and Space Exploration

In 2003, China became the third country to achieve independent human spaceflight, when it successfully orbited the crewed Shenzhou-5 spacecraft, followed by space laboratory Tiangong-1 and -2 launches in 2011 and 2016, respectively. By 2022, China intends to assemble and operate a permanently inhabited, modular space station that can host Chinese and foreign payloads and astronauts.[81,82]

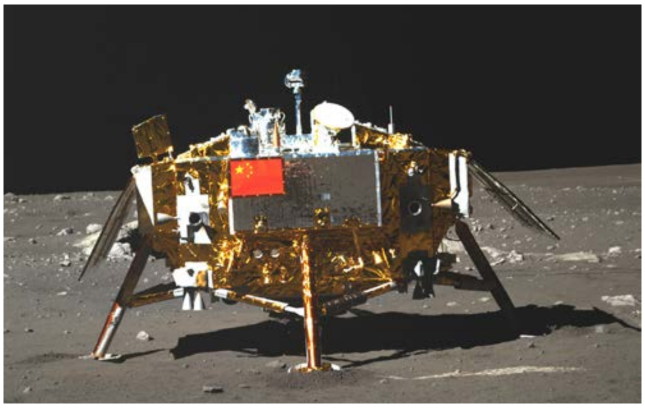


Image Source: XINHUA/AFP

In December 2013, China conducted the first "soft-landing" on the Moon since 1976.[83] The lunar rover, Yutu, took this image of the Chang'e-3 lunar lander that month.

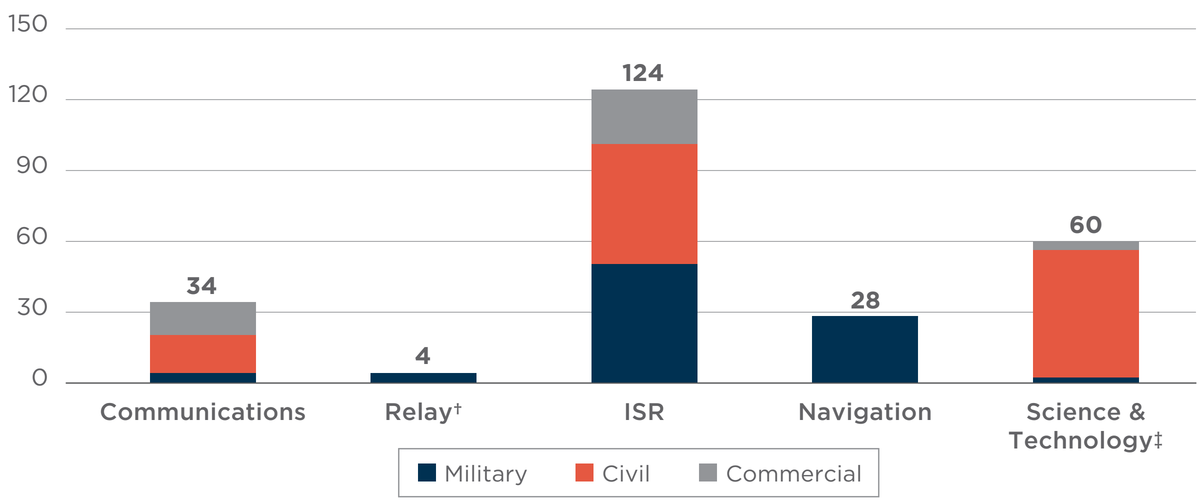
China is also the third country to have landed a rover on the Moon and performed the first-ever landing on the lunar far side with its Chang'e-4 rover and lander in January 2019.[84,85] Because it is not possible to communicate directly with objects on the far side of the Moon, China launched a lunar relay satellite in May 2018 to enable communication between the Chang'e-4 and the Earth.[86,87]

Additionally, China announced plans in March 2018 to assemble a robotic research station on the Moon by 2025 and has started establishing the foundation for a human lunar exploration program to put astronauts on the Moon in the mid-2030s.[88,89]

ISR, Navigation, and Communications Capabilities

China employs a robust space-based ISR capability designed to enhance its worldwide situational awareness. Used for military and civil remote sensing and mapping, terrestrial and maritime surveillance, and military intelligence collection, China's ISR satellites are capable of providing electro-optical and synthetic aperture radar (SAR) imagery, as well as electronic intelligence and signals intelligence data.[90]

Chinese Satellites on Orbit, as of 1 May 2018[91,92]



† Relay satellites enable communication between satellites outside the reception area of a ground station.
‡ Science and technology satellites are used for scientific research or testing new space technologies.

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Image Source: XINHUA/AFP

China launched the world's first quantum communications satellite in 2016, and this composite time-lapse photo shows a ground-to-space link to enable the quantum teleportation of data in a quantum state. The red light emanating from the ground station is the uplink laser beacon, which is connecting with the satellite. Due to the time-lapse photo, light from the downlink beacon traces the path of the satellite, shown by the white, dashed line. China has included quantum communications and computing as one of its focus areas for research and development for 2016-2020.[93]

As of May 2018, the Chinese ISR and remote sensing satellite fleet contains more than 120 systems—a quantity second only to the United States.[94]

The PLA owns and operates about half of these ISR systems, most of which could support monitoring, tracking, and targeting of U.S. and allied forces worldwide, especially throughout the Indo-Pacific region. These satellites also allow the PLA to maintain situational awareness of potential regional flashpoints, including the Korean Peninsula, Taiwan, and the South China Sea.[95,96,97]

China also owns and operates over 30 communications satellites, with 4 dedicated to military use.[98] China produces its military-dedicated satellites domestically and its civil communications satellites incorporate off-the-shelf commercially manufactured components.[99]

Additionally, China has embarked on several ambitious plans to propel itself to the forefront of the global satellite communications (SATCOM) industry.[100,101,102] China is testing multiple next-generation capabilities, such as quantum-enabled communications, which could supply the means to field highly secure communications systems.[103]

China is continuing to improve its indigenous satellite navigation constellation. China offers regional PNT services and achieved initial operating capability of its worldwide, next-generation BeiDou constellation in 2018.[104,105] In addition to providing PNT, the BeiDou constellation offers unique capabilities, including text messaging and user tracking through its short messaging service, to enable mass communications between BeiDou users and provide additional C2 capabilities for the PLA.[106,107]

China also exports its satellite technology globally, including its indigenously-developed communications satellites. China intends to provide SATCOM support to users worldwide and has plans to develop at least three new communications constellations.[108,109,110] China also intends to use its BeiDou constellation to offer additional services and incentives to countries taking part in the "Belt and Road Initiative." BeiDou supports that initiative's emphasis on building strong economic ties with other countries and shaping their interests to align with China's.[111,112]

Counterspace Capabilities

Space Situational Awareness. China has a robust network of space surveillance sensors capable of searching, tracking, and characterizing satellites in all Earth orbits. This network includes a variety of telescopes, radars, and other sensors that allow China to support missions including intelligence collection, counterspace targeting, ballistic missile early warning, spaceflight safety, satellite anomaly resolution, and space debris monitoring.[113,114]

Image Source: Wikimedia Commons

This Chinese *Yuan Wang* space tracking ship, which supports space launch operations from positions in the Pacific, is part of China's SSA network.[115]

Electronic Warfare. The PLA considers EW capabilities key assets for modern warfare and its doctrine emphasizes using EW weapons to suppress or deceive enemy equipment.[116] The PLA routinely incorporates jamming and anti-jamming techniques against multiple communication, radar systems, and GPS satellite systems in exercises.[117] China continues to develop jammers dedicated to targeting SAR aboard military reconnaissance platforms, including LEO satellites.[118,119] Additionally, China is developing jammers to target SATCOM over a range of frequency bands, including military protected extremely high frequency communications.[120,121]

Directed Energy Weapons. China likely is pursuing laser weapons to disrupt, degrade, or damage satellites and their sensors and possibly already has a limited capability to employ laser systems against satellite sensors. China likely will field a ground-based laser weapon that can counter low-orbit space-based sensors by 2020, and by the mid-to-late 2020s, it may field higher power systems that extend the threat to the structures of non-optical satellites.[122,123,124,125,126]

Cyberspace Threats. China emphasizes offensive cyberspace capabilities as key assets for integrated warfare and could use its cyberwarfare capabilities to support military operations against space-based assets.[127,128] For example, the PLA could employ its cyberattack capabilities to establish information dominance in the early stages of a conflict to constrain an adversary's actions, or slow its mobilization

Chinese International SSA Cooperation

China leads the Asia-Pacific Space Cooperation Organization—a multilateral organization with rotating leadership whose members include emerging spacefaring nations such as Iran—that oversees a space surveillance project known as the Asia-Pacific Ground-Based Optical Space Object Observation System (APOSOS). As part of the project, China provided three 15 cm telescopes to Peru, Pakistan, and Iran that are capable of tracking objects in LEO and GEO. All tasking information and subsequent observation data collected is funneled through the Chinese Academy of Science's National Astronomical Observatory of China. APOSOS has near full coverage of GEO and LEO. The organization is planning on improving optical system capabilities, coverage, and redundancy.[129,130]

and deployment by targeting network-based command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR), logistics, and commercial activities.

The PLA also plays a role in cyberespionage targeting foreign space entities, consistent with broader state-sponsored industrial and technical espionage to increase the level of technologies and expertise available to support military research and development and acquisition. The PLA unit responsible for conducting signals intelligence has supported cyberespionage against U.S. and European satellite and aerospace industries since at least 2007.[131,132]

Orbital Threats. China is developing sophisticated on-orbit capabilities, such as satellite inspection and repair, at least some of which could also function as a weapon. China has launched multiple satellites to conduct scientific experiments on space maintenance technologies and it is conducting space debris cleanup research.[133,134,135,136]

Kinetic Energy Threats. The PLA has an operational ground-based ASAT missile intended to target LEO satellites. China has also formed military units that have begun training with ASAT missiles.[137,138,139]

Other Counterspace Technology Development. China probably intends to pursue additional ASAT weapons capable of destroying satellites up to GEO. In 2013, China launched an object into space on a ballistic trajectory with a peak altitude above 30,000 km. No new satellites were released from the object, and the launch profile was inconsistent with traditional SLVs, ballistic missiles, or sounding rocket launches for scientific research.[142]

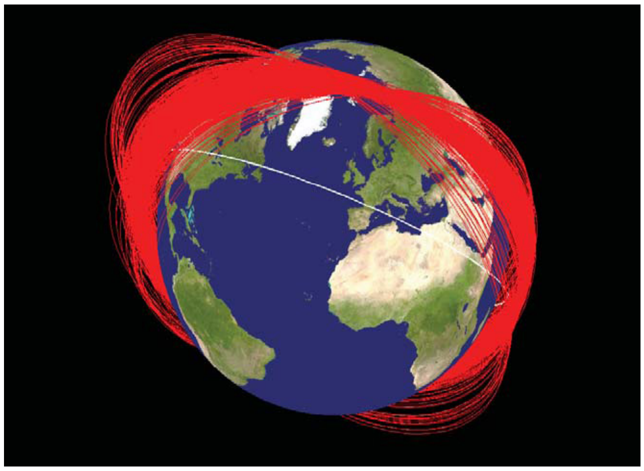

Image Source: Wikimedia Commons

China's 2007 test of its ground-based ASAT missile destroyed one of its own defunct satellites in LEO.[140,141] The graphic depicts the orbits of trackable debris generated by the test 1 month after the event. The white line represents the International Space Station's orbit.

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RUSSIA

"Only with support from space will it be possible for the Armed Forces to reach maximum effectiveness...The Russian President has repeatedly stressed that our army and navy must not only meet the requirements of today, but to [sic] be prepared for tomorrow's means of conducting armed struggle. The solution of this problem doubtlessly depends directly on the availability of a modern orbital constellation of military satellites."

–Russian Defense Minister Sergey Shoygu, March 6, 2018[143]

Russia views its space program as a longstanding example of its leadership on the international stage. Russia is a pioneer of space, dating back to its launch of the first satellite, Sputnik-1, and placing the first person into orbit around Earth, Yuri Gagarin. The International Space Station's reliance on Russian launch vehicles to send astronauts to and from the station reinforces Moscow's perspective that it remains a global leader in space. In the years following the end of the Cold War, a combination of budgetary constraints and technological setbacks caused a decay of Russian space capabilities including space-based remote sensing and satellite navigation.[144]

Russia's space program is robust but more narrowly focused and its budget more limited than China's because of competing priorities with broader military modernization efforts.[145] Nonetheless, over the last two decades, Moscow has been developing a suite of counterspace weapons capabilities, including EW to deny, degrade, and disrupt communications and navigation and DEW to deny the use of space-based imagery.[146,147] Russia is probably also building a ground-based missile capable of destroying satellites in orbit.[148,149] Similar to China, Russia supports space arms control agreements to prevent weaponization of space, even as it views space as a warfighting domain.[150]

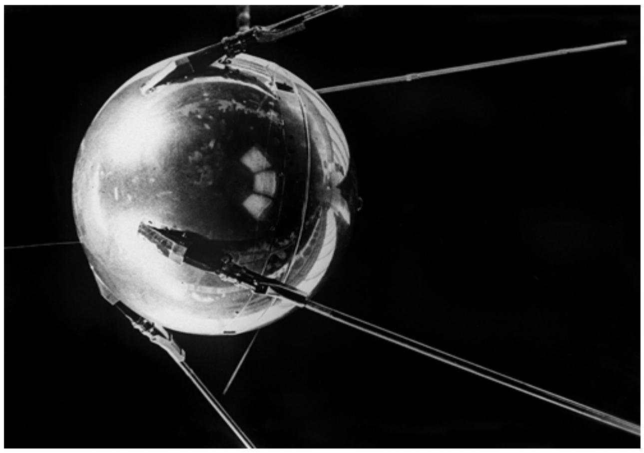


Image Source: AFP

Sputnik-1, the world's first manmade satellite, launched in 1957 and was part of the competition between the United States and Soviet Union for dominance in space.

Strategy, Doctrine, and Intent

Russian military doctrine and authoritative writings clearly articulate that Russia views space as a warfighting domain and that achieving supremacy in space will be a decisive factor in winning future conflicts.[151,152,153,154] Russian military thinkers believe the importance of space will continue to expand because of the growing role of precision weapons and satellite-supported information networks in all types of conflict.[155,156] Meanwhile, Russia regularly expresses concern over the weaponization of space and is pursuing legal, binding space arms control agreements to curb what it sees as U.S. weaponization of outer space.[157,158,159]

As Russia continues to modernize its military, it will increasingly incorporate space-provided services across its forces. Russia possesses a robust space program with a strong foundation of technical knowledge and expertise fostered by over 60 years of experience in space. However, Moscow wants to avoid becoming overly reliant on space to carry out its national defense mission.[160,161,162]

Moscow views space as a key enabler of U.S. precision strike and military force projection capabilities. When paired with U.S. missile defense systems, Russia believes U.S. space-enabled, conventional precision strike capabilities undermine strategic stability.[163,164] At the same time, Russia views America's perceived dependence on space as the "Achilles heel" of U.S. military power, which can be exploited to achieve Russian conflict objectives.[165] Russia is therefore pursuing counterspace systems to neutralize or deny U.S. space-based services, both military and commercial, as a means of offsetting a perceived U.S. military advantage and is developing an array of weapons designed to interfere with or destroy an adversary's satellites.[166,167]

Russian counterspace doctrine involves employing ground, air, and space-based systems to target an adversary's satellites, with attacks ranging from temporary jamming or sensor blinding to destruction of enemy spacecraft and supporting infrastructure.[168,169,170,171] Moscow believes developing and fielding counterspace capabilities will deter aggression by adversaries reliant upon space.[172] If deterrence fails, Russia believes its counterspace forces will offer its military leaders the ability to control escalation of a conflict through selective targeting of adversary space systems.[173,174]

Key Space and Counterspace Organizations

In 2015, Moscow reorganized its military and civilian space programs. Russia created the Aerospace Forces by merging the former Air Force and Aerospace Defense Troops. This new force includes Russia's space forces, who have the mission to conduct space launches and maintain the ballistic missile early warning system, the satellite control network, and the space surveillance network.[175,176,177] The defense minister stated the change was "prompted by a shift in the center of gravity... towards the aerospace sphere" and as a counter to the U.S. Prompt Global Strike doctrine.[178,179]

Image Source: Russia Ministry of Defense/Creative Commons 4.0 Copyright

The Russian Space Force Commander, Gen-Col Aleksandr Golovko, oversaw the launch of a GLONASS-M navigation satellite in November 2018.[180] Gen-Col Golovko is the first commander of the Space Forces, which are subordinate to the Aerospace Forces.[181]

Russia's reorganization of its civil space program was designed to improve upon inefficiencies across the sector, and now Russia's space industry is almost exclusively owned by the Russian state.[182] State corporation Roscosmos is the executive body responsible for overall management of the space industry and carries out Russia's civil space program. The space industry is primarily composed of 75 design bureaus, enterprises, and companies that carry out research, design, and production of its space technologies, satellites, and space launch vehicles for both civil and military purposes.[183,184]

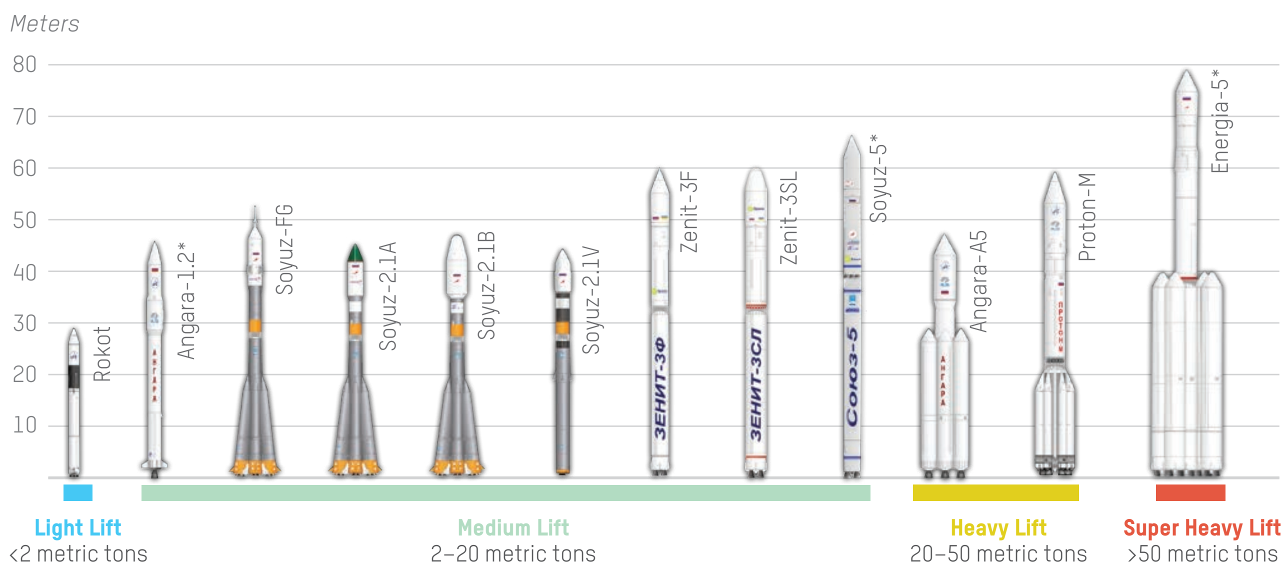
Space and Counter-space Capabilities

Space Launch Capabilities

Russia is updating and improving its space launch capabilities to enhance reliability, alleviate environmental concerns, increase manufacturing efficiencies, and support future human spaceflight and deep-space exploration missions.[185,186]

Russia's updates to its medium- and heavy-lift launch fleets include modular SLVs, which allow Russia to tailor SLVs to the specific configuration required for each customer. Unlike China, Russia has not focused on new light-lift SLV designs, usually choosing to launch small satellites on multi-payload launches. Russia is also in the early stages of developing a super heavy-lift SLV similar to the U.S. Saturn-V or the newer Space Launch System to support proposed crewed lunar and Mars exploration missions.[187]

Russian Space Launch Vehicles



* *Developmental*

Depicted payload capacity is approximate and varies depending on planned orbit.

Russia has focused on maintaining its own military and civil satellites on orbit and selling launch services commercially. Russia usually launches small satellites as multiple payloads on heavier rockets but sometimes uses the Rokot light-lift vehicle to launch smaller payloads into LEO. Russia's heavy-lift vehicles are mostly used for launching into GEO or HEO. The developmental Energia SLV, designed to boost the Russian space shuttle into orbit, was discontinued in the 1980s and revived in 2016 to support proposed lunar missions.

Visualization: DIA, D3 Design • 1811-19985

Russian Space Launch Sites and Key Satellite Control Centers

Russia owns three of its launch sites and leases one from Kazakhstan. The European Space Agency has also contracted Russia to conduct launches from Kourou, French Guiana. Russia's space control sites are spread across Russia to enable effective satellite C2.

Visualization: DIA, D3 Design • 1811-19970

Human Spaceflight and Space Exploration

Russia's human spaceflight program started in the late 1950s and saw its first major milestone with the launch of Yuri Gagarin aboard the Vostok-1 spacecraft in 1961. Since that historic launch, the Soviet Union and then the Russian Federation has launched the Salyut, Almaz, and Mir Space Stations. As of 2018, Russia is a major player in human spaceflight through their work with the International Space Station, which is completely reliant on Russian support to launch astronauts to the station.[188,189,190,191]

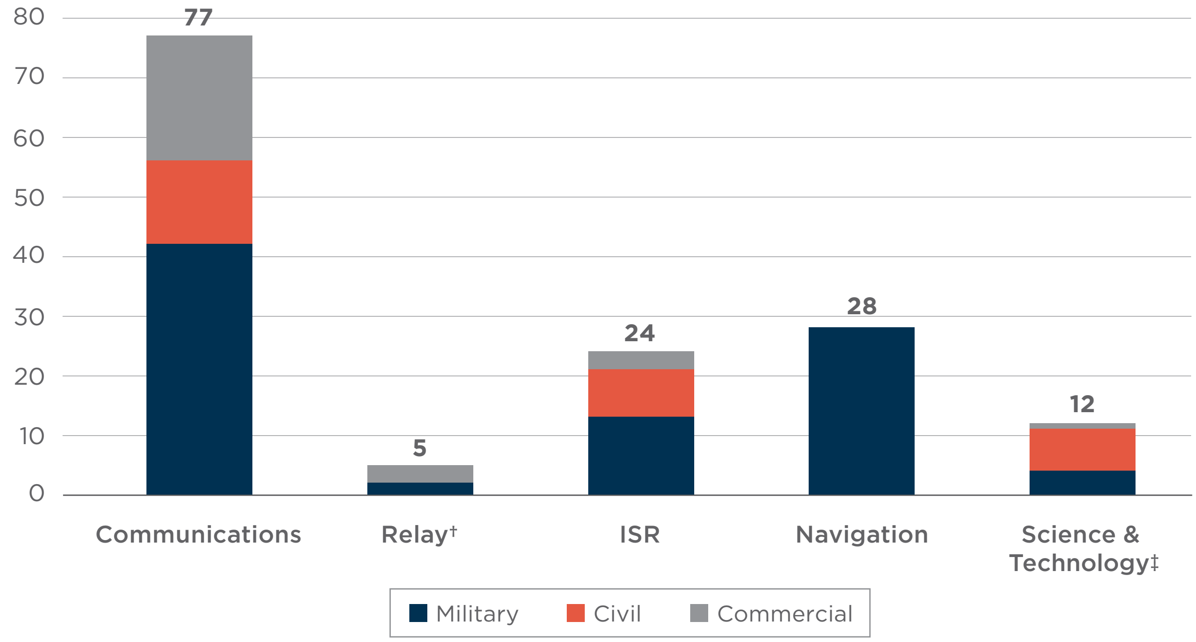
Image Source: AFP

Russia's Soyuz MS-07 carries astronauts to the International Space Station, December 2017.

ISR, Navigation, and Communications Capabilities

Russia numbers third in the world, behind the United States and China, in terms of operational satellites, with over 140 in various orbits.[192] These systems provide Russia's military with satellite communications, high-resolution imagery, navigation, ballistic missile early warning, electronic intelligence, and meteorological services.

Russian Satellites on Orbit, as of 1 May 2018[193,194,195,196]



† Relay satellites enable communication between satellites outside the reception area of a ground station.
‡ Science and technology satellites are used for scientific research or testing new space technologies.

Visualization: DIA, D3 Design • 1811-19937

Since the end of the Cold War, Russia has sought to sustain its atrophying ISR and remote sensing satellite fleet, despite funding shortfalls, economic sanctions, and technological setbacks. Though possessing fewer satellites than China, the individual capabilities of Russian ISR and remote sensing satellites can surpass China's. The Russian military owns and operates about half of those, but the military may also be able to leverage civil and commercial ISR and remote sensing satellites to supplement military-dedicated capabilities. These systems currently support ongoing military operations in Syria but can also monitor U.S. and NATO forces operating globally.[197,198]

Russia maintains a SATCOM fleet that provides resilient communications services to civil, government, and military users within its borders and worldwide. Russia continues to lag behind other worldwide providers, even though it has taken some steps toward SATCOM modernization, such as establishing partnerships with European satellite manufacturers to improve satellite reliability and capabilities.[199,200]

Russia views its Global Navigation Satellite System (GLONASS) as supporting its economic development and national security interests.[201] The constellation currently provides PNT services worldwide. Following the constellation's deterioration in the late 1990s, Russia committed to reconstituting GLONASS during the 2000s and regained full operating capability in 2011.[202] Russia now maintains its GLONASS constellation with launches as satellites become inoperative while it continues development of next-generation GLONASS satellites, promising higher accuracy.[203]

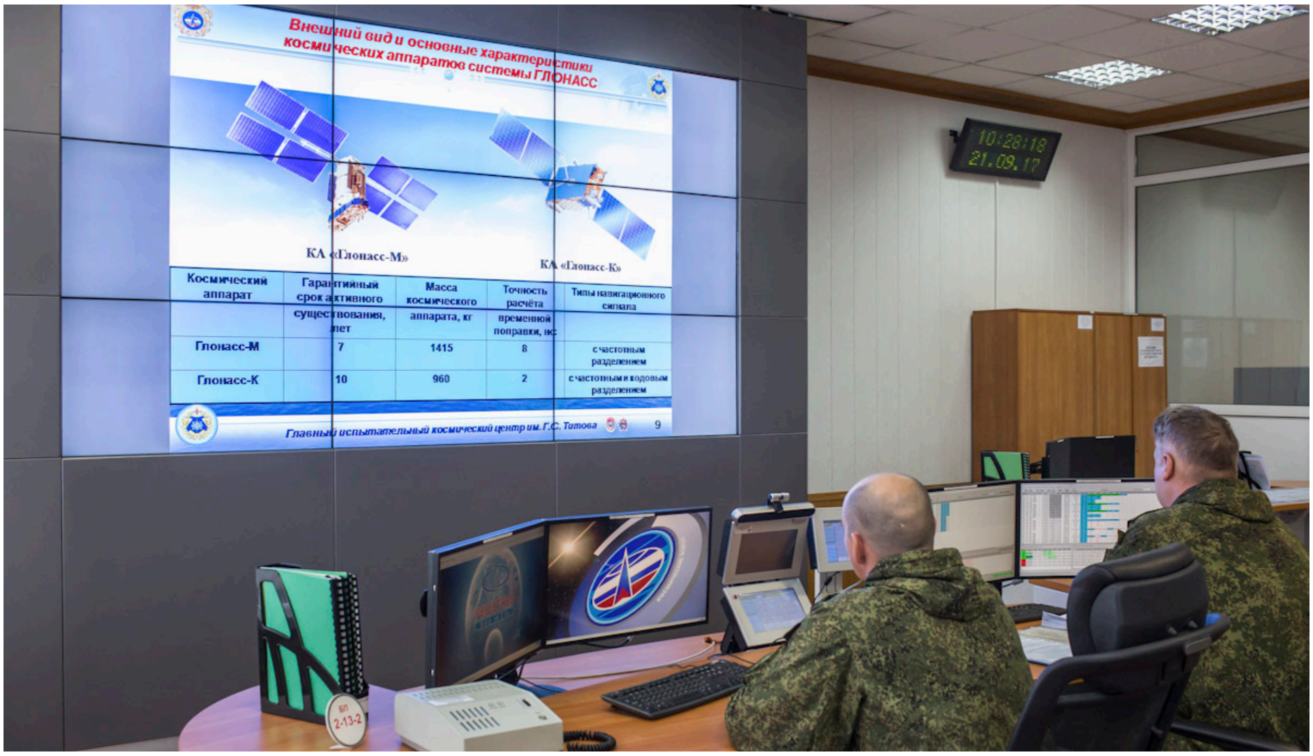


Image Source: Russia Ministry of Defense/Creative Commons 4.0 Copyright

Russian Aerospace Forces monitor GLONASS satellites at the Titov Main Test and Space Systems Control Center in Krasnoznamensk outside Moscow.[204]

Counterspace Capabilities

Space Situational Awareness. Russia's space surveillance network, composed of a variety of telescopes, radars, and other sensors, is capable of searching for, tracking, and characterizing satellites in all Earth orbits. This network allows Russia to support missions including intelligence collection, counterspace targeting, spaceflight safety, satellite anomaly resolution, and space debris monitoring. Some of these sensors also perform a ballistic missile early warning function.[205]

Electronic Warfare. The Russian military views EW as an essential tool for gaining and maintaining information superiority over its adversaries, allowing Russia to seize the operational initiative by disrupting adversary command, control, communications, and intelligence capabilities. Russia has fielded a wide range of ground-based EW systems to counter GPS, tactical communications, satellite communications, and radars.[206] Mobile jammers include radar jammers and SATCOM jammers. Russia has aspirations to develop and field a full spectrum of EW capabilities to counter Western

Russian International SSA Efforts

Russia leads the nongovernmental organization International Scientific Optical Network (ISON), which has the largest foreign network of ground-based optical space surveillance sensors. ISON can trace its existence back to 2001, and participants now include international academic and scientific organizations and government entities such as Roscosmos. The Keldysh Institute of Applied Mathematics coordinates sensor tasking and fuses information from nearly 100 ground-based optical sensors on 40 observatories spread across 16 countries.[207,208]

C4ISR and weapons guidance systems with new technology, data transfer, and capabilities for peacetime and wartime use by 2020.[209,210]

Image Source: Russia Ministry of Defense/Creative Commons 4.0 Copyright

Russia has invested heavily in developing sophisticated electronic warfare capabilities, including this Krashuka-4 jammer.

Directed Energy Weapons. Russia likely is pursuing laser weapons to disrupt, degrade, or damage satellites and their sensors. Prior to July 2018, Russia began delivering a laser weapon system to the Aerospace Forces that likely is intended for an ASAT mission. In public statements, President Vladimir Putin called it a "new type of strategic weapon," and the Russian Defense Ministry asserted that it is capable of "fighting satellites in orbit."[211,212,213,214] Russia is also developing an airborne ASAT laser weapon system to use against space-based missile defense sensors.[215]

Image Source: SPUTNIK/AFP

Russian laser weapon likely intended for use against satellites, July 2018.

Cyberspace Threats. Since at least 2010, the Russian military has prioritized the development of forces and capabilities, including cyberspace operations, for what it terms "information confrontation," which is a holistic concept for ensuring information superiority. The weaponization of information is a key aspect of this strategy and is employed in times of peace, crisis, and war. Russia considers the information sphere to be strategically decisive and has taken steps to modernize its military's information attack and defense organizations and capabilities.[216]

Orbital Threats. Russia continues to research and develop sophisticated on-orbit capabilities that could serve dual-use purposes. For example, inspection and servicing satellites can be capable of closely approaching satellites to inspect and potentially fix issues causing malfunctions; this same technology could also be used to approach another country's satellite and conduct an attack that results in temporary or permanent damage.[217] In 2017, Russia deployed what it described as an "inspector satellite capable of diagnosing the technical condition of a Russian satellite from the closest possible distance"; however, its behavior is inconsistent with on-orbit inspection activities or space situational awareness capabilities.[218,219,220]

Ground-based Kinetic Energy Threats. Russia likely is developing a ground-based, mobile missile system capable of destroying space targets in LEO and ballistic missiles.[221,222] This weapon system is likely to be operational within the next several years.[223]

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OTHER SPACE CHALLENGES

Iran

Iran recognizes the strategic value of space and counterspace capabilities and will attempt to deny an adversary use of space during a conflict. Tehran has publically acknowledged it has developed capabilities to jam communications and GPS signals.[224,225,226] Tehran may also contribute to the proliferation of jamming equipment. Since 2010, Iran Electronics Industries has marketed several GPS jammers on its website.[227]

Tehran's pursuit of a national space program supports both civilian and military goals, including boosting national pride, economic development, and military modernization.[228] The Iran Space Agency and Iran Space Research Center—which are subordinate to the Ministry of Information and Communications Technology—along with the Ministry of Defense and Armed Forces Logistics oversee the country's SLV and satellite development programs. Iran is also seeking to improve its space object tracking capabilities and, in 2005, joined the Asia-Pacific Space Cooperation Organization.[229,230,231,232,233]


Image Source: AFP

Iran launched its first satellite on its Safir space launch vehicle in February 2009.[234]

Tehran states it has developed sophisticated capabilities, including SLVs and communications and remote sensing satellites, but its SLVs are only able to launch microsatellites into LEO and have proven unreliable. Nonetheless, Iran has had a few successful launches of the two-stage Safir SLV since its first attempt in 2008. It has also revealed the larger two-stage Simorgh SLV, which could serve as a test bed for developing intercontinental ballistic missile (ICBM) technologies. Because of the inherent overlap in technology between ICBMs and SLVs, Iran's development of larger, more capable SLV boosters remains a concern for a future ICBM capability. Also, these advancements could be applied to developing a basic ground-based ASAT missile, should Iran choose to do so in the future.[235,236,237,238]

North Korea

North Korea's space program is administered by a state-run civilian agency, the National Aerospace Development Administration.[239] North Korea's space launch complex on the west coast, the Sohae Satellite Launching Station and associated space tracking facilities in Pyongyang both supported satellite launch cycles in 2012 and 2016.[240,241] An older space launch site on the east coast has not been used for a launch since 2009.[242]

Similar to Iran, North Korea will try to deny an adversary use of space during a conflict. North Korea has demonstrated non-kinetic counterspace capabilities, including GPS and satellite communication jamming.[243,244,245] North Korea also has ballistic missiles and space launch vehicles that can reach orbit and could, in theory, be used to target satellites in a conflict.[246]

Although North Korea placed two satellites in orbit and has in the past articulated further space ambitions, their program enabled them to test technology used in ballistic missiles under the guise of peaceful use of space.[247,248,249] These systems provided North Korea with valuable data applicable to the development of long-range, multistage ballistic missiles.[250]

Image Source: AFP

A Taepo Dong 2/Unha-3 space launch vehicle preparing for launch, April 2012. The launch failed, but an attempt later that year was successful.[251]

OUTLOOK

Today, space has become a seamless part of many military and civilian activities. The advantages the United States holds in space capabilities will drive some nations to improve their abilities to access and operate in space. Moreover, some actors will seek counterspace capabilities that target the perceived United States and allied reliance on space, including the ability to use secure satellite communications, precision strike capabilities, and ISR assets.

China and Russia will continue to improve their space programs, including ISR, communications, space launch, and human spaceflight. Commercially, both will compete internationally to build satellites and supply space launch, navigation, and ISR services.

Beijing and Moscow will continue to see space as integral to winning modern wars. They are developing systems that pose a threat to freedom of action in space. Both will continue their efforts to enhance their space and counterspace capabilities, and better integrate them into their respective militaries.

Iran and North Korea will avail themselves of space-based services, such as ISR, communications, and navigation, to increase their capabilities in civil and military domains.[252] Both will maintain their ability to conduct EW against adversaries and theoretically could use their missile and SLV advancements to target orbiting satellites.

Globally, the space industry will continue to expand as technological and cost barriers fall and international partnerships for joint production grow. State, non-state, and commercial actors increasingly will have access to information from space.[253] The number of satellites and debris on orbit will grow concurrently, making tracking satellites, discriminating threats from non-threats, and predicting and preventing collisions a greater challenge.[254,255]

As the number of spacefaring nations grows and as some actors integrate space and counterspace capabilities into military operations, these trends will pose a challenge to U.S. space dominance and present new risks for assets on orbit.

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APPENDIX A: Implications of Debris and Orbital Collisions

Approximately 21,000 large objects—which are at least 10 cm in size—are tracked and catalogued in Earth's orbit, and only about 1,800 of them are active satellites. The remaining objects are debris, which includes derelict spacecraft, upper stages of SLVs, and remnants from explosions or collisions. The length of time debris remains in orbit depends on the altitude, ranging from a few years for objects below 600 kilometers to over a century for objects at higher orbits. The vast majority of debris harmlessly burns up in the atmosphere upon reentry.[256]

Prior to 2007, most debris was from explosions of upper stages of SLVs. Today, more than one third of all catalogued debris is from two major events: China's destruction of a defunct satellite in 2007 and the accidental collision between a U.S. communications satellite and a defunct Russian satellite in 2009.[257] Breakups, collisions, and explosions from derelict objects will continue to add to the amount of space debris on orbit.

Space debris can cause damage and destruction to satellites and spacecraft, as well as increase costs if satellite manufacturers add additional shielding and fuel to allow for more frequent avoidance maneuvers. Between 1998 and 2017, the International Space Station, which is in LEO, has maneuvered at least 25 times to avoid potential orbital collisions.[258] With an expected increase in large constellations of satellites and space debris, there is higher potential for satellite collisions, particularly in LEO.[259]

The increase in number of objects on orbit has implications for policymakers worldwide and is encouraging the development of space debris removal technology.[260] This technology is dual-use because it could be used to damage another satellite.[261]

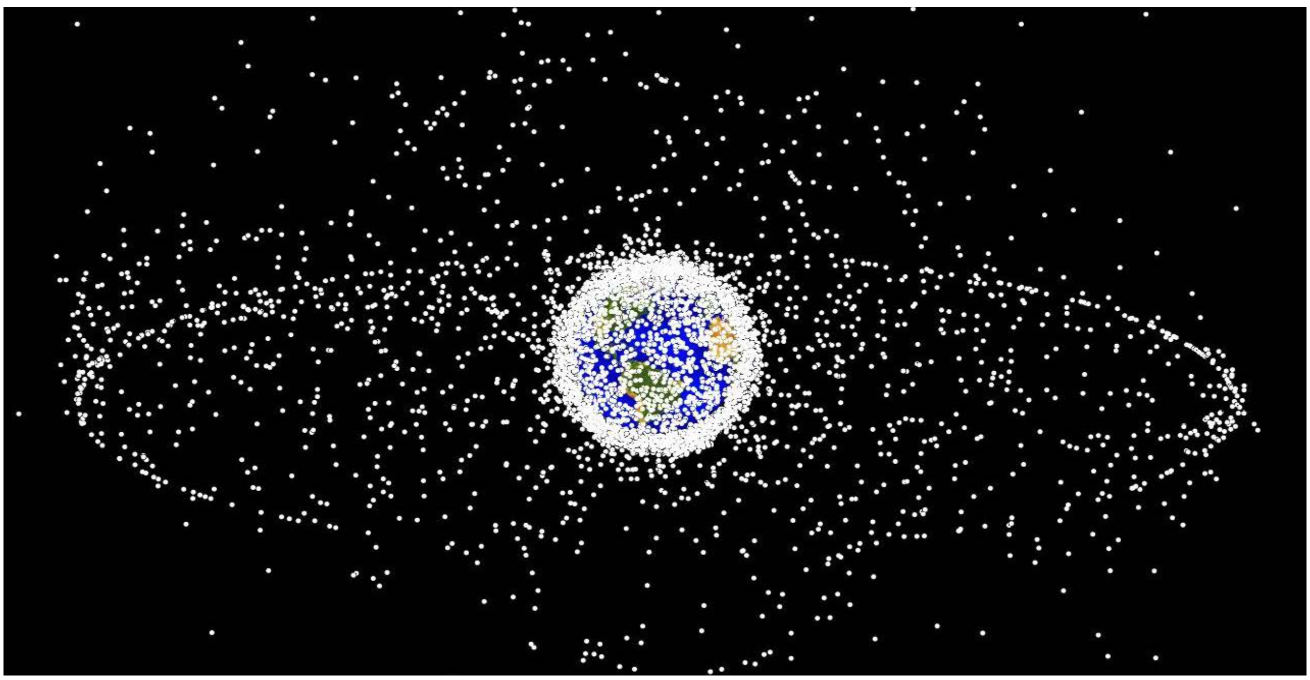
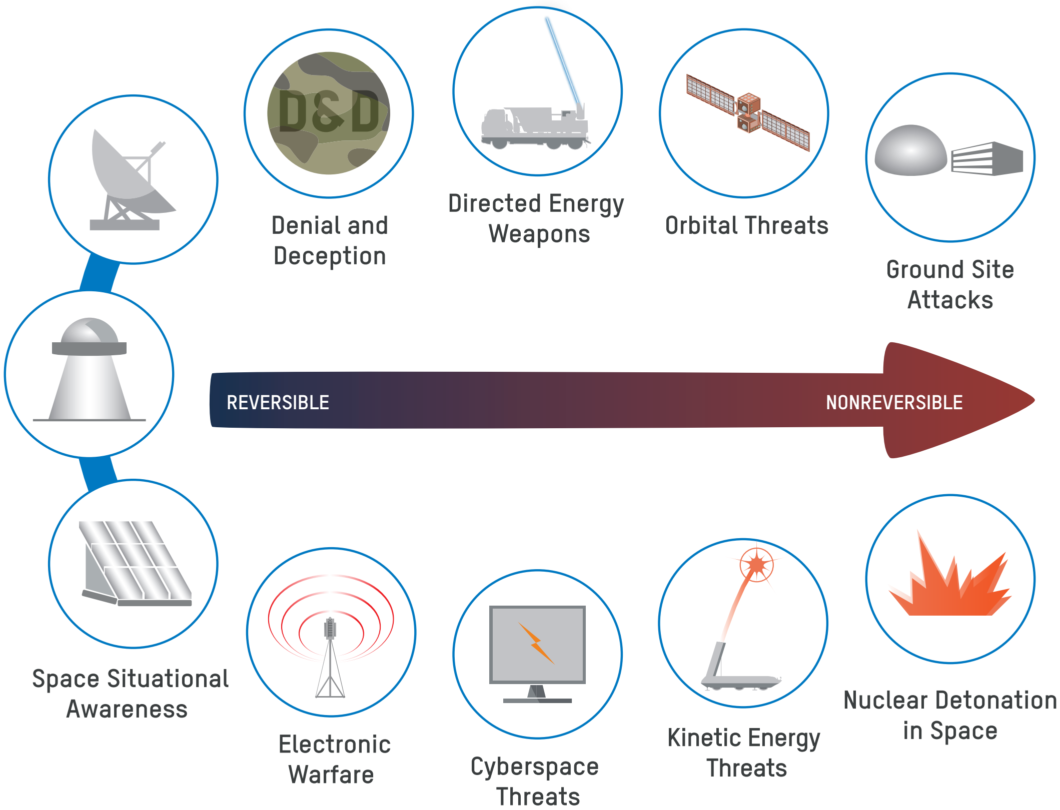


Image Source: NASA

Computer rendering of tracked large objects in Earth's orbit. Roughly 90 percent of the objects are orbital debris, not active satellites.

APPENDIX B: Counterspace Threats

Counterspace Continuum



Visualization: DIA, D3 Design • 1811-20013

The counterspace continuum represents the range of threats to space-based services, arranged from reversible to nonreversible effects. Reversible effects from denial and deception and EW are non-destructive and temporary, and the system remains capable of resuming normal operations after the incident. DEW, cyberspace threats, and orbital threats can cause temporary or permanent effects. Nonreversible effects from kinetic energy threats, physical attacks against space-related ground infrastructure, and nuclear detonation in space result in degradation or physical destruction of a space capability. In addition to counterspace capabilities already discussed, several others can be used to deny, degrade, or destroy space systems.

Denial and Deception: Actors can use knowledge of when satellites pass overhead to camouflage and conceal their activities on the ground.

Ground Site Attack: An actor could attack a ground site using physical means, disrupting an ability to communicate with and operate satellites.

Nuclear Detonation in Space: Countries that can launch a nuclear weapon with a long range rocket, such as an ICBM or SLV, likely are capable of conducting a high-altitude nuclear detonation. Both the United States and Soviet Union detonated nuclear weapons above the atmosphere in the early 1960s.[262]

APPENDIX C: Glossary of Acronyms

APOSOS	Asia-Pacific Ground-Based Optical Space Object Observation System
ASAT	Anti-satellite
C2	Command and control
C4ISR	Command, control, communications, computers, intelligence, surveillance, and reconnaissance
CNSA	China National Space Administration
DEW	Directed energy weapon
EW	Electronic warfare
GEO	Geosynchronous Earth orbit
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
HEO	Highly elliptical orbit
ICBM	Intercontinental ballistic missile
ISR	Intelligence, surveillance, and reconnaissance
KZ	Kuaizhou space launch vehicle
LEO	Low Earth orbit
LM	Long March space launch vehicle
MEO	Medium Earth orbit
PLA	People's Liberation Army
PNT	Position, navigation, and timing
SAR	Synthetic aperture radar
SASTIND	China's State Administration for Science, Technology, and Industry for National Defense
SATCOM	Satellite communications
SLV	Space launch vehicle
SSA	Space situational awareness
SSF	Strategic Support Force

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