DEFENSE INTELLIGENCE AGENCY

2022 CHALLENGES TO SECURITY IN SPACE

Space Reliance in an Era of Competition and Expansion

Committed to Excellence in Defense of the Nation

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Cover image, Cislunar space domain viewed from beyond the far side of the Moon:
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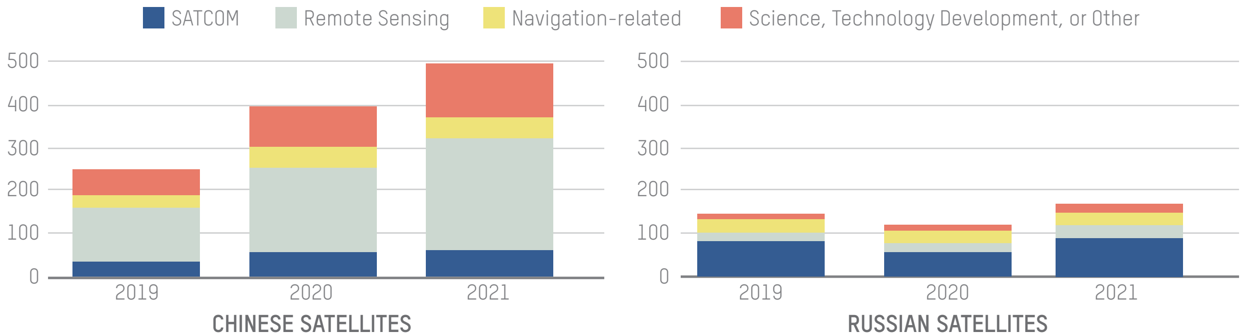
SCOPE NOTE

Challenges to Security in Space was first published in early 2019 to address the main threats to the array of U.S. space capabilities, and examine space and counterspace strategies and systems pursued primarily by China and Russia and, to a lesser extent, by North Korea and Iran. This second edition builds on that work and provides an updated, unclassified overview of the threats to U.S. space capabilities, particularly from China and Russia, as those threats continue to expand.

Growth of All Chinese and Russian Satellites In-Orbit, 2019–2021



End of year totals are represented for 2019 through 2021. China's and Russia's combined, in-orbit satellite fleets will continue to grow. *Source: Union of Concerned Scientists, 1 January 2022, Satellite Database.*

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Between 2019 and 2021 the combined operational space fleets of China and Russia have grown by approximately 70 percent. This recent and continuing expansion follows a period of growth (2015–2018) where China and Russia had increased their combined satellite fleets by more than 200 percent. The drive to modernize and increase capabilities for both countries is reflected in nearly all major space categories—satellite communications (SATCOM), remote sensing, navigation-related, and science and technology demonstration.

Since early 2019, competitor space operations have also increased in pace and scope worldwide, China's and Russia's counterspace developments continue to mature, global space services proliferate, and orbital congestion has increased. As a result, DIA has published this new edition to:

- Expand its examination of competitor space situational awareness (SSA), and command and control (C2) capabilities;
- Detail the profiles of organizations operating space and counterspace systems based on new information;
- Deepen our characterization of new space and counterspace systems deployed and in development;
- Focus on China's and Russia's interests in exploring the Moon and Mars;
- Provide a new section on the use of space beyond Earth orbit and its implications;
- Widen our treatment on the threats posed to all nations' space operations from space debris.

EXECUTIVE SUMMARY

Space Reliance In An Era Of Competition And Expansion

Capabilities. Space-based capabilities impact many day-to-day aspects of the American way of life. These capabilities enable functions that affect our homes, transportation, electric power grids, banking systems, and our global communications. Satellites provide access to a broad range of information and enable many services in real time, from watching breaking news to monitoring our deployed armed forces around the world day or night. These and other benefits enabled by space systems are the result of more than 60 years of dedicated work by government agencies—military and civilian—supported by many commercial space providers. Space systems also enable the United States and our allies to project combat power to areas of conflict and instability and allow our armed forces to collect vital intelligence on foreign threats, to navigate and maneuver rapidly, and to communicate with each other anywhere around the globe to ensure our security and quick response to international military and humanitarian crises.

Competition. Space competition between the United States and the former Soviet Union began in earnest with Moscow's launch of the world's first artificial satellite, Sputnik-1, in 1957. China's emergence as a space power in the late 20th and early 21st century and Russia's post-Soviet resurgence have expanded the militarization of space as both countries integrate space and counterspace capabilities into their national and warfighting strategies to challenge the United States. Adversaries have observed more than 30 years of U.S. military operations supported by space systems and are now seeking ways to expand their own capabilities and deny the U.S. a space-enabled advantage.[1]

China and Russia, in particular, are developing various means to exploit the perceived U.S. reliance on space-based systems and challenge the U.S. position in the space domain.[2] Beijing and Moscow seek to position themselves as leading space powers, intent on creating new global space norms. Through the use of space and counterspace capabilities, they aspire to undercut U.S. global leadership. Iran and North Korea will continue to develop and operate electronic warfare (EW) capabilities to deny or degrade space-based communications and navigation.[3]

Proliferation. Space capabilities are increasing across a growing list of nations, including: missile warning, geolocation and tracking of friendly and adversary activities, target identification, and navigation services for their citizens and armed forces. Expanding constellations of remote-sensing satellites are reducing all countries' ability to conceal sensitive tests, evaluation activities, and military exercises and operations.[4, 5]

Space commercialization is also growing as companies augment or replace government-provided launch, communications, SSA, remote-sensing—also referred to intelligence, surveillance, and reconnaissance (ISR)— and human spaceflight services. These firms are opening access to space technologies, services, and products to government and nongovernment entities that can pay for their capabilities.[6,7,8] The growth of viable commercial space enterprises best represents how the use of space has expanded in scope, scale, and importance across the globe.

Counterspace. Space is being increasingly militarized. Some nations have developed, tested, and deployed various satellites and some counterspace weapons. China and Russia are developing new space systems to improve their military effectiveness and reduce any reliance on U.S. space systems such as the Global Positioning System (GPS). Beijing and Moscow have also created separate space forces. As China's and Russia's space and counterspace capabilities increase, both nations are integrating space scenarios into their military exercises. They continue to develop, test, and proliferate sophisticated antisatellite (ASAT) weapons to hold U.S. and allied space assets at risk. At the same time, China and Russia are pursuing nonweaponization of space agreements in the United Nations.[9] Russia regularly expresses concern about space weapons and is pursuing legal, binding space arms control agreements to curb what it sees as U.S. strength in outer space.[10,11] The expansion of Chinese and Russian space and counterspace weapons combined with the general rise of other foreign space capabilities is driving many nations to formalize their space policies to better position themselves to secure the space domain and facilitate their own space services.[12,13,14,15,16,17,18,19,20,21,22,23,24,25]

Collisions. The probability of collisions of massive derelict objects in low Earth orbit (LEO) is growing and almost certainly will continue through at least 2030 because of rising numbers of space launches—especially those with multiple payloads—and continuing fragmentation from collisions, battery explosions, and further ASAT testing events.

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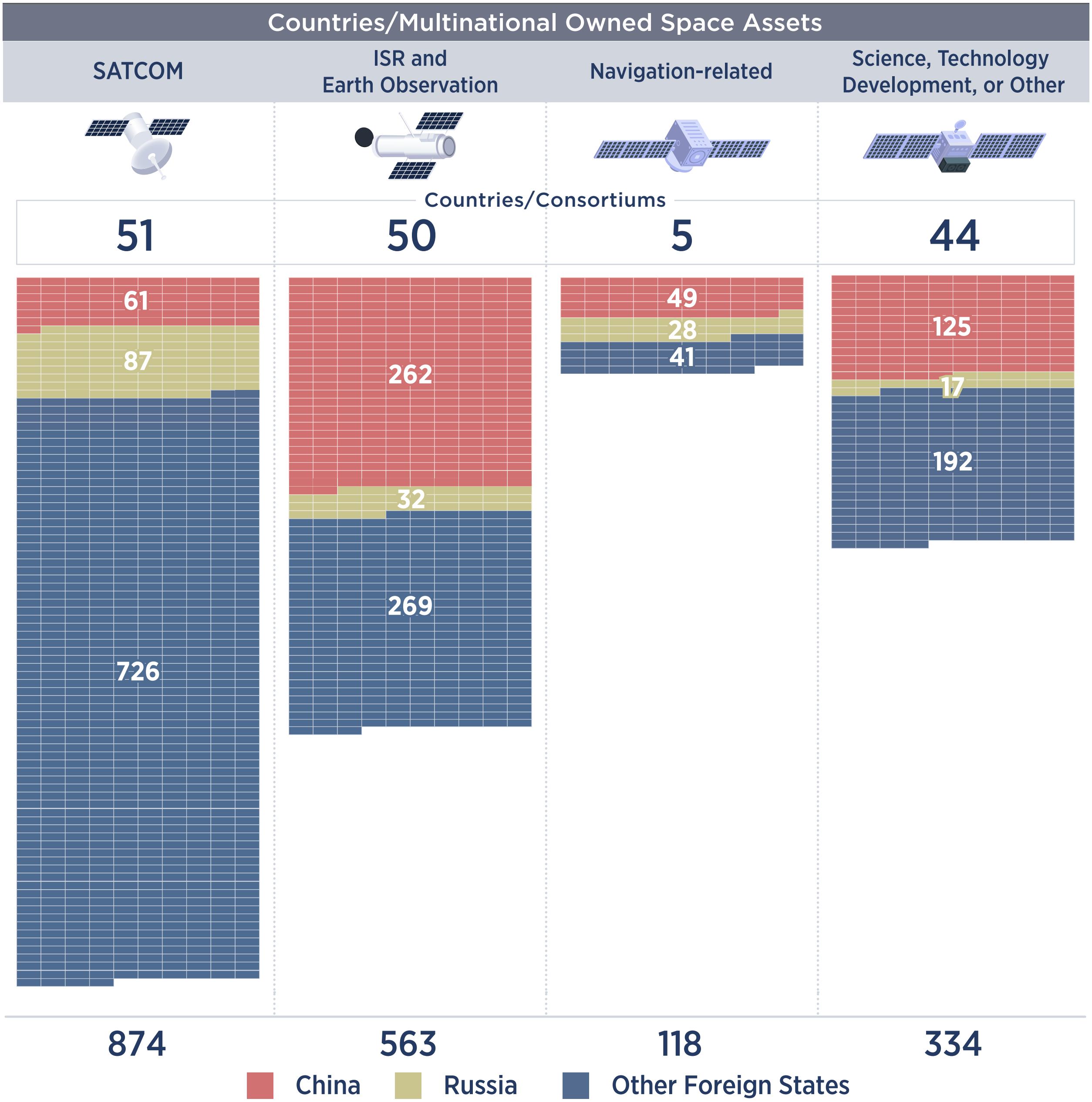
Active Foreign Satellites



Source: Union of Concerned Scientists, 1 January 2022, Satellite Database

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SPACE CAPABILITIES

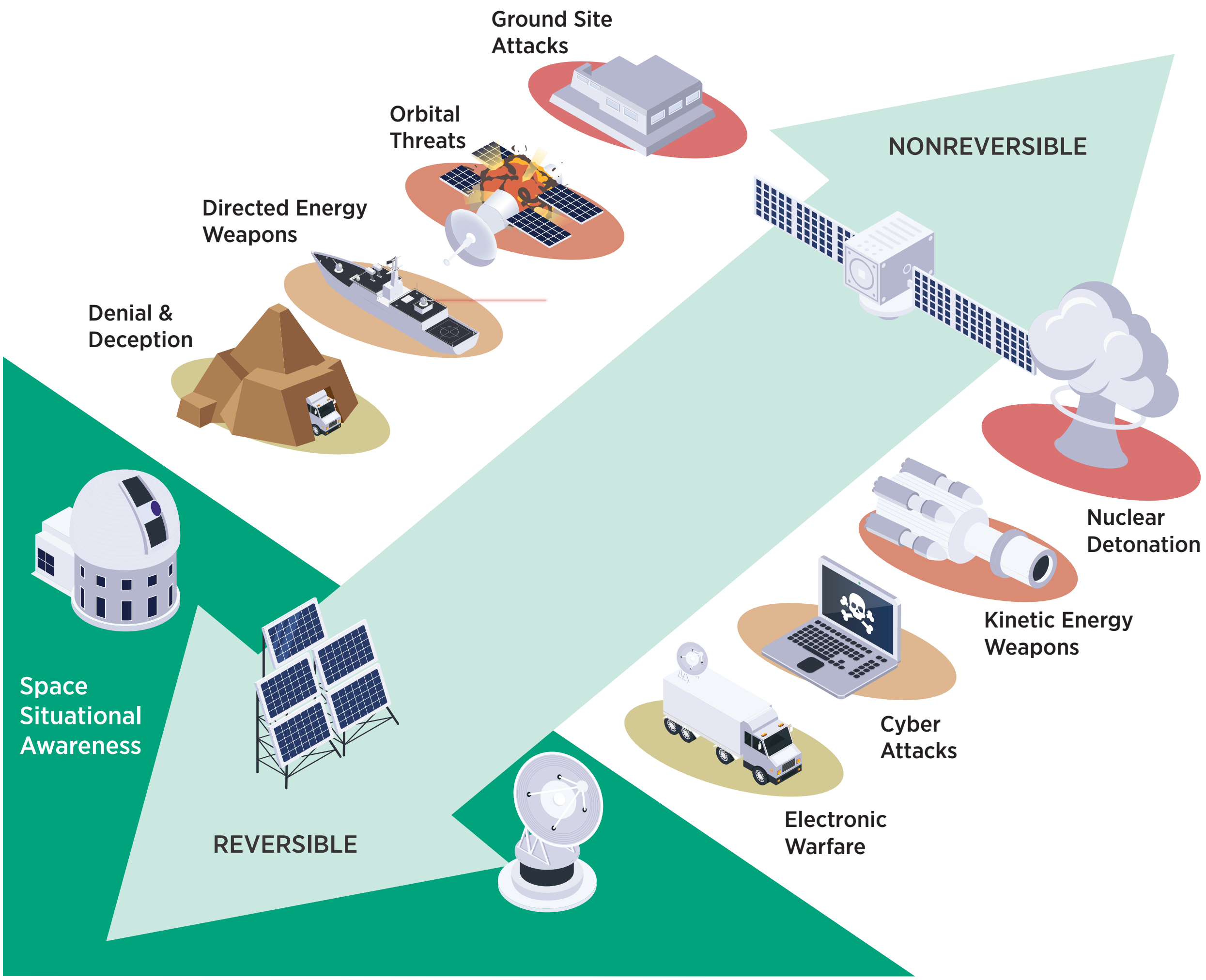
Space-based remote-sensing, communication, and navigation systems are used for various commercial, civilian, and military applications. Many nations, including China and Russia, have recognized the benefits of investing in and using space technologies. Those space capabilities include:

- Space-based remote-sensing or ISR satellites gather data of security concern and support intelligence and military activities, such as tracking and monitoring military forces and observing related events and locations. Space-based remote-sensing also supports civilian activities, such as crop and weather monitoring, as well as disaster response sites and operations.[26]
- Satellite communications is used for beyond-line-of-sight communications, including voice and television services. Communications satellites also enable Internet and other communications to reach remote areas without direct connectivity. Military SATCOM improves C2, allowing for greater mobility over greater distances by eliminating the need for ground-based infrastructure.[27]
- Positioning, navigation, and timing (PNT) services transmit timing signals for various applications, including air, land, sea, and space navigation; asset tracking; and precision weapons guidance. PNT also supports civilian transportation; precision farming; autonomous vehicle guidance; time synchronization for electrical power grids and banking transactions; communications across wireless Internet and emergency medical, fire, and police services; as well as navigation services for rail, road, air, and ocean cargo operations.[28]
- Space launch vehicles (SLVs) place objects in Earth orbit or put them on trajectories to explore the farthest reaches of space. For decades, this capability was restricted to a few spacefaring nations. The number of organizations able to launch satellites is small and placing satellites in orbit has usually been the largest expense in space operations. However, during the past 10–12 years, other nations have been developing SLVs, and increasing numbers of commercial entities worldwide have steadily fielded new capabilities. As a result, the average price, and thus barrier, to entry into space, has declined.[29]

As more nations and more services depend on space-based capabilities—especially in critical social and economic sectors, such as medical, disaster response, weather forecasting, and financial transactions—the loss or degradation of those capabilities will increasingly disrupt daily life.[30] Space asset disruption will probably lead to degradation of critical military and intelligence capabilities. Such disruptions can deny access to space for scientific purposes and negatively impact technological innovation.[31,32,33]

[See the Appendix on Space and Counterspace Concepts for additional details.]

Counterspace Threat Continuum



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 nondestructive and temporary, and the system is able to resume normal operations after the incident. Directed energy weapons (DEW), cyberspace threats, and orbital threats can cause temporary or permanent effects. Permanent effects from kinetic energy attacks on space systems, physical attacks against space-related ground infrastructure, and nuclear detonation in space would result in degradation or physical destruction of a space capability.

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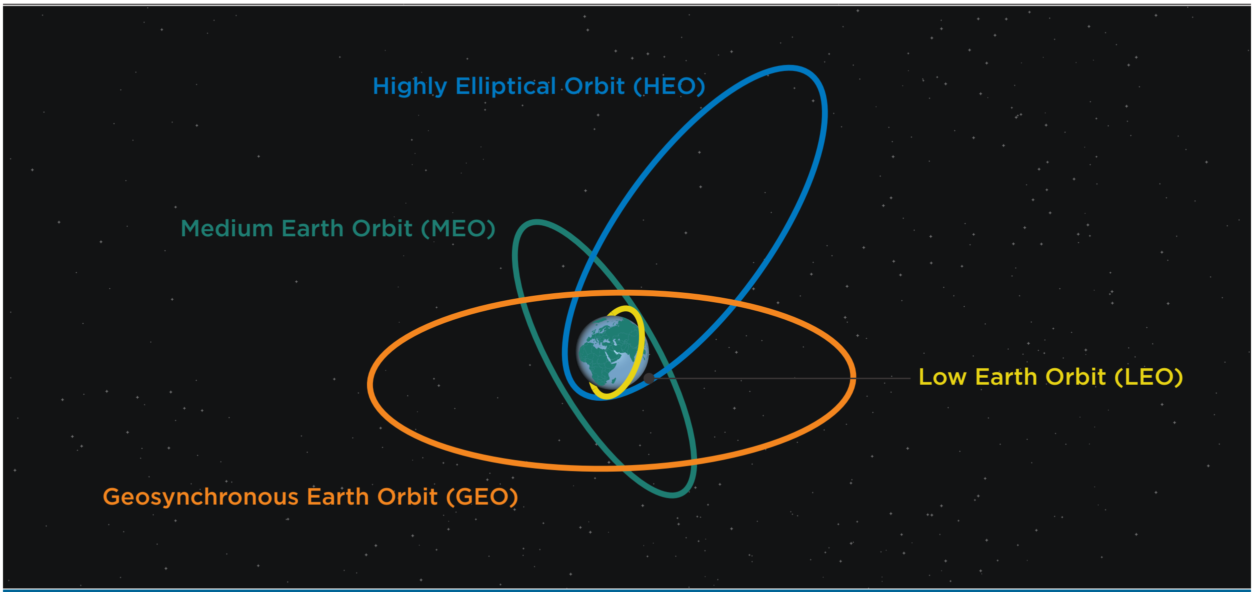
DENYING SPACE

Competitor nations have capabilities to deny others the use of space assets. Space is a critical enabler for U.S. and allied military forces during operations, exercises, and logistics around the world providing for near-instantaneous communications, situational awareness, and precision navigation for our forces. Military and civilian space services are not easily separated. Actions taken by any nation to interfere with space services used by the military probably would deny civilian space services as well, either accidentally or with purpose. Although many counterspace weapons are intended to degrade space services temporarily, others can damage or destroy satellites permanently.

- Physical or cyberattacks against ground sites and infrastructure supporting space operations can threaten satellite services.
- Space situational awareness sensors predict when satellites pass overhead. This allows for tracking, warning, and, if necessary, targeting of space-based systems.
- Adversaries can jam global navigation and communications satellites used for C2 of naval, ground, and air forces as well as manned and unmanned vehicles.
- Adversary DEWs that target ISR satellites almost certainly are able to temporarily or permanently blind imagery satellites and other strategic sensors, thereby denying the ability to monitor, track, and target forces.
- Adversary ASAT missiles can be used to attack satellites in LEO and would produce massive amounts of debris that can remain in orbit for decades or even centuries. China tested an ASAT missile against its own defunct weather satellite in 2007, which created a debris cloud that poses a threat to satellites in nearby orbits today.[34] Russia used an ASAT missile as recently as 15 November 2021 to destroy one of its derelict satellites in orbit.[35]
- Other space-based weapons can deliver temporary or permanent effects on other satellites.

Countries with nuclear weapons can launch a warhead on a long-range booster, such as an intercontinental ballistic missile (ICBM) or SLV, and probably conduct a high-altitude nuclear detonation, which would create widespread electromagnetic disruptions in space and on Earth leading to potential damage or destruction of satellites.[36]

Orbit Types and Uses[37,38]



Orbit	Altitude*	Uses
Low Earth Orbit	Up to 2,000 kilometers	- Communications - ISR - Human Spaceflight †
Medium Earth Orbit	Approx. 2,000 to 20,000 kilometers	- Communications - Positioning, Navigation, and Timing
Highly Elliptical Orbit	LEO altitudes at perigee (nearest to Earth) Approx. 40,000 kilometers at apogee (farthest from Earth)	- Communications - ISR - Missile Warning
Geosynchronous Earth Orbit	Approx. 36,000 kilometers	- 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, with the exception of Earth's polar regions where it is limited. 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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Image Source: Noel CELIS/AFP

Long March-5 (LM-5) carrying China's Tianwen-1 mission to Mars, launching from Wenchang Space Launch Center.

CHINA

Exploring the vast universe, developing space programs, and becoming an aerospace power have always been the dream we have been striving for.

—Xi Jinping, General Secretary of the Chinese Communist Party, 24 April 2016, Remarks on the first China Space Day[39]

Space has already become a new domain of modern military struggle; it is a critical factor for deciding military transformation; and it has an extremely important influence on the evolution of future form-states, modes, and rules of war. Therefore, following with interest the military struggle circumstance of space and strengthening the study of the space military struggle problem is a very important topic we are currently facing.

—China's *Science of Military Strategy*, 2020 *National Defense University* [40]

China has devoted considerable economic and technological resources to growing all aspects of its space program, improving military space applications, developing human spaceflight, and conducting lunar and Martian exploration missions.[41] During the past 10 years, China has doubled its launches per year and the number of satellites in orbit.[42,43] China has placed three space stations in orbit, two of which have since deorbited, and the third of which launched in 2021.[44,45,46,47,48] Furthermore, China has launched a robotic lander and rover to the far side of the Moon;[49] a lander and sample return mission to the Moon;[50,51,52,53] and an orbiter, lander, and rover in one mission to Mars.[54,55,56] China has also launched multiple ASAT missiles that are able to destroy satellites and developed mobile jammers to deny SATCOM and GPS.[57,58,59,60,61,62,63]

Beijing's goal is to become a broad-based, fully capable space power.[64] Its rapidly growing space program—second only to the United States in the number of operational satellites—is a source of national pride and part of Chairman Xi Jinping's "China Dream" to establish a powerful and prosperous China. The space program, managed by the People's Liberation Army (PLA), supports both civilian and military interests, including strengthening its science and technology sector, growing international relationships, and modernizing the military. China seeks to rapidly achieve these goals through advances in the research and development of space systems and space-related technology.[65,66,67,68,69]

China will continue to launch a range of satellites that substantially enhance its ISR capabilities; field advanced communications satellites able to transmit large amounts of data; increase PNT capabilities; and deploy new weather and oceanographic satellites.[70] China has also developed and probably will continue to develop weapons for use against satellites in orbit to degrade and deny adversary space capabilities.[71,72,73]

Image Source: Xinhua via AFP

The Beijing Aerospace Control Center (BACC) during the 2 August 2020 launch of the Tianwen-1 mission to Mars.

Military Strategic Guidelines

In 2015, Beijing's official release of *China's Military Strategy* directed the PLA to research and give priority to strategies to win "informatized local wars" and emphasized "maritime military struggle."[74] Chinese military strategy documents also emphasize the growing importance of offensive air, long-distance mobility, and space and cyberspace operations. China expects its future wars to be fought mostly outside its borders and in the maritime domain. China promulgated its military strategy and the supporting documents 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.[75]

The PLA uses "informatized warfare" to describe the process of acquiring, transmitting, processing, and using information to conduct joint military operations across the land, sea, air, space, and cyberspace domains and the electromagnetic spectrum during a conflict. PLA writings guide much of China's military modernization today and highlight the benefit of near-real-time shared awareness of the battlefield in enabling quick, unified efforts to seize tactical opportunities. In November 2020, China's Central Military Commission issued a trial update to PLA joint doctrine to codify warfighting reforms and will almost certainly improve its ability to conduct joint operations.[76] Space-based systems will play an increasingly important role in support of these goals.[77]

Space Strategy and Doctrine

China officially advocates for the peaceful use of space and is pursuing agreements in the United Nations on the nonweaponization of space.[78] China also continues to improve its counterspace weapons capabilities and has enacted military reforms to better integrate cyberspace, space, and EW into joint military operations. China's space strategy is expected to evolve over time, keeping pace with the application of new space technology. These changes probably will be reflected in published national space strategy documents, through space policy actions, and in programs enacted by political and military leadership.

The PLA views space superiority, the ability to control the space-enabled information sphere and to deny adversaries their own space-based information gathering and communication capabilities, as a critical component to conduct modern "informatized warfare."[79,80,81,82] China's first public mention of space and counterspace capabilities came as early as 1971, largely from academics reviewing foreign publications on ASAT technologies. However, Chinese science and technology efforts on space began to accelerate in the 1980s, most likely as a result of the U.S. space-focused Strategic Defense Initiative to defend against the former Soviet Union's nuclear weapons.[83] Subsequently, after observing the U.S. military's performance during the 1991 Gulf War through actions in Kosovo, Afghanistan, and the second Iraq War, the PLA embarked on an effort to modernize weapon systems, across all domains including space, and update its doctrine to focus on using and countering adversary information-enabled warfare.[84]

China's perceptions of the importance of space-enabled operations to the United States and its allies has shaped integral components of PLA military planning and campaigns. In addition, space is a critical enabler of beyond-line-of-sight operations for deployed Chinese forces, and the PLA probably sees counterspace operations as a means to deter and counter a U.S. intervention during a regional military conflict.[85,86] China has claimed that "destroying or capturing satellites and other sensors" would make it difficult for the U.S. and allied militaries to use precision-guided weapons.[87] Moreover, Chinese defense academics suggest that reconnaissance, communication, navigation, and early warning satellites could be among the targets of attacks designed to "blind and deafen the enemy."[88]

Space and Counterspace Organizations

China's space program comprises organizations in the military, political, defense-industrial, and commercial sectors. The PLA historically has managed China's space program and continues to invest in improving China's capabilities in space-based ISR, SATCOM, satellite navigation, human spaceflight, and robotic space exploration.[89] Although state-owned enterprises are China's primary civilian and military space contractors, China is placing greater emphasis on decentralizing and diversifying its space industry to increase competition.[90]

In 2015, China established the Strategic Support Force (SSF) to integrate cyberspace, space, and EW capabilities into joint military operations as part of its military reforms.[91,92,93] 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, led by PLA General Ju Qiansheng,[94] is divided into two major departments: the Space Systems Department (SSD), very likely consolidating the majority of the PLA's space functions, and the Network Systems Department (NSD), very likely in charge of cyberspace operations and EW.[95,96] The SSD focuses primarily on satellite launches and operations to support ISR, navigation, and communication requirements.[97] The SSD's China Launch and Tracking Control (CLTC) operates all four launch sites, in addition to Yuanwang space support ships, two major satellite control centers—Xian Satellite Control Center (XSCC) and the BACC—and the PLA telemetry, tracking, and control (TT&C) system for all Chinese satellites.[98,99] The EW functions of the PLA before 2015 were probably transferred to the NSD when it was stood up in 2015 as well.[100,101]

The State Council's State Administration for Science, Technology, and Industry for National Defense (SASTIND) is the primary civilian organization that coordinates and manages China's space activities, including allocating space research and development funds.[102] 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.[103]

The China National Space Administration (CNSA), subordinate to SASTIND, serves as the public face of China's civilian space efforts.[104] China is increasingly using CNSA efforts to bolster relationships with countries around the world, providing opportunities to cooperate on space issues.[105,106,107] As of 2019, China had more than a hundred cooperative space-related agreements with more than three dozen countries and four international organizations.[108,109]

Many space technologies can serve a civilian and military purpose and China emphasizes "military-civil fusion"—a phrase used, in part, to refer to the use of dual-use technologies, policies, and organizations for military benefit.[110] The SSF works with civilian organizations like universities and research organizations to incorporate civilian support to military efforts since there is an already high demand for aerospace talent and competition for finite human resources.[111] China's commercial space sector features partially state-owned enterprises such as Zhuhai Orbita, Expace, Galactic Energy, and OK-Space for remote sensing, launch, and communication services.[112,113,114,115]

Acquisition of Foreign Space and Counterspace Technologies

The PLA continues to rely on overt and covert acquisition of foreign space and counterspace technologies to build Chinese knowledge and advance technological modernization as a supplement to its domestic research. China uses traditional technical espionage and cyberespionage techniques as well as its open-source collection network, technology transfer organizations, and exploitation of overseas scholars. Acquisition of foreign technology is used to circumvent the costs of research and facilitate “leapfrog” development by exploiting the creativity of other nations.[116]

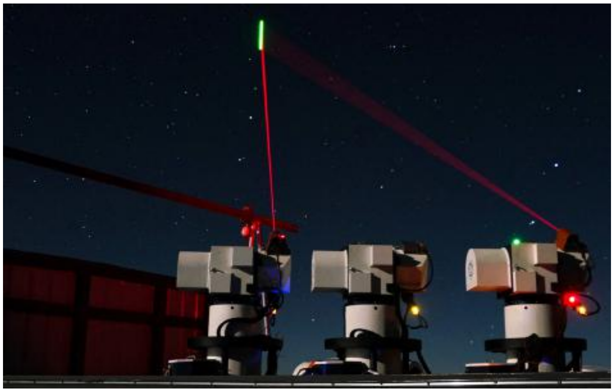


Image Source: Xinhua via AFP

A 10 December 2016 satellite-to-Earth link from Ali, Tibetan Autonomous Region to China’s Micius Quantum Teleportation Satellite Experiment.

ISR Satellite Capabilities

China employs a robust space-based ISR capability designed to enhance its worldwide situational awareness. Used for military and civilian remote sensing and mapping, terrestrial and maritime surveillance, and intelligence collection, China’s ISR satellites are capable of providing electro-optical and synthetic aperture radar (SAR) imagery as well as electronic and signals intelligence data.[117] China also exports its satellite technology globally, including its domestically developed remote-sensing satellites.

As of January 2022, China’s ISR satellite fleet contained more than 250 systems—a quantity second only to the United States, and nearly doubling China's in-orbit systems since 2018.[118,119] The PLA owns and operates about half of the world’s 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 monitor potential regional flashpoints, including the Korean Peninsula, Taiwan, Indian Ocean, and the South China Sea.[120,121,122]

Recent improvements to China’s space-based ISR capabilities emphasize the development, procurement, and use of increasingly capable satellites with digital camera technology as well as space-based radar for all-weather, 24-hour coverage. These improvements should increase China’s monitoring capabilities—including observation of U.S. aircraft carriers, expeditionary strike groups, and deployed air wings, making them more susceptible to long-range strikes. Space capabilities probably will enhance potential PLA military operations farther from the Chinese coast.[123,124,125,126] These capabilities are being augmented with electronic reconnaissance satellites that monitor radar and radio transmissions.[127]

Satellite Communications

China owns and operates more than 60 communications satellites, at least 4 of which are dedicated to military use.[128] China produces its military-dedicated satellites domestically. Its civilian communications satellites incorporate off-the-shelf commercially manufactured components.[129] China is fielding advanced communications satellites capable of transmitting large amounts of data.[130] Existing and future data relay satellites and other beyond-line-of-sight communications systems could convey critical targeting data to Chinese military operation centers.[131,132,133]

In addition, China is making progress on its ambitious plans to propel itself to the forefront of the global SATCOM industry.[134,135,136] China is continuing to test next-generation capabilities like its Quantum Experimentation at Space Scale (QUESS) space-based quantum-enabled communications satellite, which could supply the means to field highly secure communications systems.[137,138] In June 2020, a team of Chinese scientists claimed to achieve quantum supremacy, reporting successful satellite-based distributions of entangled photon pairs at a distance of more than 1,200 kilometers and that the photon pairs’ integrity remained intact after traveling such distances. Testing satellite-based quantum entanglement represents a major milestone in building a practical, global, ultrasecure quantum network, but the widespread deployment and adoption of this technology still faces hurdles.[139,140]

China also intends to provide SATCOM support to users worldwide and plans to develop at least seven new SATCOM constellations in LEO. However, as these constellations are still in the early stages of development their effectiveness remains uncertain.[141,142,143,144,145]

PNT Capabilities

China's satellite navigation system, known as BeiDou, is an independently constructed, developed, and exclusively China-operated PNT service. China's priorities for BeiDou are to support national security and economic and social development by adopting Chinese PNT into precise agriculture, monitoring of vehicles and ships, and aiding with civilian-focused services across more than 100 countries in Africa, Asia, and Europe.[146,147] BeiDou provides all-time, all-weather, and high-accuracy PNT services to users domestically, in the Asia-Pacific region, as well as globally and consists of 49 operational satellites.[148,149,150,151,152,153,154] Initially deployed to facilitate regional PNT services, BeiDou achieved worldwide initial operating capability in 2018.[155,156] In June 2020, China successfully launched the final satellite in the BeiDou satellite constellation, completing its global navigation system.[157] China's military uses BeiDou's high-accuracy PNT services to enable force movements and precision-guided munitions delivery.[161,162]

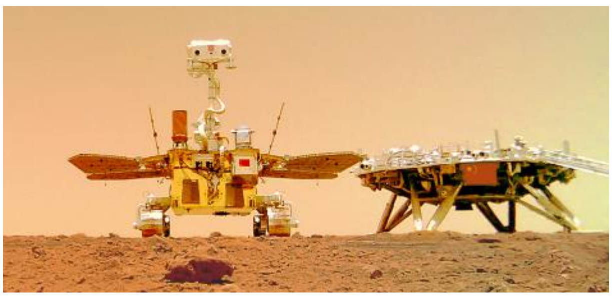


Image Source: Xinhua via AFP

China's Zhurong rover and Tianwen lander on Utopia Planitia, Mars, 11 June 2021.[158,159,160]

BeiDou has a worldwide positional accuracy standard of 10 meters; accuracy in the Asia-Pacific region is within 5 meters.[163] In addition to providing PNT, the BeiDou constellation offers unique capabilities, including text messaging and user tracking through its Regional Short Message Communication service to enable mass communications among BeiDou users. The system also provides additional military C2 capabilities for the PLA.[164,165,166]

China intends to use its BeiDou constellation to offer additional services and incentives to countries taking part in its Belt and Road Initiative emphasizing building strong economic ties to other countries to align partner nations with China's interests.[167,168] As of May 2021, China is predicting Beidou products and services will be worth $156 billion by 2025, and potentially export BeiDou products to more than 100 million users in 120 countries.[169]

Human Spaceflight and Space Exploration

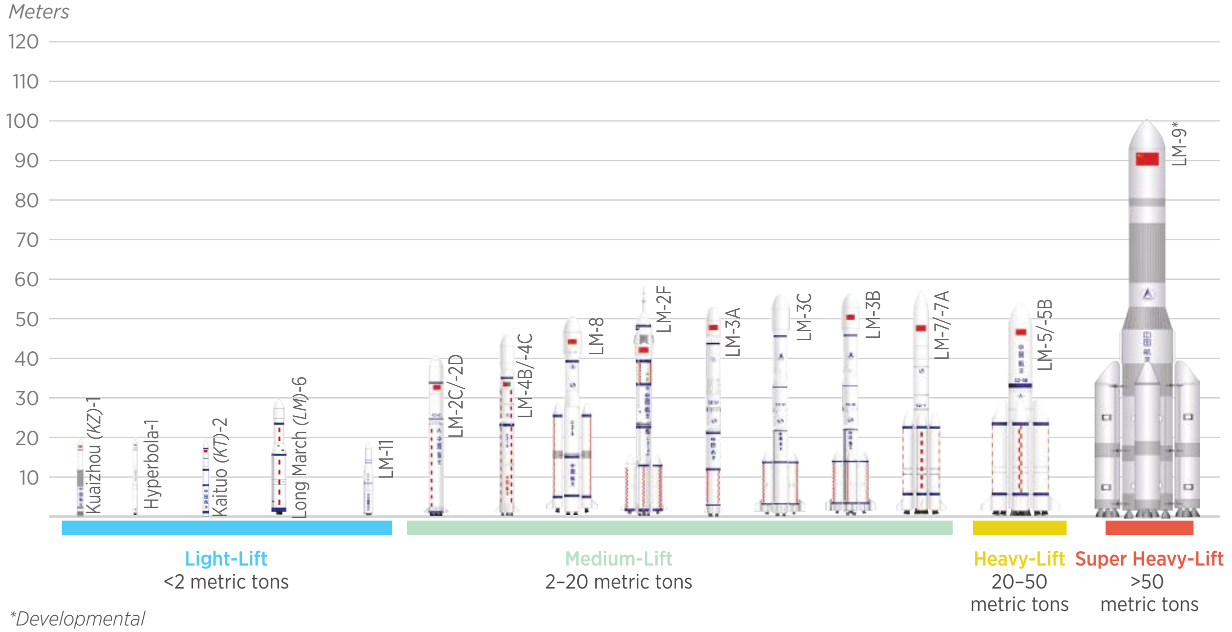
Following uncrewed missions that began in 1999, China became the third country to achieve independent human spaceflight when it successfully orbited the crewed Shenzhou-5 spacecraft in 2003.[170,171,172] In 2011, China then launched its first space station, Tiangong-1, and in 2016, it launched its second space station, Tiangong-2.[173,174,175] In 2020, China conducted its first orbital test of the New-Generation Manned Spaceship, which is expected to replace the Shenzhou series of crewed spacecraft.[176] On 29 April 2021, China launched the first element, Tianhe, of its new Tiangong space station.[177] Beijing launched the first supply vessel, Tianzhou, and has launched two Chinese crews since then.[178,179]

China has also taken on a greater role in deep space exploration and space science and has made notable accomplishments during the past several years. China has demonstrated its interest in working with Russia and the European Space Agency (ESA) to con

China: Space Exploration Missions

Mission	Description	Launch Date
Yinghou-1	Mars orbiter launched aboard Russian *Phobos-Grunt* space-craft. Mission failed to exit LEO.[180]	2011
XPNAV-1	The world's first X-ray navigation satellite test—uses distant X-ray pulsars to navigate and determine its location in the solar system within 5 kilometers.[181]	2016
SISASAIL-1	Solar sail technology test for future deep-space missions.[182]	2019
Chang'e-4	First-ever landing on lunar far side; mission included a rover and lander and the lunar relay satellite, which was launched in May 2018.[183,184,185,186]	2019
Tianwen-1	Martian orbiter, lander, and rover.[187,188,189,190]	2020
Chang'e-5	Robotic mission landed on the Moon, collected samples, and returned them to Earth.[191,192,193,194]	2020
Tiangong	Modular space station designed to host Chinese and foreign payloads and astronauts.[195,196,197,198,199,200]	2021–2022
Chang'e-6	Robotic mission to land, collect samples from the Moon's south pole, and return to Earth.[201]	2023
Chang'e-7	Orbiter, relay satellite, lander, rover, and flyby craft. The lander and rover will have ground-penetrating radar, surface magne-tometer, and a spectrometer for lunar exploration.[202]	2024
Chang'e-8	Test and verification mission for future lunar expeditions.[203]	TBD
Lunar Robotic Mission	Robotic research station on the Moon.[204,205]	2025
Human Lunar Program	Human lunar exploration program to put astronauts on the Moon.[206,207,208]	Mid-2030s
Lunar Research and Development Base	Establish a research base on the Moon, primarily supported by robotic technology and capable of supporting human visits.[209,210]	By 2050

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—specifically the LM-2, LM-3, and LM-4—to place larger satellites into LEO and 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 super heavy-lift LM-9 primarily will support missions to the Moon and Mars.

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duct deep-space exploration.[211,212] China is the third country to place a robotic rover on the Moon and was the first to land a rover on the lunar far side in 2019, which is communicating through the Queqiao relay satellite that China launched the year before to a stable orbit around an Earth-Moon Lagrange point [See Cislunar Chart, page 35].[213,214]

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. China continues to improve manufacturing efficiencies and launch capabilities overall, supporting continued human spaceflight and deep-space exploration missions—including to the Moon and Mars.[215] New modular SLVs that allow China to tailor an SLV to the specific configuration required for each customer are beginning to go into operation, leading to increased launch vehicle reliability and overall cost savings for launch campaigns.[216] China is also in the early stages of developing a super heavy-lift SLV similar to the U.S. Saturn V or the newer U.S. Space Launch System to support proposed crewed lunar and Mars exploration missions.[217]

In addition to land-based launches, in 2020 China demonstrated the ability to launch a Long March-11 (LM-11) from a sea-based platform. This capability, if staged correctly, would allow China to launch nearer to the equator than its land-based launch sites, increase the rocket's carrying capacity, and potentially lower launch costs.[218]

China has developed quick-response SLVs to increase its attractiveness as a commercial small satellite launch provider and to rapidly reconstitute LEO space capabilities, which could support Chinese military operations during a conflict or civilian response to disasters. Compared with medium- and heavy-lift SLVs, these quick-response SLVs are able to expedite launch campaigns because they are transportable via road or rail and can be stored launch-ready with solid fuel for longer periods than liquid-fueled SLVs. Because their size is limited, quick-response SLVs such as the Kuaizhou-1 (KZ-1), LM-6, and LM-11 are only able to launch relatively small payloads of up to approximately 2 metric tons into LEO.

Chinese Space Launch, SSA, Satellite Control Centers, Command and Control, and Data Reception Stations[219,220]

China has four fixed 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. In 2020, China launched a LM-11 from a barge based in Haiyang Port. China's main satellite control center is in Xian, and its primary control center for human space flight and lunar missions is in Beijing. The PLA operates four large phased array radars (LPAR) most likely used for missile warning and SSA. Additionally, there are at least six ground stations used for satellite C2—including one in Neuquén, Argentina, and five for receiving remote sensing data from satellites—including one located in Kiruna, Sweden.

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In June 2020, China announced its intention to upgrade the payload capacity of the LM-11 in the new LM-11A, designed for land or sea launches, beginning in 2022.[221,222,223,224]

The expansion of nonstate-owned Chinese launch vehicle and satellite operation companies in China's domestic market since 2015 suggests that China is successfully advancing military-civil fusion efforts. Military-civil fusion blurs the lines between these entities and obfuscates the end users of acquired foreign technology and expertise.[225]

Image Source: Xinhua via AFP

The four Chinese Yuanwang space tracking ships—based in Jiangyin, near Shanghai, and usually supporting space launch operations from positions in the Pacific and Indian Oceans—are part of China's SSA network. In early 2020, China's Yuanwang-7 conducted operations in the Atlantic Ocean, a first for Yuanwang space support vessels.

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 its missions including intelligence collection, counterspace targeting, ballistic missile early warning

Chinese International SSA Efforts Collaboration and Overseas Tracking, Telemetry, and Control Sites

China leads the Asia-Pacific Space Cooperation Organization (APSCO), a multilateral organization with rotating leadership whose members include China, Bangladesh, Iran, Mongolia, Pakistan, Peru, Thailand, and Turkey with Egypt, Indonesia, and Mexico as associate members.[226] APSCO 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 to Iran, Pakistan, and Peru 15-cm telescopes that are able to track 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 LEO and GEO. The organization is planning to improve optical system capabilities, coverage, and redundancy as well as data sharing networks.[227,228,229]

China has established locations worldwide to aid in TT&C of space missions both around the Earth as well as in cislunar and deep space. There are ground stations in Argentina, Australia, Brazil, Canada, Chile, Ethiopia, France, Greenland, Kenya, Kiribati, Namibia, Norway, Pakistan, South Africa, Spain, and Sweden. There are also four sites in Antarctica that can provide similar support as well as a BeiDou reference station: Great Wall, Kunlun, Taishan, and Zhongshan Stations.[230]

(BMEW), spaceflight safety, satellite anomaly resolution, and space debris monitoring.[231,232]

Electronic Warfare Capabilities

The PLA considers EW capabilities to be critical assets for modern warfare, and its doctrine emphasizes using EW to suppress or deceive enemy equipment.[233] The PLA routinely incorporates in its exercises jamming and antijamming techniques that probably are intended to deny multiple types of space-based communications, radar systems, and GPS navigation support to military movement and precision-guided munitions employment.[234] China probably is developing jammers dedicated to targeting SAR, including aboard military reconnaissance platforms. Interfering with SAR satellites very likely protects terrestrial assets by denying imagery and targeting in any potential conflict involving the United States or its allies.[235,236] In addition, China probably is developing jammers to target SATCOM over a range of frequency bands, including military-protected extremely high frequency communications.[237,238]

Cyberthreats

The PLA emphasizes offensive cyberspace capabilities as a major component of integrated warfare and could use its cyberwarfare capabilities to support military operations against space-based assets.[239,240] For example, the PLA could employ its cyberattack elements to establish information dominance in the early stages of a conflict to constrain an adversary's actions or slow its mobilization and deployment by targeting network-based command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR); logistics; and commercial activities.

The PLA also conducts cyberespionage against foreign space entities, consistent with broader state-sponsored industrial and technical espionage, to increase its level of technologies and expertise available to support military research, 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.[241,242]

Directed Energy Weapons

During the past two decades, Chinese defense research has proposed the development of several reversible and nonreversible counterspace DEWs for reversible dazzling of electro-optical sensors and even potentially destroying satellite components. China has multiple ground-based laser weapons of varying power levels to disrupt, degrade, or damage satellites that include a current limited capability to employ laser systems against satellite sensors.[243] By the mid- to late-2020s, China may field higher power systems that extend the threat to the structures of nonoptical satellites.[244,245,246,247,248]

ASAT Missile Threats

In 2007, China destroyed one of its defunct weather satellites more than 800 kilometers above the Earth with an ASAT missile. The effect of this destructive test generated more than 3,000 pieces of trackable space debris, of which more than 2,700 remain in orbit and most will continue orbiting the Earth for decades.[249,250] The PLA's operational ground-based ASAT missile system is intended to target LEO satellites. China's military units have continued training with ASAT missiles.[251,252]

China probably intends to pursue additional ASAT weapons that are able to destroy satellites up to GEO. In 2013, China launched an object into space on a ballistic trajectory with a peak orbital radius above 30,000 kilometers, near GEO altitudes. 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, suggesting a basic capability could exist to use ASAT technology against satellites at great distances and not just LEO.[253,254]

Orbital Threats

China is developing other sophisticated space-based capabilities, such as satellite inspection and repair. At least some of these capabilities could also function as a weapon. China has launched multiple satellites to conduct scientific experiments on space maintenance technologies and is conducting research on space debris cleanup; the most recent launch was the Shijian-21 launched into GEO in October 2021.[255,256,257] In January 2022, Shijian-21 moved a derelict BeiDou navigation satellite to a high graveyard orbit above GEO.[258] The Shijian-17 is a Chinese satellite with a robotic arm. Space-based robotic arm technology could be used in a future system for grappling other satellites.[259]

Since at least 2006, the government-affiliated academic community in China began investigating aerospace engineering aspects associated with space-based kinetic weapons—generally a class of weapon used to attack ground, sea, or air targets from orbit. Space-based kinetic weapons research included methods of reentry, separation of payload, delivery vehicles, and transfer orbits for targeting purposes.[260,261,262,263,264,265] China conducted the first fractional orbital launch of an ICBM with a hypersonic glide vehicle from China on 27 July 2021. This demonstrated the greatest distance flown (~40,000 kilometers) and longest flight time (~100+ minutes) of any Chinese land attack weapons system to date.[266]

Image Source: Xinhua via AFP

The 15 September 2020 LM-11 launch from the Yellow Sea carrying nine satellites including the Jilin-1 Gaofen 03-1.

Image Source: Sputnik via AFP

Russian Space Agency ROSCOSMOS launch of a Soyuz-2.1b from Vostochnyy Cosmodrome. Vostochnyy is Russia's newest space launch facility, located in the Russian Far East. It is partially operational with construction still ongoing and once complete, this location will reduce Russia's reliance on the Baikonur Cosmodrome in Kazakhstan to access orbits which are unreachable from its more northerly main space launch center, Plesetsk.

RUSSIA

General Colonel Aleksandr Golovko, the first and current Commander of Russia's Aerospace Forces, is seen here at the launch of a Global Navigation Satellite System-M (GLONASS M) satellite in November 2018.[267,268]

> In the new, 21st century, Russia must maintain its status as a leading nuclear and space power because the space industry is directly linked with defence [sp] and I would like to remind you of this. Today, we will discuss issues related to long-term priorities of space exploration and will analyse [sp] what we must do to strengthen our positions in this truly strategic area.
>
> —Russian President Vladimir Putin, 12 April 2021[269]

> Slowly but surely, we are heading toward [militarization of space]. Roscosmos has no illusions about this. Everyone is working on it.
>
> —Dimtry Rogozin, Chief, *Russian State Corporation Roscosmos*[270]

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 the former Soviet Union launching the first satellite, Sputnik-1, in 1957 and placing the first person into Earth orbit, Yuri Gagarin, in 1961. The International

Space Station's (ISS) reliance on Russian launch vehicles to carry astronauts to and from the station from 2011 to 2020 reinforced the perception of Moscow as a global leader in space, which garnered Russia a measure of prestige and economic support for its space program.[271]

Russia's space program is robust but more narrowly focused than China's. Additionaly, Moscow's budget is more limited than Beijing's because of competing priorities within Russia's broader military modernization efforts.[272] In the years following the end of the Cold War, a combination of economic constraints and technological setbacks caused a decay of Russian space capabilities, including space-based remote sensing and satellite navigation.[273] Nonetheless, during the past two decades, Moscow has continued to pursue space services in support of terrestrial applications while developing a suite of counterspace weapon capabilities, including EW to deny, degrade, and disrupt communications and PNT and DEWs to deny the use of space-based imagery.[274,275] Russia is developing a mobile missile that is able to destroy satellites and crewed space vehicles.[276,277,278,279]

Space Strategy and Doctrine

Russia openly supports space arms control agreements to prevent weaponization of space, even as 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.[280,281,282,283,284] 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.[285,286] Moscow regularly expresses concern about space weapons and is pursuing legal, binding space arms control agreements to curb what it sees as U.S. strength in outer space.[287,288,289] At the same time, Russia is developing an arsenal of counterspace capabilities to attack U.S. and allied assets.[290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306]

As Russia continues to modernize its military, it will increasingly integrate space services into its armed forces. Russia has a strong foundation of technical knowledge and expertise fostered by more than 60 years of experience in space. However, Moscow sees overreliance on space as a potential vulnerability and is determined to avoid becoming excessively dependent on space to conduct its national defense mission.[307,308,309,310] Russia has developed terrestrial redundancies to complement or replace space services that may be denied in a wartime environment.[311]

Russia views space as a critical enabler of U.S. precision-strike and military force projection capabilities. Russia believes that U.S. missile defense systems paired with U.S. space-enabled, conventional precision-strike capabilities undermine strategic stability.[312,313] At the same time, Russia perceives the U.S. dependence on space as its Achilles' heel, which can be exploited to achieve Russian conflict objectives.[314] 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.[315,316]

Image Source: U.S. National Archives

The Nedelin-class missile range instrumentation ship (AGM) *Marshal Krylov*, subordinate to Russia's Pacific Fleet. AGM *Marshal Krylov* supports space and missile instrumentation tracking and range support missions.

Russian counterspace doctrine involves employing ground-, air-, cyber-, 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.[317,318,319,320] Moscow believes that developing and fielding counterspace capabilities will deter aggression from adversaries reliant on space.[321] 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.[322,323]

Space and Counterspace Organizations

In 2015, Russia created the Aerospace Forces by merging the former Air Force and Aerospace Defense Troops. This new force includes the Space Forces, Russia's military element that conducts space launches and operates the BMEW, the satellite control network, and the space surveillance network.[324,325,326] Russia's defense minister stated that the change was "prompted by a shift in the center of gravity toward the aerospace sphere" and as a counter to the U.S. Prompt Global Strike doctrine.[327,328] To accomplish space and counterspace operational tasks, Russia's Space Forces were organized into the 15th Special Purpose Aerospace Army, which consists of the 820th Main Missile Attack Warning Center, the 821st Main Space Reconnaissance Center, and the 153rd Titov Main Test and Space Systems Control Center.[329,330,331,332,333] The Space Forces also operate the Plesetsk Cosmodrome, where they launch military satellites, and the Mozhayskiy Military Space Academy, where they train officers and enlisted personnel in strategic and operational military operations theory and aerospace engineering specialties.[334,335,336]

The reorganization of Russia's civilian space program was designed to improve upon inefficiencies across the sector and readjust from the loss of control over former Soviet space production enterprises in Ukraine. Today the Russian space industry is almost exclusively state owned.[337] The state-owned corporation Roscosmos is the executive body responsible for overall management of the space industry and for carrying out Russia's civilian space program. The space industry primarily comprises 75 design bureaus, enterprises, and companies that carry out research, engineering development, and production of Russia's space technologies, satellites, and SLVs for both civilian and military purposes.[338,339]

During the past few years, Russia has faced several obstacles to its space program. Corruption has been prevalent and has stalled developments,[340] budget cuts and sanctions have delayed projects,[341,342,343] and negligible private space investment has stymied growth and innovation.[344]

Acquisition of Foreign Space and Counterspace Technologies

Moscow directs a whole-of-government approach to select and acquire foreign space and counterspace technologies in support of Russia's economic and military goals. Following the imposition of sanctions by the United States, western Europe, Australia, and Japan in response to Russia's 2014 invasion of the Crimean Peninsula, Moscow has exploited multiple collection paths to mitigate U.S. and European Union (EU) restrictions on Russia's access to space technology, information, and expertise, but sanctions are still affecting space systems production.[345,346] Russia relies on acquisition of Western components because of the decline of its domestic microelectronics industry and because of its inability to realize its import substitution program goals.[347,348,349,350,351,352,353]

ISR Satellite Capabilities

Russia designs and employs some of the world's most capable individual ISR satellites, despite funding shortfalls and technological setbacks limiting the number of such systems in orbit. The fleet contains more than

30 satellites providing electro-optical imagery, a new radar observation platform, missile warning, and electronic and signals intelligence.[354,355,356] At least half of these systems are owned and operated by the Russian Defense Ministry. Space-based sensors provide Russia strategic warning of ballistic missile launches, support targeting of Russian antiship cruise missiles,[357] and support electro-optical imagery requirements for Russian military operations in Syria.[358,359] Setbacks have hindered Russia's ability to launch and maintain its military-dedicated ISR satellites, leading to increased use of its civilian and commercial satellites to fulfill military tasks.[360]

Image Source: Sputnik via AFP

Russia's Luch 5A relay satellite in the Space Pavilion at the Cosmonautics and Aviation Center at the Exhibition of Achievements of the National Economy.

Satellite Communications

Russia owns and operates a diverse constellation of commercial and military communications satellites capable of providing mobile and fixed SATCOM services from various orbital altitudes. In spite of lagging behind other competitors, and the instituting of Western sanctions in 2014, Russia continues to replace aging communications satellites with modern and more capable satellites to preserve and expand its SATCOM capabilities, including through partnerships with European satellite manufacturers.[361,362] The satellites are able to support worldwide military and paramilitary deployments, enabling Moscow to maintain C2 over its military units to support its national objectives.[363,364,365,366,367,368]

PNT Capabilities

GLONASS provides Russia worldwide satellite navigation services and supports Russia's economic development and national security interests.[369] Following the GLONASS constellation's deterioration in the late 1990s, Russia committed to reconstituting GLONASS during the 2000s.[370] Full operating capability was regained in 2011; Russia now launches satellites as needed to maintain the constellation while developing next-generation GLONASS satellites.[371] Russia's military also uses GLONASS to enable military system deployments, force movement, and precision-guided munitions delivery.[372,373,374]

Human Spaceflight and Space Exploration Efforts

Russia's human spaceflight program started in the late 1950s and had its first major milestone with the launch of Yuri Gagarin aboard the *Vostok-1* spacecraft in 1961.[375] Since that historic launch, the former Soviet Union and then Russia has launched the Salyut, Almaz, and Mir Space Stations, multiple elements of the ISS, and several Mars exploration missions; however, only two Mars missions were successful—the last in 1971.[376] Although Russia has talked about withdrawing from the ISS as late as April 2021, it is committed to the effort through at least 2025.[377]

Russia's Luch relay satellites allow Moscow to communicate between the ISS and Earth without reliance on National Aeronautics and Space Administration's (NASA) and U.S. SATCOM systems.[378] Since the manned launch of SpaceX's Crew Dragon to the ISS in May 2020, Russia has offered to sell Soyuz seats to other international partners, such as the United Arab Emirates, to make up revenue from losing U.S. astronaut transportation requirements to the ISS.[379,380]

Like other spacefaring nations, Russia has ambitious plans for lunar exploration and settlement

Russia: Space Exploration Missions[381,382,383]

Mission	Description	Launch Date
Nauka	Russian ISS science module.[384,385]	July 2021[386]
Luna-25	Joint lunar lander project with ESA.[387]	2022[388]
Prichal	Russian ISS docking module.[389]	2021
ExoMars	Joint Mars lander with ESA.[390,391]	TBD
Luna-Grunt	Lunar lander and sample return.[392]	2024
Luna-27	First mission to explore the lunar south pole, where frozen water lies under the surface and where Russia intends to build a base.[393]	2025[394]
Luna-26	Lunar orbital mapping mission.[395]	2024
Luna-28	Lunar sample return mission.[396]	2027–2028
Luna-29	Lunar rover mission.[397]	2028
Expedition-M	Phobos sample return mission.[398]	2026–2035
International Lunar Research Station	Establish a research base on the Moon, primarily supported by robotic technology and capable of supporting human visits.[399]	2025–2035

Russian Aerospace Forces monitor GLONASS satellites at the Titov Main Test and Space Systems Control Center in Krasnoznamensk outside Moscow.[400]

during the next 40 years.[401] Russia has discussed partnering with China, the EU, and the United States to achieve its lunar aspirations.[402] China and Russia signed a memorandum of understanding in March 2021 to work together on the International Lunar Research Station (ILRS).[403,404]

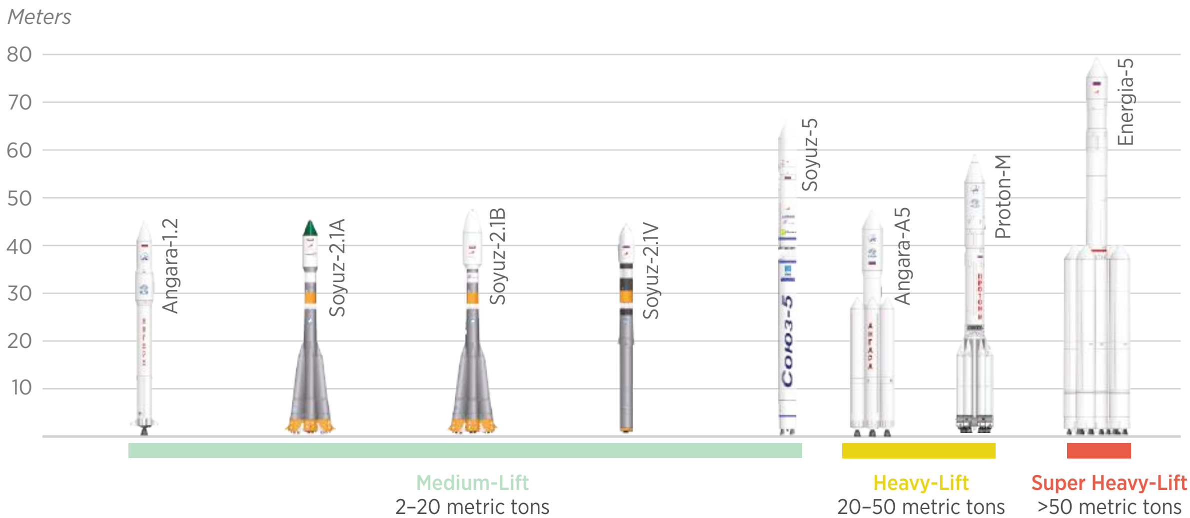
Space Launch Capabilities

Russia is updating and improving its space launch capabilities to enhance reliability, alleviate environmental concerns, increase manufacturing efficiencies, and support future human spaceflight and

Image Source: Sputnik via AFP

Russian Space Agency ROSCOMOS launches Progress MS-14 on Soyuz-2.1a from Baikonur Cosmodrome, Kazakhstan.

Russian Space Launch Vehicles



Russia has focused on maintaining its own military and civil strategies, using heavier rockets 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. However, it was revived in 2016 to support proposed lunar missions and renamed "Yensei."

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Russian Space Launch, SSA, Satellite Control Centers, and Command and Control Stations[405,406,407,408,409,410,411,412,413,414,415,416,417,418,419,420,421,422,423,424,425,426,427,428,429,430,431,432,433]

Russia owns two of its launch sites and leases one from Kazakhstan. The European Space Agency has contracted Russia to conduct launches from Kourou, French Guiana. Inactive spaceports include Kapustin Yar and Svobodny Spaceports. Russia's space control sites are spread across Russia to enable effective satellite C2. GLONASS TT&C stations are similarly spread across Russia to ensure timely control of the navigation constellation. Moscow has spread nine radars at eight locations of various types across its landmass to enable a dual-role BMEW and SSA mission.

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deep-space exploration missions.[434,435]

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, instead usually choosing to launch small satellites in multipayload launches on larger rockets. Russia is also in the early stages of developing a super heavy-lift SLV similar to the U.S. Saturn V or the newer U.S. Space Launch System to support proposed crewed lunar and Mars exploration missions.[436] In 2019, Moscow retired the Soyuz-FG and Rokot, and it has since focused on newer SLVs with similar capabilities.[437,438]

Russia's commercial launch industry acquired the launch systems of a previously Russia-Ukraine-U.S. consortium called Sea Launch. This capability features a mobile floating platform for space launches; however, this effort is plagued by financial hardship and is on hold.[439]

A ban on U.S. purchases of Russian rocket engines is currently set to take effect in 2022, but Russian enterprises probably began to see negative consequences beginning in 2020, as the U.S. demand for these engines decreased. In 2018, 17 of the 19 total engines on order were destined for the United States. Roscosmos has offered to cut prices by 30 percent.[440]

Space Situational Awareness

Russia's space surveillance network, managed by the 821st Main Space Reconnaissance Center, is composed of a variety of telescopes, radars, and other sensors, and is capable of searching for, tracking, and characterizing satellites in all Earth orbits. This network allows Russia to support its various missions including intelligence collection, counter-

Russian International SSA Collaboration

Russia leads the nongovernmental organization International Scientific Optical Network (ISON), which is the largest foreign network of ground-based optical space surveillance sensors. ISON was established in 2001, and participants include international academic and scientific organizations and government entities such as Roscosmos. Russia's Keldysh Institute of Applied Mathematics coordinates sensor tasking and combines information from nearly 100 ground-based optical sensors of varying sizes at 40 observatories across 16 countries—Australia, Bolivia, China, Georgia, Germany, Italy, Kyrgyzstan, Mexico, Moldova, Mongolia, Russia (seven locations) Spain, Switzerland, Ukraine (4 locations), the United States, and Uzbekistan.[441,442,443]

space targeting, spaceflight safety, satellite anomaly resolution, and space debris monitoring. Some of these sensors also perform a BMEW function as their primary mission.[444]

Image Source: NASA Spaceflight Online Forum

Deployed SATCOM jammer in the field.[445]

Electronic Warfare Capabilities

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 C4ISR capabilities. Russia has fielded a wide range of ground-based EW systems to counter GPS, tactical communications, SATCOM, and radars.[446] Mobile jammers target radar and communications satellites. Russia has developed and fielded a full spectrum of EW capabilities with mobility, automation, and performance improvements able to counter Western space-enabled C4ISR and weapons guidance systems.[447,448,449]

In February 2020, Russian military officials confirmed that Russia is actively employing EW capabilities in Syria to counter GPS-enabled capabilities such as drones.[450,451,452]

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

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

Cyberthreats

Since at least 2010, the Russian military has placed a priority on the development of forces and capabilities, including cyberspace operations, for what it terms “information confrontation”—a holistic concept for ensuring information superiority. The weaponization of information is a critical aspect of this strategy and is employed in times of peace, crisis, and war. Russia considers the information sphere, especially space-enabled information collection and transmission, to be strategically decisive and has taken steps to modernize its military’s information attack and defense organizations and capabilities.[453]

Directed Energy Weapons

Directed energy weapons pose a direct threat to space operations. Russia has several ground-based lasers, for example, that can blind satellite sensors.[454] By July 2018, Russia began delivering the Peresvet laser weapon system to its Aerospace Forces. Russian leaders indicate that Peresvet has an ASAT mission. In public statements, Russian 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.”[455,456,457,458] In December 2019, Russian Defense Minister Sergey Shoygu stated that this laser weapon has been deployed to five strategic missile divisions.[459,460,461] Additional press reporting indicates that the ground-mobile Peresvet laser system is designed to blind enemy optical tracking systems, including those on satellites, with its laser.[462,463] The system is meant to mask the movement of strategic missile systems, according to Moscow Interfax.[464]

Russia probably will field lasers that are more capable of damaging satellites in the mid-to-late 2020s.[465] By 2030, Russia may also field higher power systems that extend the threat to the structures of all satellites, not just electro-optical ISR.[466]

ASAT Missile Threats

Russia is also developing ASAT missile systems. These missiles can destroy U.S. and allied space systems in LEO, threatening ISR and communications satellites. Russia is developing and testing a mobile missile defense complex referred to as Nudol, which Russian sources describe as capable of destroying ballistic missiles and low-orbiting satellites.[467,468,469,470,471,472] Although Russia publicly describes Nudol as a ballistic missile defense system, it has an inherent counterspace capability. Deputy Prime Minister, then Deputy Defense Minister, Yuri Borisov remarked in 2018 that Nudol is a “counterspace attack complex” for the Russian military.[473] This weapon system—most recently-tested in November 2021—created over 1,500 pieces of trackable space debris and tens of thousands of pieces of lethal but nontrackable debris. This debris endangers spacecraft of all nations in LEO, including astronauts and cosmonauts on the ISS and China's Tiangong space station. With this test, Russia demonstrated the capability of the missile to destroy satellites in LEO.[474,475]

Image Source: SPUTNIK/AFP

Russian Peresvet laser weapon probably is intended for use against satellites (July 2018).

Image Source: The Space Review (Alex Snow)

MiG-31BM taking off from Zhukovskiy with potential Burevestnik ASAT missile.

a The name Burevestnik is also associated with a Russian developmental nuclear-powered cruise missile. [Source: National Air and Space Intelligence Center; 2020; 2020 Ballistic and Cruise Missile Threat Report*; p.36.]*

Russia is reportedly developing an air launched ASAT weapon called Burevestnik[a], targeting spacecraft in LEO. This system is based on the Soviet-era system called "Contact" that was designed for launching an ASAT missile from a MiG-31 fighter aircraft.[476,477] In September 2018, a MiG-31 was photographed in flight at the Zhukovskiy aircraft test site near Moscow carrying a large missile that could be related to air-launched ASAT weapon testing.[478] An Aerospace Forces squadron commander remarked that Russia would deploy an ASAT weapon on a MiG-31 ballistic missile "capable of destroying targets in near-space."[479]

Orbital Threats

In 2020, Russia tested a space-based ASAT weapon and continues to research and develop sophisticated orbital capabilities that could serve dual-use purposes. For example, inspection and servicing satellites can closely approach satellites to inspect and repair malfunctions; this same technology could also be used to conduct an attack on other countries' satellites, resulting in temporary or permanent damage.[480]

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," possibly as part of its Nivelir program. However, the satellite's behavior has been inconsistent with on-orbit inspection or SSA activities.[481,482,483] In November 2019, Russia deployed two satellites, Cosmos 2542 and 2543.[484,485] After the launch, one of the satellites appeared to begin following a U.S. national security satellite, approaching close enough to create potentially dangerous operating conditions.[486,487,488] In July 2020, Russia ejected an object into orbit from Cosmos 2543 near another Russian satellite in a test of a space-based ASAT weapon.[489,490] Additionally, Cosmos 2504 and Cosmos 2536 are prototype Russian ASAT weapons that could kinetically kill satellites in LEO.[491]

According to Russian press reporting, Roscosmos is creating a satellite intended for GEO operations, which will have orbital servicing capabilities. The same report also recognizes the ASAT capabilities of servicing satellites in all orbits.[492]

EMERGING CHALLENGES

Iran

Image Source: IRNA

On 22 April 2020, Iran's Islamic Revolutionary Guard Corps-Aerospace Force (IRGC-ASF) successfully launched the Ghased SLV, placing the Noor-1 satellite into LEO.[493]

Iran's pursuit of a national space program supports both its civilian and military goals, including boosting national pride, economic development, and military modernization.[494,495,496] Tehran states it has developed sophisticated capabilities, including SLVs as well as communications and remote-sensing satellites;[497] however, its SLVs are only able to launch small satellites into LEO and have proven unreliable.

The Iranian Space Agency (ISA) and Iranian Space Research Center (ISRC)—subordinate to the Ministry of Information and Communications Technology—along with the Ministry of Defense and Armed Forces Logistics (MODAFL) oversee part of the country's satellite development programs.[498,499] ISA and ISRC work with Iranian universities, private industry, and foreign partners to develop satellites to test communications and remote-sensing technologies.[500,501,502] However, Iran's limited space launch capacity has led to a significant backlog of built-but-unlaunched satellites.[503]

To ensure access to space-based ISR, Iran's Project 505 is probably an attempt to buy an ISR system from Russia that started in August 2015; however, this system is not yet in orbit.[504,505] A Russian aerospace company, NPK Barl, and the All-Russian Scientific Research Institute of Electromechanics would provide the ground system and the satellite respectively which would be operated by the Iranian state-run trade company, Bonyan Danesh Shargh.[506,507]

MODAFL and the IRGC-ASF oversee Iran's SLV development programs. MODAFL's first launch attempt, the two-stage Safir SLV in 2008,[508] was followed by four successful launches, numerous failures, and retirement in 2020.[509,510]

In 2016, MODAFL tested the larger liquid-fueled Simorgh SLV, and as of March 2020, MODAFL planned to use the Simorgh's technologies to develop other larger more capable SLVs, including the Sarir and Soroush.[511] Iran conducted launches of the IRGC-ASF–developed hybrid liquid- and solid-fueled Ghased SLV in 2020 and 2022.[512] The IRGC-ASF subsequently announced its intent to continue SLV development, including a future SLV with GEO launch capability.[513,514,515,516,517,518,519] Iran has also revealed plans for a larger four-stage Ghaem SLV, which could serve as a test bed for developing ICBM technologies. Because of inherent overlapping technology between ICBMs and SLVs, some Western analysts are concerned that Iran's development of booster technology for larger, more capable SLVs will improve Iran's ICBM potential.[520,521,522,523] On 12 June 2021, Iran launched an unknown SLV and was preparing a second SLV for launch in late-June.[524]

Iran recognizes the strategic value of space and counterspace capabilities and will attempt to deny an adversary use of space during a conflict.[525] Tehran has publicly acknowledged it has developed capabilities to jam space-based communications and GPS signals.[526,527,528] Iran may also contribute to the proliferation of such jamming equipment. Since 2010, state-owned Iran Electronics Industries has marketed several GPS jammers on its website.[529] Advancements in SLV technology could also be applied to developing a basic ground-based ASAT missile, if Iran chooses to do so in the future.[530,531,532,533]

Iran has improved its domestic space domain awareness capabilities, establishing its first space-monitoring center in 2013.[534] In 2005, Iran joined China-led APSCO to access SSA from other countries and hopes to expand its cooperation with the organization.[535,536,537,538]

North Korea

North Korea's space program is administered by a state-run civilian agency, the National Aerospace Development Administration.[539] North Korea's space launch complex on the west coast, Sohae Satellite Launching Station, and associated space

Image Source: KCTV

Launch of Unha-3 SLV.[540]

tracking facilities in Pyongyang supported satellite launch cycles in 2012 and 2016. In January 2021, North Korean leader Kim Jong Un announced that Pyongyang—in an attempt to secure its own space-based reconnaissance capability—had completed its design of a satellite and will launch it in the near future. Kim Jong Un emphasized that North Korea is undertaking, "full scale work," toward space capabilities, suggesting development of new or modified SLVs or a satellite intended for operational use.[541,542] An older space launch site on the east coast, Tonghae, has not been used for a launch since 2009.[543,544] North Korea has demonstrated nonkinetic counterspace capabilities, including GPS and SATCOM jamming, and probably intends to deny space-based navigation and communications during a conflict.[545,546,547]

In 2020, North Korean actors conducted numerous cyberoperations against our foreign partners' defense industries and attempted to compromise various U.S. Government networks.[548] Multiple North Korean hacker groups have targeted the aerospace industries potentially including space technologies.[549,550,551] This activity, if left unchecked, could enable North Korea's weapons and space system development and procurement programs.[552,553,554,555,556]

North Korea's ballistic missiles and SLVs, such as the Unha-3 SLV, in theory could be used to target satellites in a conflict.[557] North Korea has placed two satellites in orbit and has articulated further space ambitions. Its space program has also enabled testing of technology used in ballistic missiles under the guise of peaceful use of space.[558,559,560] These systems provided North Korea with valuable data applicable to the development of long-range and multistage ballistic missiles.[561]

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KEY SPACE ISSUES THROUGH 2030 AND BEYOND

Growth of Reusable Space Technology: Commercial Opportunities and Military Advantage

Access to space has traditionally required the use of expendable spacecraft: single-use launch vehicles, satellites, and capsules that are designed to maximize performance and then be discarded. Reliance on expendable vehicles has made access to space expensive and exclusive. Reusable technologies, while even more difficult and expensive to develop and build, stand to greatly reduce the cost of spaceflight by recovering, refurbishing, and reusing rocket stages, fairings, and capsules. Foreign nations increasingly seek to repeat U.S. successes in reusable technologies by developing their own reusable SLVs (R-SLVs) and spacecraft.

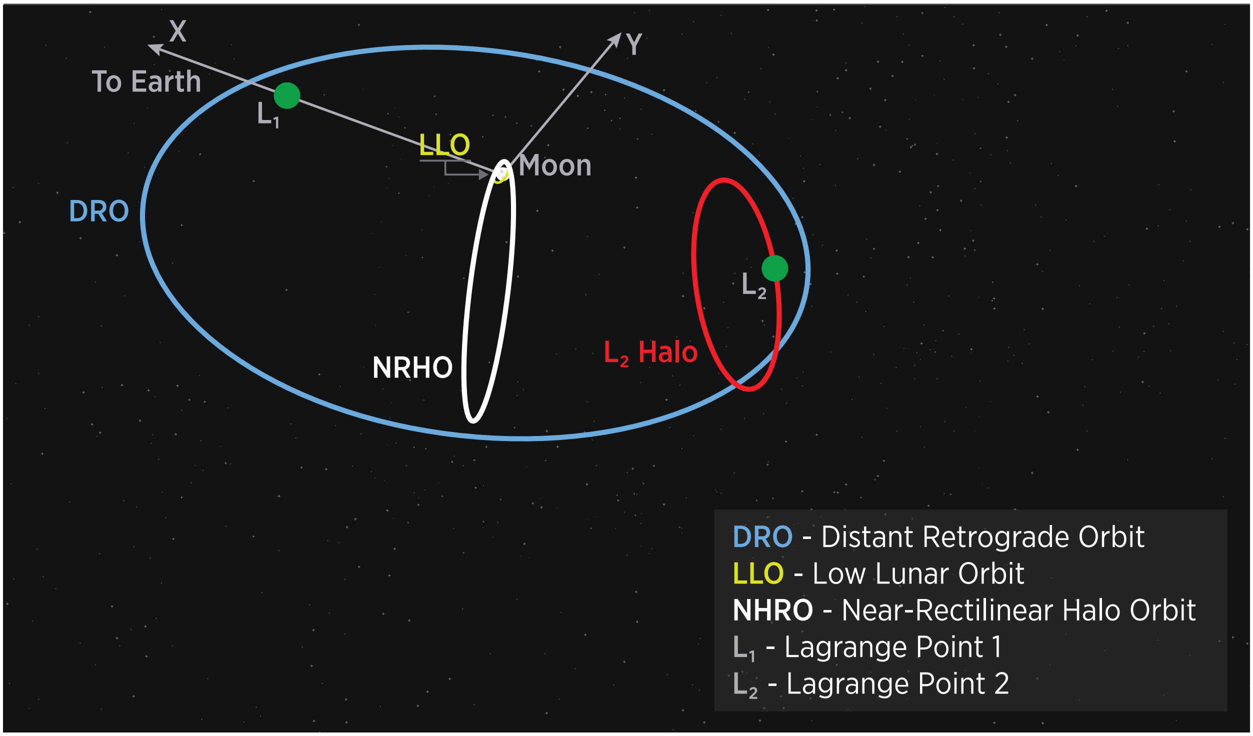
The state-owned enterprise, China Academy of Launch Vehicle Technology, modified the LM-8—launched for the first time on 22 December 2020—into an R-SLV.[562] The Chinese company, i-Space, plans to launch the country's first commercially developed R-SLV, called Hyperbola-2, in late-2021, but a Hyperbola-1 failure probably delayed that launch.[563,564] China is also developing two partially reusable capsules: the New-Generation Manned Spaceship intended to replace the Shenzhou capsule, and the New-Generation Reusable Recoverable Satellite as an inexpensive platform for microgravity experiments and rapid space equipment testing.[565,566]

In 2019, the chief designer for NPO Energomash, one of Russia's rocket propulsion companies, said that the company is moving forward with a proposal to create an R-SLV.[567] NPO Energomash has also stated that it hopes to modify its successful RD-180 engine to be reusable as many as 10 times.[568] Another Russian space corporation, Myasishchev, is designing an R-SLV first-stage that will return to its launch center after second stage separation.[569]

Space planes are another form of reusable technology. Space planes also feature enhanced maneuverability, making them uniquely suitable for certain missions as compared with traditional satellites. Developing a space plane requires overcoming the obstacles of hypersonic flight, a rarified atmospheric environment, and extreme external heating. China has developed hypersonic glide vehicles for ballistic missile warhead delivery probably enabling further achievements in space application.[570] China is developing the Shenlong and Tengyun space planes. In 2020, China launched into orbit its first-ever prototype of a space plane, which stayed in orbit for 2 days before returning to Earth. Beijing stated its space plane was testing reusable spacecraft technologies as part of advancing the peaceful use of space.[571,572] The Shenlong program previously conducted a drop test as early as 2011, and Tengyun has only completed a model wind tunnel test.[573,574] Russia announced multiple space plane projects during the past two decades, but it has made no serious progress following the one and only flight of Buran, a copy of the U.S. Space Shuttle, in 1988.[575,576,577,578]

Reusable spaceflight technology will also enable the commercial space tourism industry, both for suborbital and orbital flight. The cost savings provided by

Cislunar Chart



Most satellites operate in orbits near Earth to provide services for users on the ground. Satellite orbits are selected to best serve their application, for example, satellites that are required to remain over a single region on Earth are placed in GEO. Satellites will be placed in various cislunar orbits in the near future. In addition to direct orbits around the Moon, there are other points in the Earth-Moon system that are useful for satellite operations. Lagrange points are stable positions in space between two celestial bodies. Gravitational pull equals the centripetal force required for a smaller object to orbit there, and subsequently reduces fuel requirements to remain in these positions. L1 and L2—between the Moon and Earth and the far side of the Moon respectively—are depicted here. There are three other Lagrange points associated with the Earth-Moon system, L3-L5.[579]

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reusable technology will be key for lowering ticket prices and widening the market. British, Japanese, and Russian firms are among those developing tourist spacecraft.[580,581]

Human Spaceflight and Cislunar Operations

Human spaceflight and space operations of most types to and beyond the moon will very likely increase in the future. Threats to U.S. and allied military space capabilities will persist as humanity expands its reach into space. Nations are motivated to pursue new scientific missions, compete for military advantage, expand communications and data processing, and obtain greater national and international prestige. Economic competition to exploit the potentially large amount of natural resources on the Moon, Mars, or even asteroids, while a nascent endeavor today, will become a driver for more space-capable states or consortiums in the future.

Space exploration initiatives are also opportunities for many nations to cooperate and benefit from scientific discoveries and technological innovation. This trend will expand and feed the presence of nations beyond Earth orbit on a level greater than that already demonstrated by the operation of interplanetary probes to date.

During the past two decades, foreign competitors have looked to lunar missions as major demonstrations of technological sophistication and national strength. Other nations have been involved in human spaceflight—more than 40 nations have orbited astronauts with Russian or U.S. human spaceflight missions.[582,583] Many nations have contributed to the scientific knowledge of Earth with deep-space probes and missions to the Moon and Mars.[584,585,586]

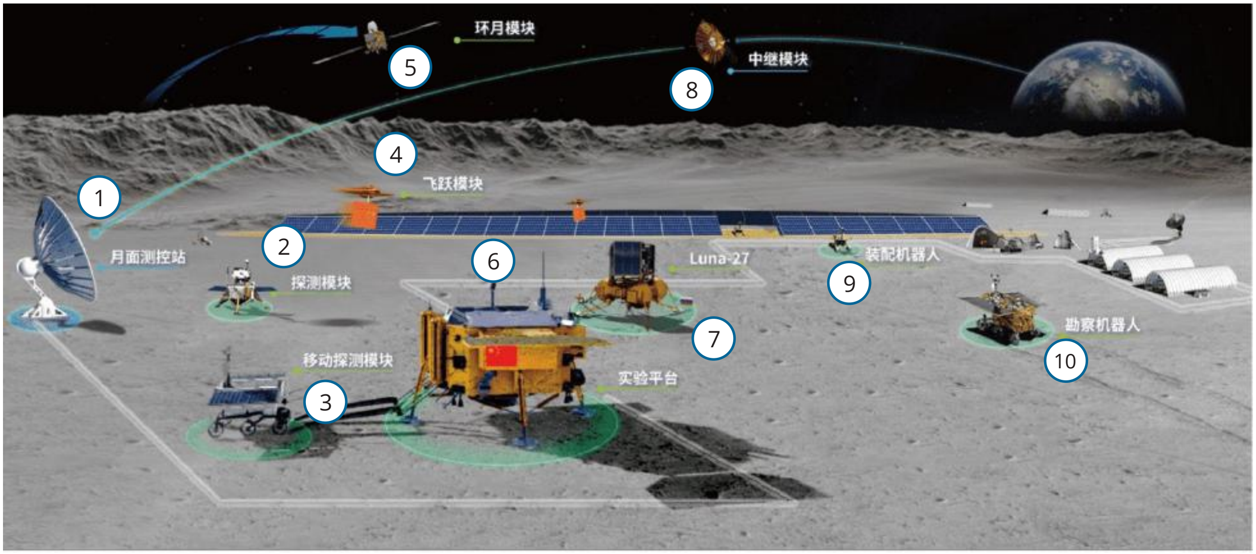


Image Source: China National Space Administration (CNSA)

A China National Space Agency graphic depicting the Proposed Chinese-Russian International Lunar Research Station. The individual elements are ❶ lunar surface tracking & command station; ❷ survey module; ❸ mobile survey module; ❹ leaping module; ❺ lunar orbit module; ❻ test platform; ❼ Russia's Luna-27; ❽ relay module; ❾ assembly robot; and ❿ reconnaissance robot.

New Competition for Space Beyond Earth's Orbit

Deep-space operations beyond Earth orbit, sometimes called xGEO,[587] are focused on scientific missions and exploration of the Moon and other celestial bodies. Spacecraft in xGEO are much harder to track and characterize, and could threaten U.S. or allied high-value satellites.[588] Adversaries could also place operational or reserve satellites in deep space so they are much harder to monitor for later use in lower orbits.[589]

Challenge to Space Operations: Debris and Orbital Collisions

The probability of collision between massive derelict objects in LEO is rising and almost certainly will continue to rise until at least 2030 as a result of fragmentation events such as collisions or battery explosions, ASAT testing, and a rapidly increasing number of space launches worldwide.[590,591,592,593,594,595] The collision risk is to all civilian, commercial, and government satellites of all nations. This adds to the difficulty of ensuring safe space operations and the overall stability of the space environment.

Debris in Orbit. Collisions between and explosions of massive derelict objects almost certainly will continue to add to the amount of space debris in orbit. As of January 2022, more than 25,000 objects of at least 10 centimeters in size were tracked and cataloged in Earth's orbit to include active satellites.[596,597] The primary risk to spacecraft in orbit is from uncataloged lethal nontrackable debris (LNT), which are objects between 5 millimeters and 10 centimeters in size. An estimated 600,000 to 900,000 pieces of uncataloged LNT are in LEO.[598]

Prior to 2007, most debris came from explosions of upper stages of SLVs. Today, nearly one-half of all cataloged debris are fragments from three major events: China's destruction of its own defunct weather satellite in 2007, the accidental collision between a U.S. communications satellite and a dead Russian satellite in 2009, and the 2021 Russian Nudol ASAT test.[599,600]

Threats of Massive Object Collision. Of the cataloged objects, there are nearly 1,300 massive—greater than the size and weight of an automobile—derelict objects in LEO that pose a unique threat to LEO space operations. These objects approach each other within 5 kilometers daily, some passing well within 1 kilometer monthly, at 10–15 kilometers per second.[601]

Computer rendering of tracked objects greater than 10 centimeters in Earth's orbit. Red, yellow, and green objects are representations of active satellites in the GEO orbital belt and in MEO. [Note: The objects are not drawn to scale; the objects are approximately 10,000 times greater than actual size.]

Massive Derelict Cluster Collision Probabilities

Cluster*	In-Cluster P_C** (Per Year)	In-Cluster P_C Increase by 2030	No. of Likely Catalogued Fragments	LNT Likely Produced	Comments
C615	~1/280	5–7%	~5,500	~80,000	Short-lived debris (years to decades). Near many satellites.
C775	~1/715	2–3%	~4,500	~70,000	Moderate-lived debris (decades). Near many satellites.
C850	~1/800	8–15%	~15,000	~225,000	Long-lived debris (many decades). Fewer satellites than C775 or C615.
C975	~1/120	16–26%	~3,500	~55,000	
C1,500	~1/5,000	~1%	~6,000	~75,000	Very long-lived debris (many centuries). Not near many satellites

** Cluster number represents orbital radius to the center of the cluster in kilometers, for example C850 is centered at 850 kilometers in altitude*

*** P_C is probability of collision*

A collision between these objects almost certainly would create 3,500–15,000 cataloged fragments and 55,000–225,000 LNT fragments, whereas a typical satellite breakup generally creates about 250 pieces of cataloged debris.[602] The annual probability of collision for massive derelict objects clustered at 1,500 kilometers is 1 in 5,000 and for separate cluster objects at 850 kilometers in altitude is 1 in 800. Although the debris contribution for a collision at 850 kilometers would nearly double the LEO catalog population (i.e., generate ~15,000 trackable fragments), the debris from a collision at 1,500 kilometers would remain in orbit potentially for thousands of years.

Threats Posed by Debris. Space debris can cause damage and destruction to satellites and crewed spacecraft, as well as increase costs if satellite manufacturers add additional shielding to withstand small fragment impacts and fuel to allow for more frequent avoidance maneuvers. The cost of any maneuvers increases fuel usage, adds to operational complexity and expense, and shortens spacecraft lifetimes which may require more space launches to maintain the same level of capability. Between 1998 and 2022, the ISS, in LEO, maneuvered at least 30 times to avoid potential collisions with orbital debris.[603] With an expected increase in large constellations of satellites and space debris, there is higher potential for satellite collisions, particularly in LEO.[604]

Orbital Lifetime of Debris. The time that debris remains in orbit depends largely on its size and altitude— the smaller objects are and the higher they orbit, the longer they remain in space. Fragments from explosions and collisions will tend to be smaller and exist in lower orbits, and therefore, will have shorter orbital lifetimes than abandoned payloads and rocket bodies. Atmospheric drag acts as a natural cleaner by causing most debris at lower altitudes to reenter Earth's atmosphere and burn up. Some intact objects at 500 kilometers can remain in orbit for about 10 years. As the altitude gets closer to 1,500 kilometers, derelicts and debris can remain for more than 10,000 years.[605]

Orbital collisions tend to occur at high relative velocities (i.e., greater than 25,000 miles per hour in LEO and disperse fragments into many different orbital altitudes). A collision of two objects at 975 kilometers—the most likely of the collision probabilities at about 1 in 120 chance per year—would leave many fragments in orbit for more than a thousand years.[606]

Postmission Disposal (PMD). In 1993, the United States set debris guidelines for space operators, which were adopted by many nations and the UN-affiliated Inter-Agency Space Debris Coordination Committee. In LEO, all objects were to be placed in orbits allowing for their eventual decay within 25 years of the end of mission. The usual PMD maneuver placed objects at or below 650 kilometers.[607] However, even if international and national guidelines were made legally binding, mitigation thresholds were made more stringent, or if compliance were even close to 100 percent; there would still be a formidable debris problem from the remnants of the first 63 years of space operations.[608,609] While U.S. compliance is higher, current worldwide compliance with this guideline is well under 50 percent. The increase in the number of objects in orbit has implications for policymakers worldwide and is encouraging the development of space debris remediation technology.

OUTLOOK

The advantages space provides will drive some nations to improve their ability to access and operate in space. Additionally, some nations will pursue new and improved counterspace capabilities to target the perceived U.S. and allied reliance on space-based assets.

Space services will continue to proliferate worldwide as technological and cost barriers fall and international partnerships for space support increase. State, non-state, and commercial actors will increasingly gain access to data and services emanating from space.[610,611] The number of space launch companies and satellite service providers will expand at least through 2025. And with more groups—commercial, academic, and even private—now able to reach orbit, the growth of satellites and debris in space is expected to increase. This growth of orbital objects will drive a need for more satellite tracking—commercial and government—to help distinguish threats from nonthreats, and to predict and prevent collisions which will prove to be an even greater task.[612,613]

China and Russia value superiority in space. As a result, they will seek ways to strengthen their space and counterspace programs, and determine ways to better integrate them into their respective militaries. Both nations are also seeking to broaden their space exploration initiatives—together and individually—outside Earth's orbit with plans to explore the Moon and Mars during the next 30 years. Lunar exploration by China and Russia aims to expand their scientific knowledge and prestige. If successful, it will likely lead to attempts by China and Russia to exploit the Moon's natural resources.

Iran and North Korea will focus on increasing their capabilities in the civil and military domains to counter space-based services such as communications and navigation.[614] Both will maintain their ability to conduct EW against adversaries and theoretically could use their missile and SLV advancements to target orbiting satellites.

The combination of increasing counterspace capabilities—especially those of China and Russia—a general growth in numbers of space objects, and the proliferation of requirements for space-enabled services will make space an increasingly competitive and crowded environment for the foreseeable future.

As the number of spacefaring nations grows and space and counterspace capabilities become more integrated into military operations, the U.S space posture will be increasingly challenged and on orbit assets will face new risks.

Deep space operations will pose potential challenges to space assets due to the inherent difficulty in tracking and monitoring spacecraft at distances beyond GEO.[615,616] Moreover, the growing incorporation of dual-use technology will continue as the development and testing of government and commercial satellite servicing spacecraft increases—some with potential counterspace capabilities.[617]

APPENDIX: Space and Counterspace Concepts

Satellite C2 Architecture

Satellite C2 architecture uses TT&C to communicate with and control satellites. The control center uses an uplink to deliver commands to a spacecraft. The spacecraft sends data via a downlink to a ground station with 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.[618] Any component of the architecture is vulnerable to attack, ranging from physical vulnerabilities of a ground site to EW disrupting the connection between the space segment and the operator.

Remote Sensing

Remote sensing—generally called ISR—satellites collect images, electronic emissions, and other data of the Earth's land, sea, and atmosphere. Civilian and commercial applications are used for activities such as environmental monitoring, urban planning, and disaster response.

High demand for this data and falling costs for capable technology have spurred the rapid growth and proliferation of these satellites. A decade ago, foreign ISR satellites numbered nearly 100, and by January 2022, that number reached more than 550. ISR satellites support a variety of military activities by providing signals intelligence, enabling battle damage assessments, and assisting military operations.[619,620] They have reduced the ability of all countries to perform sensitive military activities undetected.

Some countries' militaries use space-based ISR. For example, militaries use space-based sensors to augment terrestrial platforms as part of their missile attack warning networks and can enable defensive or offensive operations in response. Space-based sensors usually provide the first indication of a missile launch, and ground-based radars provide follow-on information and confirm the attack.

Satellite Communications

Global communications networks rely on communications satellites for worldwide voice communications, television broadcasts, broadband Internet, mobile services, and data transfer for civilian, military, and commercial users worldwide. SATCOM systems are rapidly deployable, expandable, and increasingly affordable as the demand for services continues to rise globally.[621]

Today, most communications satellites operate in GEO more than 36,000 kilometers above the Earth. This distance provides wider coverage of the globe with fewer satellites; however, it is more expensive to place satellites in orbit at this distance. To reduce cost and gain new markets, SATCOM service providers have proposed future constellations with tens of thousands of satellites in low and medium altitude LEO.[622] Better technology promises greater affordability, efficiency, and flexibility for civilian government, and military users worldwide.

Satellite Positioning, Navigation, and Timing

Satellite navigation constellations provide PNT data that enable civilian, commercial, and military users to determine their precise location and local time.[623] Satellite navigation services—with applications in navigation, munitions guidance, communications, agriculture, banking, and power supply—are critical to military and civilian users worldwide.[624] Advances in satellite navigation technology offer foreign countries improved military situational awareness and accuracy in precision-guided munitions.[625]

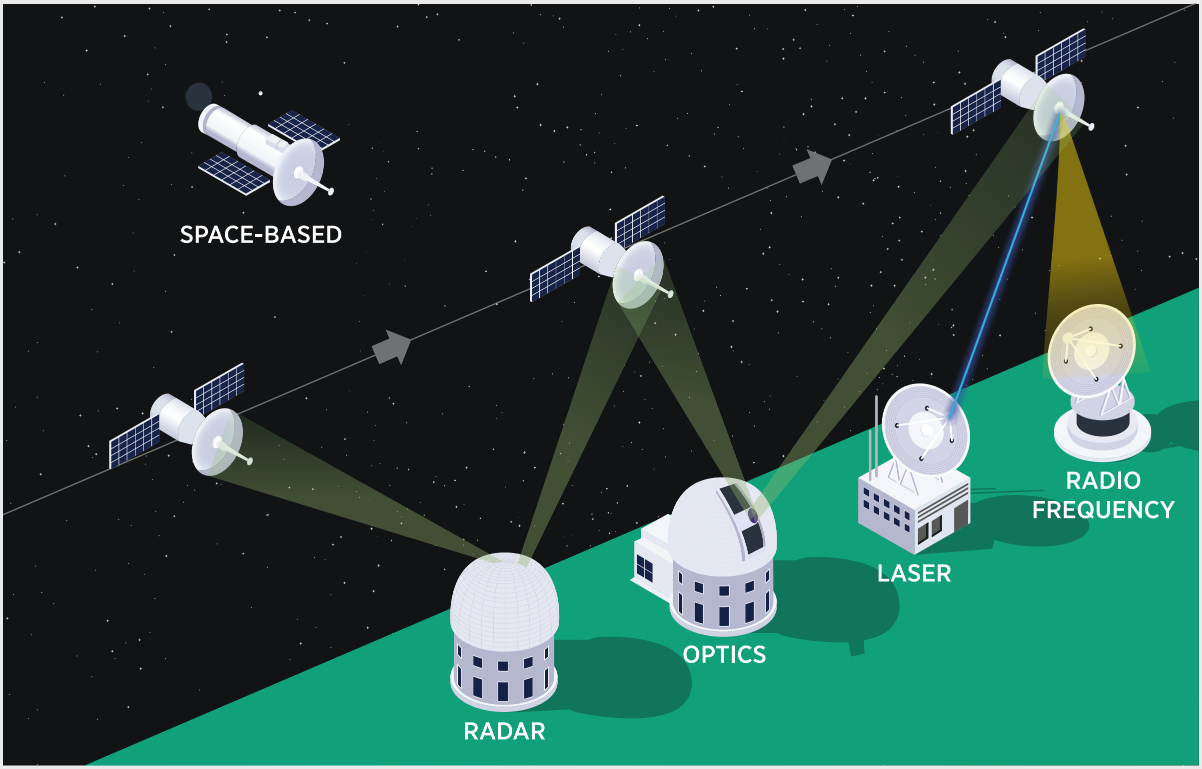
The 1991 Gulf War and subsequent U.S. military operations illustrated the value of the U.S. GPS satellite navigation system for troop movement, force tracking, and precision munition delivery.[626] This prompted other countries to develop their own satellite navigation systems. Today, satellite navigation constellations of China, Russia, the European Union and the United States offer global coverage, and Japan and India operate regional systems.[627,628,629] The rise of foreign satellite navigation services reduces dependence on GPS and provides worldwide users multiple satellite navigation options.[630,631,632]

Space Launch Capabilities

Space launch is the ability to deliver payloads into space. SLVs place satellites in orbit to deploy, sustain, augment, or reconstitute constellations in support of military, civilian, or commercial customers.[633]

Many countries developed space launch capabilities to compete in the international market or to advance national security strategies that require domestic access to space. Many commercial entities are attempting to enter the launch industry with the assistance of a state with established launch capabilities. Some commercial entities are independently developing space launch means.

Space Situational Awareness

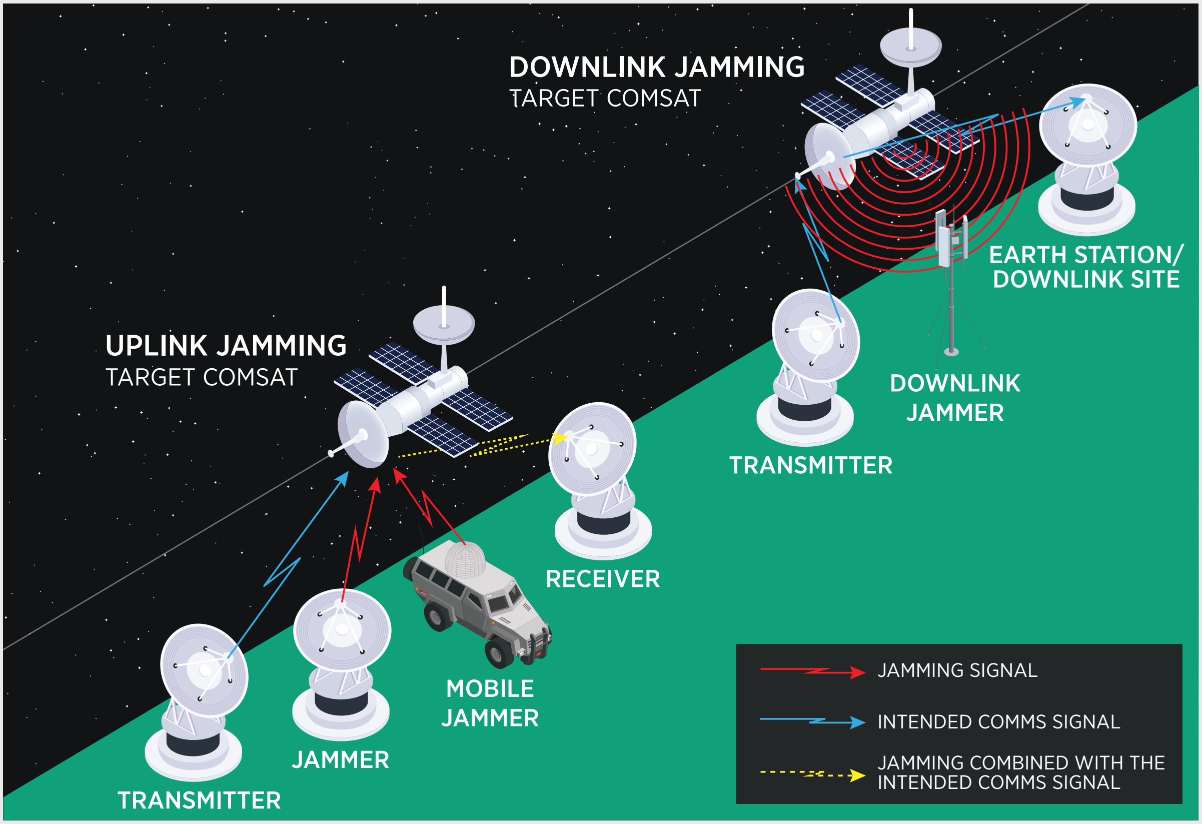


Space situational awareness (SSA) is the detection and characterization of a space object, including its location, and the ability to track it, identify it, and predict its future location.[634] Terrestrial and space-based sensors search the sky for foreign satellites and record their orbits, allowing for the prediction of their orbits and determination of the object's function and operational status. This continuous process is the first in a sequence of steps that potential adversaries will use to target satellites, attack space assets with counterspace weapons, and assess the effectiveness of those attacks. Countries without advanced space tracking sensors can attain basic SSA by purchasing commercially available data.

Cyberthreats to Space Systems[635]

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. Satellite command and data distribution networks expose space systems, ground infrastructure, users, and the links connecting these segments to cyber threats.

Electronic Warfare[636]



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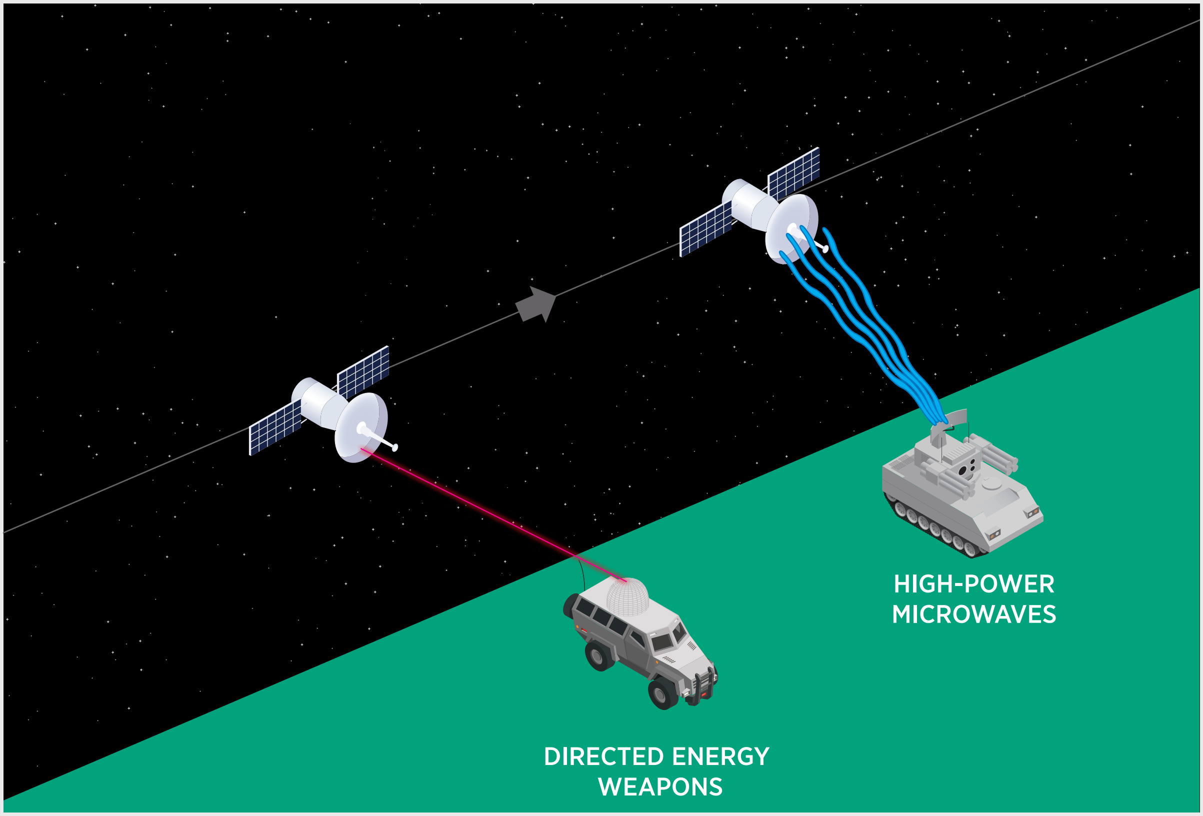
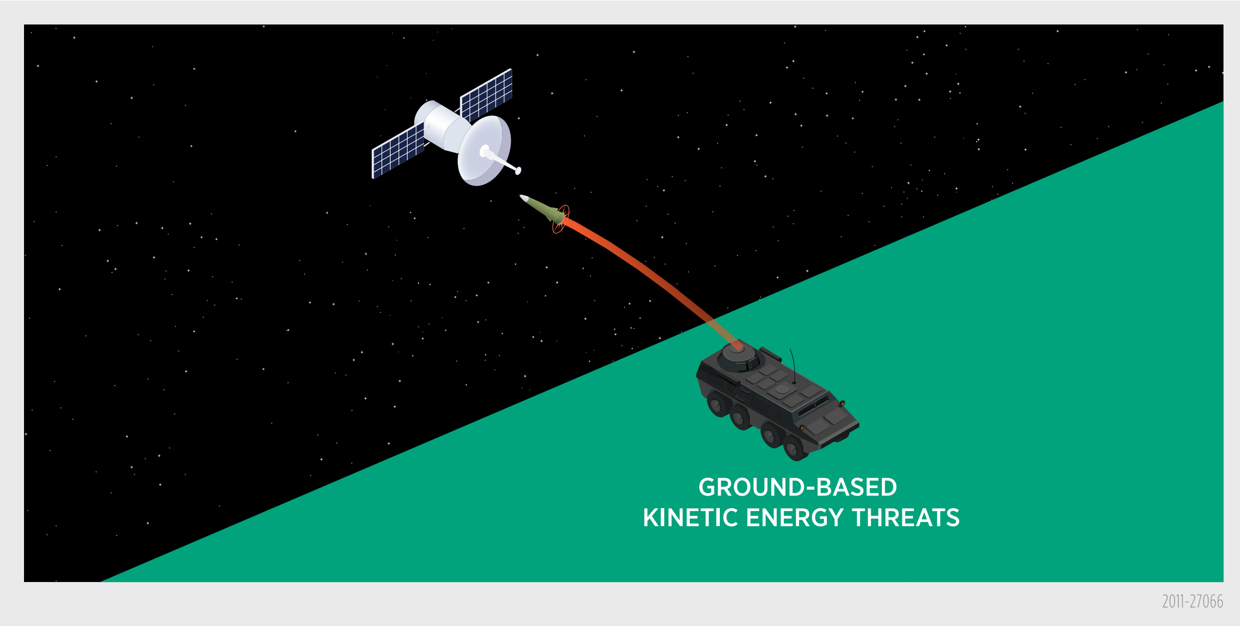
Foreign competitors are able to conduct electronic attacks to disrupt, deny, deceive, or degrade space services. Electronic warfare includes using jamming and spoofing techniques to control the electromagnetic spectrum. Jamming prevents users from receiving intended signals and can be accomplished by two primary methods: uplink jamming and downlink jamming. 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. EW can be challenging to attribute and distinguish from unintentional interference.

Directed-Energy Weapons



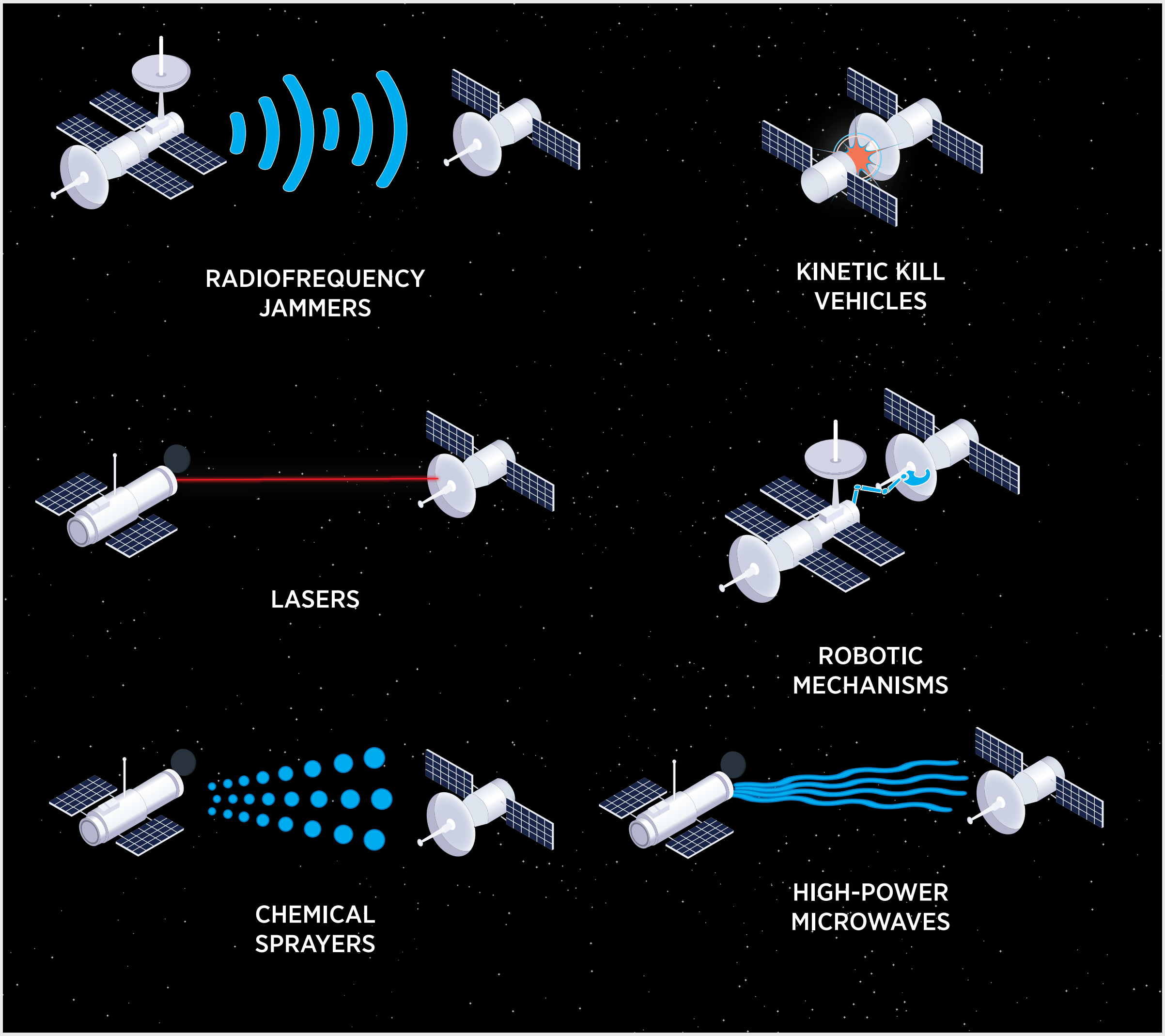
Directed energy weapons are designed to produce reversible or nonreversible effects against space systems to disrupt, damage, or destroy enemy equipment and facilities.[637] Directed energy weapons systems include lasers, high-power microwave weapons, and other types of radiofrequency weapons. Reversible effects include temporarily blinding optical sensors to deny imagery of targeted military forces. Nonreversible effects include permanently damaging or destroying sensors or other satellite components, which causes the operators to lose data and time and face the burdens of replacement or reliance on lesser assets.

Ground-Based ASAT Missiles



Antisatellite 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 or ships at sea. 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 other counterspace weapons because launches are detectable, and their effects can create orbital debris.

Space-based Weapons



Orbital or space-based weapons are satellites that can attack other spacecraft, delivering temporary or permanent damage. These systems can include radiofrequency jammers, kinetic kill vehicles, lasers, robotic mechanisms, chemical sprayers, and high-power microwaves. Some of these systems—such as robotic technology for satellite servicing and repair or space debris removal—have peaceful uses but can also be used in ASAT operations.

Glossary of Acronyms

AGM	missile range instrumentation ship	**ISS**	International Space Station
APOSOS	Asia-Pacific Ground-Based Optical Space Object Observation System	**KZ**	Kuaizhou
APSCO	Asia-Pacific Space Cooperation Organization	**LEO**	low Earth orbit
ASAT	antisatellite	**LM**	Long March
BACC	Beijing Aerospace Control Center	**LNT**	lethal nontrackable debris
BMEW	ballistic missile early warning	**MEO**	medium Earth orbit
C2	command and control	**MODAFL**	Ministry of Defense and Armed Forces Logistics
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance	**NASA**	National Aeronautics and Space Administration
CLTC	China Launch and Tracking Control (PLA SSF SSD)	**NSD**	PLA SSF Network Systems Department
CNSA	China National Space Administration	**PLA**	People's Liberation Army
DEW	directed energy weapon	**PMD**	post-mission disposal
ESA	European Space Agency	**PNT**	positioning, navigation, and timing
EW	electronic warfare, also referred to as "electromagnetic warfare"	**QUESS**	Quantum Experimentation at Space Scale
GEO	geosynchronous Earth orbit	**SAR**	synthetic aperture radar
GLONASS	Global Navigation Satellite System	**SASTIND**	State Administration for Science, Technology, and Industry for National Defense
GPS	Global Positioning System	**SATCOM**	satellite communications
HEO	highly elliptical orbit	**SLV**	space launch vehicle
ICBM	intercontinental ballistic missile	**SSA**	space situational awareness
ILRS	International Lunar Research Station	**SSD**	PLA SSF Space Systems Department
IRGC-ASF	Islamic Revolutionary Guard Corps – Aerospace Force	**SSF**	PLA Strategic Support Force
ISA	Iranian Space Agency	**TT&C**	telemetry, tracking, and control
ISON	International Scientific Optical Network	**xGEO**	deep space orbits beyond 35,000 kilo-meters, but in the Earth-Moon system
ISR	intelligence, surveillance, and reconnaissance	**XSCC**	Xian Satellite Control Center
ISRC	Iranian Space Research Center		

SOURCES/ENDNOTES

[1] Greenemeier, Larry; 8 February 2016; "GPS and the World's First 'Space War'"; *Scientific American;* https://www.scientificamerican.com/article/gps-and-the-world-s-first-space-war/. Accessed 2 August 2021.

[2] Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community,* p. 13.

[3] Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 13.

[4] Chin, Carrey A.; June 2011; *A Study on the Commercialization of Space-based Remote Sensing in the Twenty-First Century and Its Implications to United States National Security;* Naval Postgraduate School; http://faculty.nps.edu/thuynh/Theses/11Jun_Chin.pdf. Accessed 2 August 2021.

[5] Army Space & Missile Defense Command; 2003; "Space – An Enabler"; *Army Space Journal*; https://apps.dtic.mil/dtic/tr/fulltext/u2/a525767.pdf. Accessed 2 August 2021.

[6] Sellers, Jerry Jon; 2015; *Understanding Space: An Introduction to Astronautics, 4th Edition*, pp. 59-60, 657-659; CEI: United States.

[7] Weinbaum, C., Berner, S., and McClintock, B.; PE273; 2017; "SIGINT for Anyone: The Growing Availability of Signals Intelligence in the Public Domain"; *RAND Corporation*; https://www.rand.org/content/dam/rand/pubs/perspectives/PE200/PE273/RAND_PE273.pdf. Accessed 2 August 2021.

[8] Satellite Industry Association; June 2020; SIA: *State of the Satellite Industry Report*; https://brycetech.com/reports/report-documents/SIA_SSIR_2020.pdf. Accessed 2 August 2021.

[9] United Nations Conference on Disarmament; 10 October 1967; "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies"; http://disarmament.un.org/treaties/t/outer_space. Accessed 2 August 2021.

[10] United Nations Conference on Disarmament; CD/1839; 29 February 2008; "Letter Dated 12 February 2008 from the Permanent Representative of the Russian Federation and the Permanent Representative of China to the Conference On Disarmament Addressed to the Secretary-General of the Conference Transmitting the Russian and Chinese Texts of the Draft 'Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects (PPWT)' Introduced by the Russian Federation and China"; https://undocs.org/pdf?symbol=en/CD/1839. Accessed 2 August 2021.

[11] United Nations Conference on Disarmament; CD/1985; 12 June 2014; "Letter dated 10 June 2014 from the Permanent Representative of the Russian Federation and the Permanent Representative of China to the Conference on Disarmament addressed to the Acting Secretary-General of the Conference transmitting the updated Russian and Chinese texts of the draft 'Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects (PPWT)' introduced by the Russian Federation and China"; https://undocs.org/CD/1985. Accessed 2 August 2021.

[12] UK Ministry of Defense; 11 November 2015; *National Security Strategy and Strategic Defence and Security Review 2015*, p. 19; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/478933/52309_Cm_9161_NSS_SD_Review_web_only.pdf. Accessed 2 August 2021.

[13] UK Ministry of Defense; 28 March 2018; *National Security and Capability Review*, p. 19; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/705347/6.4391_CO_National-Security-Review_web.pdf. Accessed 2 August 2021.

[14] UK Ministry of Defense; 17 June 2020; *Toward a Defence Space Strategy*; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712376/MOD_Pocket_Tri-Fold_-_Defence_Space_Strategy_Headlines.pdf. Accessed 2 August 2021.

[15] Lye, Harry; 2 April 2020; "Will the UK get a Space Command?" *Airforce Technology*; https://www.airforce-technology.com/features/will-the-uk-get-a-space-command/. Accessed 2 August 2021.

[16] Chuter, Andrew; 15 January 2020; "Former Fighter Pilot Picked to Lead British Military's Space Command"; *Defense News*; https://www.defensenews.com/global/europe/2020/01/15/former-fighter-pilot-picked-to-lead-british-militarys-space-command. Accessed 2 August 2021.

[17] EuroNews; 13 July 2019; "France's Macron announces creation of French Space Force"; https://www.euronews.com/2019/07/13/france-s-macron-announces-creation-of-french-space-force. Accessed 2 August 2021.

[18] Blenkin, Max; 3 February 2020; "Germany signs up for multinational Combined Space Operations Initiative"; *Space Connect*; https://www.spaceconnectonline.com.au/operations/4116-germanysigns-up-for-multinational-combined-space-operations-initiative. Accessed 2 August 2021.

[19] Miles, Cody, Maj.; 11 February 2020; "German delegation visits Vandenberg, discusses future of space operations"; *Combined Force Space Component Command Public Affairs*; https://www.spacecom.mil/MEDIA/NEWS-ARTICLES/Article/2081290/german-delegation-visits-vandenberg-discusses-future-space-cooperation/. Accessed 2 August 2021.

[20] Jungholt, Thorsten; 21 August 2019; "Armament in Space – Still Without Weapons"; *Die Welt*; https://www.welt.de/politik/deutschland/plus198779675/Bundeswehr-So-laeuft-die-Aufruestung-im-Weltraum.html. Accessed 2 August 2021.

[21] AP News; 21 September 2020; "German military opens new space operations center"; https://apnews.com/article/national-security-germany-europe-archive-russia-94aaa4939c5c736e268f-388700b49c6b. Accessed 2 August 2021.

[22] Johnston, Eric; 2 June 2020; "Japan's New Space Squadron Takes a Giant Leap Forward"; *The Japan Times*; https://www.japantimes.co.jp/news/2020/06/02/national/japan-space-force-self-defense-forces/. Accessed 2 August 2021.

[23] Republic of Korea Ministry of National Defense; 11-1290000-000446-11; 31 December 2018; *2018 Defense White Paper*, p. 19; https://www.mnd.go.kr/user/mnd/upload/pblictn/PBLICTNEBOOK_201907110548253080.pdf. Accessed 2 August 2021.

[24] DOD News; 5 September 2014; "DoD Agrees to Share Space Data with South Korea"; https://www.defense.gov/Explore/News/Article/Article/603194/. Accessed 2 August 2021.

[25] Republic of Korea Ministry of National Defense; 11-1290000-000446-11; 31 December 2018; *2018 Defense White Paper*, p. 74; https://www.mnd.go.kr/user/mnd/upload/pblictn/PBLICTNEBOOK_201907110548253080.pdf. Accessed 2 August 2021.

[26] Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. II-4 – II-5.

[27] Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. II-4 - II-5.

[28] Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. II-3 - II-4.

[29] Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. II-8, II-17 – II-18.

[30] The Chicago Tribune; 21 May 1998; "Satellite Outage Felt By Millions"; https://www.chicagotribune.com/news/ct-xpm-1998-05-21-9805210138-story.html. Accessed 28 July 2021.

[31] Brinson, Linda C.; March 2011; "What breakthroughs in medicine came from NASA?" *How Stuff Works*; https://science.howstuffworks.com/innovation/nasa-inventions/nasa-breakthroughs-in-medicine.htm. Accessed 28 July 2021.

[32] International Space Exploration Coordination Group; *Benefits Stemming from Space Exploration*; September 2013; https://www.nasa.gov/sites/default/files/files/Benefits-Stemming-from-Space-Exploration-2013-TAGGED.pdf. Accessed 2 August 2021.

[33] NASA Jet Propulsion Laboratory; *20 Inventions We Wouldn't Have Without Space Travel*; https://www.jpl.nasa.gov/infographics/infographic.view.php?id=11358. Accessed 28 July 2021.

[34] Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. I-13.

[35] U.S. Space Command Public Affairs; 15 November 2021; "Russian direct-ascent anti-satellite missile test creates significant, long-lasting space debris"; https://www.spacecom.mil/news/article-display/article/2842957/russia-direct-ascent-anti-satellite-missile-creates-significant-long-last/#.yzrxfviqul4. Accessed 16 November 2021.

[36] Comprehensive Nuclear Test Ban Treaty Organization; 5 November 2020; "9 July 1962: 'Starfish Prime', Outer Space"; https://www.ctbto.org/specials/testing-times/9-july-1962starfish-prime-outer-space. Accessed 5 August 2020.

[37] Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. I-11 – I-12.

[38] Riebeek, Holli; 4 September 2009; "Catalog of Earth Satellite Orbits"; *NASA*; https://earthobservatory.nasa.gov/features/Orbits-Catalog. Accessed 5 August 2020.

[39] The State Council of the People's Republic Of China; 28 December 2016; *Full text of white paper on China's space activities in 2016*; http://english.www.gov.cn/archive/white_paper/2016/12/28/content_281475527159496.htm. Accessed 2 August 2021.

[40] Xiao Tianliang, Lt. Gen., ed.; September 2020; *The Science of Military Strategy* (2020 Edition), p. 142; PLA National Defense University.

[41] Gebhardt, Chris; 22 July 2020; "China seeks 'Heavenly Questions' with ambitious Tianwen-1 mission to Mars"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/07/china-ambitious-tianwen1-mars/. Accessed 2 August 2021.

[42] Bryce Space and Technology; 31 October 2020; *2020 Year in Review*; https://www.brycetech.com/reports/report-documents/Bryce_2020_Year_In_Review.png. Accessed 2 August 2021.

[43] Bryce Space and Technology; 31 December 2019; *"China's Orbital Launch Activity"*; https://brycetech.com/reports/report-documents/China_Orbital_Launch_Activity_2020.pdf. Accessed 21 March 2022.

[44] Krebs, Gunther; 14 September 2020; "Tiangong-1 (TG-1)"; *Gunther's Space Page*; https://space.skyrocket.de/doc-sdat/tg-1.htm. Accessed 2 August 2021.

[45] Howell, Elizabeth; 26 March 2018; "Tiangong-1: China's First Space Station"; *Space.com*; https://www.space.com/27320-tiangong-1.html. Accessed 2 August 2021.

[46] Krebs, Gunther; 14 September 2020; "Tiangong-2 (TG-2)"; *Gunther's Space Page*; https://space.skyrocket.de/doc-sdat/tg-2.htm. Accessed 2 August 2021.

[47] Nowakowski, Tomasz; 22 May 2016; "China reveals design for planned Tiangong 3 space station"; *Space Flight Insider*; https://www.spaceflightinsider.com/missions/human-spaceflight/china-reveals-design-planned-tiangong-3-space-station/. Accessed 3 August 2021.

[48] Graham, William and Gebhardt, Chris; 28 June 2021; "China launches Tianhe module, start of ambitious two-year station construction effort"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2021/04/china-station-construction-begins/. Accessed 30 June 2021.

[49] Chang, Kenneth; 7 December 2018; "China's Chang'e-4 Launches on Mission to the Moon's Far Side"; *The New York Times*; https://www.nytimes.com/2018/12/07/science/china-moon-change-4.html. Accessed 3 August 2021.

[50] Amos, Jonathan; 16 December 2020; "China's Chang'e-5 Moon mission probe touches down"; *BBC*; https://www.bbc.com/news/science-environment-55148998. Accessed 3 August 2021.

[51] Burghardt, Thomas; 23 November 2020; "China launches world's first lunar sample return mission since 1976"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/11/change5-sample-return-launch/. Accessed 3 August 2021.

[52] Gebhardt, Chris; 1 December 2020; "China lands on Moon after causing deep confusion by stopping broadcast"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/12/china-preparing-to-land-sample-return-mission-on-the-moon/. Accessed 3 August 2021.

[53] AP News; 17 December 2020; "Chinese capsule returns to Earth carrying moon rocks"; https://apnews.com/article/technology-china-moon-da510a5fd9a97505296ddbdb5749c393. Accessed 3 August 2021.

[54] Gebhardt, Chris; 22 July 2020; "China seeks 'Heavenly Questions' with ambitious Tianwen-1 mission to Mars"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/07/china-ambitious-tianwen1-mars/. Accessed 2 August 2021.

[55] Gebhardt, Chris; 10 February 2021; "China, with Tianwen-1, begins tenure at Mars with successful orbital arrival"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2021/02/china-ready-to-begin-mars-tenure-with-tianwen-1-orbit-insertion/. Accessed 12 February 2021.

[56] Hanneke, Weitering; 14 May 2021; "China's 1st Mars rover 'Zhurong' lands on the Red Planet"; *Space.com*; https://www.space.com/china-mars-rover-landing-success-tianwen-1-zhurong. Accessed 14 May 2021.

[57] Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. I-13.

[58] 18 Space Control Squadron; "Box Score"; Space-Track.org; https://www.space-track.org/#boxscore. Accessed 19 March 2022.

[59] Office of the Director of National Intelligence; 11 May 2017; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 9.

[60] Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 13.

[61] Office of the Secretary of Defense; April 2015; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, p. 14; https://dod.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf. Accessed 27 July 2021.

[62] Newman, Scott and Kuhn, Anthony; 10 April 2018; "Beijing Reportedly Installs Communications Jamming Equipment in South China Sea"; *National Public Radio*; https://www.npr.org/sections/parallels/2018/03/02/589876233/the-u-s-positions-warships-in-tense-asia-pacific-waters. Accessed 2 August 2021.

[63] Martini, Paul; 21 September 2016; "Cybersecurity is threatening America's military supremacy"; *Crunch Network* (Reposted on *Resilient Navigation and Timing Foundation* blog); https://rntfnd.org/2016/09/26/china-jamming-us-forces-gps/. Accessed 2 August 2021.

[64] The State Council of the People's Republic Of China; 28 December 2016; *Full text of white paper on China's space activities in 2016*; http://english.www.gov.cn/archive/white_paper/2016/12/28/content_281475527159496.htm. Accessed 2 August 2021.

[65] The State Council of the People's Republic Of China; 28 January 2022; Full Text: China's Space Program: A 2021 Perspective; http://www.xinhuanet.com/english/20220128/eb9fb038eb-fe4a3d93887b9f120ef74a/c.html. Accessed 28 January 2022.

[66] Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, pp. 63-65; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

[67] U.S.-China Economic and Security Review Commission; 8 September 2017; *China's Position on a Code of Conduct in Space*, p. 2; https://www.uscc.gov/sites/default/files/Research/USCC_China's%20Position%20on%20a%20Code%20of%20Conduct%20in%20Space.pdf. Accessed 3 August 2021.

[68] Kulaki, Gregory and Lewis, Jeffery G.; January 2009; *A Place for One's Mat: China's Space Program, 1956-2003*, p. 15; Carnegie Corporation; https://media.carnegie.org/filer_public/34/26/34264093-10f5-4f7c-a02c-6611514f5ee7/ccny_grantee_2009_china.pdf. Accessed 2 August 2021.

[69] Goswami, Namrata; 15 October 2018; "Waking Up to China's Space Dream"; *The Diplomat*; https://thediplomat.com/2018/10/waking-up-to-chinas-space-dream/. Accessed 2 August 2021.

[70] Stokes, M., Alvarado, G., Weinstein, E., Easton, I.; 30 March 2020; "China's Space and Counterspace Capabilities and Activities", p. 28; *Project 2049 Institute prepared for The U.S.-China Economic and Security Review Commission*; https://www.uscc.gov/sites/default/ files/2020-05/China_Space_and_Counterspace_Activities.pdf. Accessed 3 August 2021.

[71] Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. I-13.

[72] 18 Space Control Squadron; "Box Score"; Space-Track.org; https://www.space-track.org/#boxscore. Accessed 19 March 2022.

[73] Office of the Director of National Intelligence; 11 May 2017; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community, p. 9.*

[74] The State Council Information Office of the People's Republic of China; 26 May 2015; *China's Military Strategy (2015)*, pp. 6, 11, 16-17; http://www.chinadaily.com.cn/china/2015-05/26/content_20820628.htm. Accessed 2 August 2021.

[75] The State Council Information Office of the People's Republic of China; 26 May 2015; *China's Military Strategy (2015)*, p. 3; http://www.chinadaily.com.cn/china/2015-05/26/content_20820628.htm. Accessed 2 August 2021.

76 Defense Intelligence Agency; 26 April 2021; *Statement of the Record Worldwide Threat Assessment*, pp. 8-9.

77 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, p. 82; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 2 August 2021.

78 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 13.

79 Pollpeter, Kevin, et al; 2017; "The Creation of the PLA Strategic Support Force and Its Implications for Chinese Military Space Operations", p. ix, 7; *RAND Corporation*; https://www.rand.org/content/dam/rand/pubs/research_reports/RR2000/RR2058/RAND_RR2058.pdf. Accessed 2 August 2021.

80 MacDonald, B.W., Blair, D., Cheng, D., Mueller, K., and Sampson, V.; 2016; *Crisis Stability in Space: China and Other Challenges*; Johns Hopkins School of Advanced International Studies, Foreign Policy Institute.

81 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 13.

82 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress; Military and Security Developments Involving the People's Republic of China 2020*, pp. 81-82; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

83 Kulacki, Greg; 1 July 2009; "Anti-Satellite (ASAT) Technology in Chinese Open-Source Publications"; *Union of Concerned Scientists*; https://ucsusa.org/sites/default/files/2019-09/Kulacki-Chinese-ASAT-Literature-6-10-09.pdf. Accessed 2 August 2021.

84 Xianqi, Chang Maj. Gen., ed.; January 2005; *Military Astronautics*, pp. 247-266; Academy of Equipment Command Technology.

85 Pollpeter, Kevin, et al; 2 March 2015; "China Dream, Space Dream – China's Progress in Space Technologies and Implications for the United States", p. iv; *U.S.-China Economic and Security Review Commission*; https://www.uscc.gov/sites/default/files/Research/China%20Dream%20Space%20Dream_Report.pdf. Accessed 3 August 2021.

86 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2018*, pp. 72, 74; https://media.defense.gov/2018/Aug/16/2001955282/-1/-1/1/2018-CHINA-MILITARY-POWER-REPORT.PDF. Accessed 3 August 2021.

87 Chang Long; 28 October 2003; "Grasp the Trend of New Military Changes – Review and Prospect from the Gulf War to Iraq War"; *Jiefangjun Bao*.

88 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, p. 65; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

89 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, p. 63; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

90 Xinhua; 15 November 2013; "China to tackle monopolies, introduce competition: CPC"; http://www.globaltimes.cn/content/825209.shtml. Accessed 2 August 2021.

91 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, pp. viii, 61; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

92 Costello, John; 8 February 2016; "The Strategic Support Force: China's Information Warfare Service"; *The Jamestown Foundation*; https://jamestown.org/program/the-strategic-support-force-chinas-information-warfare-service/. Accessed 2 August 2021.

93 Pollpeter, Kevin, et al; 2017; "The Creation of the PLA Strategic Support Force and Its Implications for Chinese Military Space Operations", p. ix; *RAND Corporation*; https://www.rand.org/content/dam/rand/pubs/research_reports/RR2000/RR2058/RAND_RR2058.pdf. Accessed 2 August 2021.

94 Xinhua; 6 July 2021; "Xi promotes four military officers to rank of general"; http://www.xinhuanet.com/english/2021-07/06/c_1310044470.htm. Accessed 23 July 2021.

95 Ni, Adam and Gill, Bates; 29 May 2019; "The People's Liberation Army Strategic Support Force: Update 2019"; *The Jamestown Foundation: China Brief, Vol. 19, Iss. 10*, pp. 13-16; https://jamestown.org/program/the-peoples-liberation-army-strategic-support-force-update-2019/. Accessed 23 July 2021.

96 Chopra, Anil; 8 March 2021; "People's Liberation Army Strategic Support Force – A Comprehensive Look"; *Air Power Asia*; https://airpowerasia.com/2021/03/08/peoples-liberation-army-strategic-support-force-a-comprehensive-look/. Accessed 23 July 2021.

97 Pollpeter, Kevin, et al; 2017; "The Creation of the PLA Strategic Support Force and Its Implications for Chinese Military Space Operations", p. ix; *RAND Corporation*; https://www.rand.org/content/dam/rand/pubs/research_reports/RR2000/RR2058/RAND_RR2058.pdf. Accessed 2 August 2021.

98 Wood, P., Stone, A., and Lee, T.A.; 1 March 2021; "China's Ground Segment: Building the Pillar of a Great Space Power", p. 22; *China Aerospace Studies Institute;* https://airuniversity.af.edu/portals/10/casi/documents/research/space/2021-03-01 chinas ground segment.pdf?ver=z4ogy_mrxadurwvt-r9j6w%3d%3d. Accessed 2 August 2021.

99 Ni, Adam and Gill, Bates; 29 May 2019; "The People's Liberation Army Strategic Support Force: Update 2019"; *The Jamestown Foundation: China Brief, Vol. 19, Iss. 10*, pp. 13-16; https://https://jamestown.org/program/the-people's-liberation-army-strategic-support-force-update-2019/. Accessed 2 August 2021.

100 Ni, Adam and Gill, Bates; 29 May 2019; "The People's Liberation Army Strategic Support Force: Update 2019"; *The Jamestown*

Foundation: China Brief, Vol. 19, Iss. 10, pp. 16-17; https://https://jamestown.org/program/the-peoples-liberation-army-strategic-support-force-update-2019/. Accessed 2 August 2021.

[101] Chopra, Anil; 8 March 2021; "People's Liberation Army Strategic Support Force – A Comprehensive Look"; *Air Power Asia*; https://airpowerasia.com/2021/03/08/peoples-liberation-army-strategic-support-force-a-comprehensive-look/. Accessed 26 July 2021.

[102] The State Council of the People's Republic of China; 6 October 2014; *State Administration for Science, Technology and Industry for National Defense*; http://english.www.gov.cn/state_council/2014/10/06/content_281474992893468.htm. Accessed 2 August 2021.

[103] Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, p. 142; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

[104] Jones, Andrew; 25 May 2018; "China appoints new space agency administrator"; *GB Times*; https://www.spacetechasia.com/zhang-kejian-appointed-administrator-of-chinas-space-agency/. Accessed 2 August 2021.

[105] The State Council of the People's Republic Of China; 28 January 2022; Full Text: China's Space Program: A 2021 Perspective; http://www.xinhuanet.com/english/20220128/eb9fb038ebfe4a3d93887b9f120ef74a/c.html. Accessed 28 January 2022.

[106] UNOOSA; 28 May 2018; "Handbook: China Space Station and its Resources for International Cooperation", pp. 8, 27-28; http://www.unoosa.org/documents/doc/psa/hsti/CSS_1stAO/CSS_1stAO_Handbook_2018.pdf. Accessed 3 August 2021.

[107] Luxembourg Ministry of Economy; 17 January 2018; T*he National Space Science Center of the Chinese Academy of Sciences to establish a Research Laboratory in Luxembourg*; https://gouvernement.lu/en/actualites/toutes_actualites/communiques/2018/01-janvier/17-schneider-agreement-china-en.html. Accessed 2 August 2021.

[108] Wood, P., Stone, A., and Lee, T.A.; 1 March 2021; "China's Ground Segment: Building the Pillar of a Great Space Power", p. 62; *China Aerospace Studies Institute*; https://airuniversity.af.edu/portals/10/casi/documents/research/space/2021-03-01 chinas ground segment.pdf?ver=z4ogy_mrxadurwvt-r9j6w%3d%3d. Accessed 2 August 2021.

[109] Prague Security Studies Institute; 31 March 2019; S*tate Actor Strategies in Attracting Space Sector Partnerships: Chinese and Russian Economic and Financial Footprints*, p. 11.

[110] Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, p. 138; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

[111] Herbert, Natalie; February 2021; "Achieving the PLA's Strategic Support Force talent needs through MCF"; *China Aerospace Studies Institute*; https://airuniversity.af.edu/portals/10/casi/documents/research/casi articles/2021-02-01 achieving the plassf talent needs through mcf.pdf?ver=r2p5iwlumz_bvmqohmtwuw%3d%3d. Accessed 2 August 2021.

[112] OK-Space; 5 May 2017; "OKW and CASC 1st Academy carry out cooperation and exchange".

[113] China Spaceflight Blog; 16 September 2017; "Orbita".

[114] Barbosa, Rui; 8 November 2020; "Introducing China's new commercial rocket, Ceres-1"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/11/introducing-chinas-new-commercial-rocket-ceres-1/. Accessed 2 August 2021.

[115] Expace Technology Co Ltd. "KZ Promotional Flier".

[116] Hannas, W.C., Mulvenon, J.C., Puglisi, A.B.; 2013; *Chinese Industrial Espionage*: *Technology Acquisition and Military Modernization*, pp. 19, 22-23, 33-34, 78, 176, 189, 204-205, 216.

[117] Harvey, Brian; 2013; *China in Space: The Great Leap Forward*, pp. 105-119, 184-214; Springer Science + Business Media: New York.

[118] 18 Space Control Squadron; "Catalog"; Space-Track.org; https://www.space-track.org/#catalog. Accessed 19 March 2022.

[119] Union of Concerned Scientists (UCS); 1 January 2022; "Satellite Database"; https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database. Accessed 19 March 2022.

[120] Keluo Liaofu; 8 October 2015; "Jilin-1 Satellite Liftoff into Space: US Aircraft Carrier has Nowhere to Hide"; *Dingsheng Military Forum.*

[121] Sina (China Youth Network Reprint); 4 October 2015; "China's High Score 4 satellite will be able to lock down U.S. aircraft carriers by global surveillance at the end of the year".

[122] Union of Concerned Scientists (UCS); 1 January 2022; "Satellite Database"; https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database. Accessed 7 December 2021.

[123] Stokes, M., Alvarado, G., Weinstein, E., Easton, I.; 30 March 2020; "China's Space and Counterspace Capabilities and Activities", p. 33; *Project 2049 Institute prepared for the U.S.-China Economic and Security Review Commission*, https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf. Accessed 3 August 2021.

[124] Pan Changpeng, Gu Wenjin, and Chen Jie, 2006; "An Analysis on the Capabilities of Military Satellites to Support an ASBM in Offense and Defense Operations"; *Winged Missiles Journal*, No. 5 (2006).

[125] Gao Fei, Hu Xujie, Gao Lungyun, and Liu Xiangmin; 19 March 2008; "An Analysis on the Influence of Military Satellite Information Systems on Missile Operations"; *Defense Science and Technology, Vol. 29, No.4 (2008)*.

[126] Stokes, M., Alvarado, G., Weinstein, E., Easton, I.; 30 March 2020; "China's Space and Counterspace Capabilities and Activities", p. 33; *Project 2049 Institute prepared for the U.S.-China Economic and Security Review Commission*; https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf. Accessed 3 August 2021.

127 Stokes, M., Alvarado, G., Weinstein, E., Easton, I.; 30 March 2020; "China's Space and Counterspace Capabilities and Activities", p. 28; *Project 2049 Institute prepared for the U.S.-China Economic and Security Review Commission*; https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf. Accessed 3 August 2021.

128 Union of Concerned Scientists (UCS); 1 January 2022; "Satellite Database"; https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database. Accessed 19 March 2022.

129 Stokes, Mark A. and Cheng, Dean; 26 April 2012; "China's Evolving Space Capabilities: Implications for U.S. Interests", p. 36; *Project 2049 Institute prepared for the U.S.-China Economic and Security Review Commission*; https://www.uscc.gov/sites/default/files/Research/USCC_China-Space-Program-Report_April-2012.pdf. Accessed 3 August 2021.

130 Stokes, M., Alvarado, G., Weinstein, E., Easton, I.; 30 March 2020; "China's Space and Counterspace Capabilities and Activities", p. 28; *Project 2049 Institute prepared for the U.S.-China Economic and Security Review Commission*; https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf. Accessed 3 August 2021.

131 Xinhua; 25 April 2008; "China Blasts Off First Data Relay Satellite".

132 Chen Lihu, Wang Shilian, and Zhang Eryang; 1 June 2007; "Modeling and Simulation of Missile Satellite-Missile Link Channel in Flying-Control Data-Link", *Systems Engineering and Electronics*, Vol. 29: Issue 6 (2007).

133 Wu Ting-yong, Wu Shi-qi, and Ling Xiang, December 2005; "A MEO Tracking and Data Relay Satellite System Constellation Scheme for China", *Journal of Aerospace Electronic Information Engineering, Control*, pp. 248-252.

134 The State Council of the People's Republic Of China; 28 January 2022; Full Text: China's Space Program: A 2021 Perspective; http://www.xinhuanet.com/english/20220128/eb9fb038ebfe4a3d93887b9f120ef74a/c.html. Accessed 28 January 2022.

135 Office of the Secretary of Defense; 16 May 2018; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2018*, p. 85-86; https://media.defense.gov/2018/Aug/16/2001955282/-1/-1/1/2018-CHINA-MILITARY-POWER-REPORT.PDF. Accessed 27 July 2021.

136 Chan, Minnie; 6 November 2016; "Chinese Aerospace Giant Unveils First Smartphone for Country's Satellite Communications Network"; *South China Morning Post*; http://www.scmp.com/news/china/article/2042978/chinese-aerospace-giant-unveils-first-smartphone-countrys-satellite. Accessed 2 August 2021.

137 Conover, Emily; 13 December 2017; "A quantum communications satellite proved its potential in 2017"; *Science News*; https://www.sciencenews.org/article/global-quantum-communication-top-science-stories-2017-yir. Accessed 2 August 2021.

138 Krebs, Gunther; 14 September 2020; "QSS (QUESS, Mozi)"; *Gunther's Space Page*; https://space.skyrocket.de/doc_sdat/qss.htm. Accessed 27 July 2021.

139 Makichuk, Dave; 17 June 2020; "China claims quantum supremacy with satellite test"; *Asia Times*; https://asiatimes.com/2020/06/chinese-team-claim-quantum-supremacy-with-satellite-test/. Accessed 2 August 2021.

140 Stokes, M., Alvarado, G., Weinstein, E., Easton, I.; 30 March 2020; "China's Space and Counterspace Capabilities and Activities", pp. 64-65; *Project 2049 Institute prepared for the U.S.-China Economic and Security Review Commission*; https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf. Accessed 3 August 2021.

141 Curcio, Blaine; 4 December 2020; "Constellation Watch: China's Incubating Answer to Starlink"; *Satellite Markets*; http://satellitemarkets.com/constellation-watch-china-incubating-answer-starlink. Accessed 2 August 2021.

142 Economic Times of India; 16 July 2018; "China to build 300 satellite communications constellation in low Earth orbit"; https://economictimes.indiatimes.com/news/international/world-news/china-to-launch-300-satellites-to-provide-worldwide-low-orbit-communications/articleshow/65005723.cms?from=mdr. Accessed 2 August 2021.

143 China National Administration of GNSS and Applications; 10 November 2017; "China's Rainbow Project Will Launch 156 Small Satellites to Build Space-Based Internet".

144 Ok-Space; 29 January 2018; "National Constellation – We have been helping".

145 Jones, Andrew; 21 April 2021; "China is developing plans for a 13,000-satellite megaconstellation"; *Space News*; https://spacenews.com/china-is-developing-plans-for-a-13000-satellite-communications-megaconstellation/. Accessed 2 August 2021.

146 Jones, Andrew; 28 February 2020; "China to complete its answer to GPS with Beidou navigation satellite launches in March, May"; *Space News*; https://spacenews.com/china-to-complete-its-answer-to-gps-with-beidou-navigation-satellite-launches-in-march-may/. Accessed 3 August 2021.

147 Wencheng, Gao; 23 June 2020; "Commentary: China's BeiDou system primed for serving whole world; *Xinhua*.

148 Yuanxi Yang, Weiguang Gao, Shuren Guo, Yue Mao, Yufei Yang; 11 December 2018; "Introduction to BeiDou-3 navigation satellite system"; *Navigation*.

149 Betz, J. Mingquan Lu, Morton, Y.T. J., Yuanxi Yang; 3 January 2019; "Introduction to the special issue on the BeiDou navigation system"; *Navigation*.

150 Mingquan Lu, Wenyi Li, Zheng Yao, Xiaowei Cui; 16 December 2018; "Overview of BDS III new signals"; *Navigation*.

151 Barbosa, Rui; 22 June 2020; "China Launches final Beidou-3 with Long march 3B Return to Flight"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/06/china-complete-beidou-constellation-long-march-3b/. Accessed 2 August 2021.

152 International GNSS Service; 11 August 2020; "BeiDou"; http://mgex.igs.org/IGS_MGEX_Status_BDS.php. Accessed 2 August 2021.

[153] Beidou Navigation Systems; 19 March 2020; "China Successfully Launched the 54th BDS Satellite"; http://en.beidou.gov.cn/WHATSNEWS/202004/t20200401_20279.html. Accessed 2 August 2021.

[154] Jones, Andrew; 28 February 2020; "China to complete its answer to GPS with Beidou navigation satellite launches in March, May"; *Space News*; https://spacenews.com/china-to-complete-its-answer-to-gps-with-beidou-navigation-satellite-launches-in-march-may/. Accessed 3 August 2021.

[155] China Satellite Navigation Office; 5 March 2018; "Development of BeiDou Navigation Satellite System (BDS) – A System Update Report (2017-2018)"; *Munich Satellite Navigation Summit 2018 Proceedings*.

[156] Xinhua; 27 December 2018; "China's BeiDou navigation system starts global service"; http://www.xinhuanet.com/english/2018-12/27/c_137702496.htm. Accessed 2 August 2021.

[157] Howell, Elizabeth; 23 June 2020; "China launches final Beidou satellite to complete GPS-like navigation system"; *Space.com*; https://www.space.com/china-launches-final-beidou-navigation-satellite.html?jwsource=cl. Accessed 2 August 2021.

[158] Gebhardt, Chris; 10 February 2021; "China, with Tianwen-1, begins tenure at Mars with successful orbital arrival"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2021/02/china-ready-to-begin-mars-tenure-with-tianwen-1-orbit-insertion/. Accessed 20 July 2021.

[159] Hanneke, Weitering; 14 May 2021; "China's 1st Mars rover 'Zhurong' lands on the Red Planet"; *Space.com*; https://www.space.com/china-mars-rover-landing-success-tianwen-1-zhurong. Accessed 20 July 2021.

[160] Woo, Ryan and Sun Yilei; 22 May 2021; "China says Martian rover takes first drive on surface of Red Planet"; *Reuters*; https://www.reuters.com/lifestyle/science/china-says-martian-rover-takes-first-drive-surface-red-planet-2021-05-22/. Accessed 20 July 2021.

[161] China Central Television; 28 August 2020; "China PLA 74th Group Army's Amphibious Brigade Holds Joint Land-Sea-Air Island Landing Drill".

[162] Liu Jiasheng, Sun Datong, and Peng Fubing; 1 February 2019; "Building Strategic Projection Carrying Tools Based on National Security Requirements"; *Journal of Military Transportation University*.

[163] BeiDou Navigation Systems; December 2019; "Development of the BeiDou Navigation Satellite System (Version 4.0)".

[164] Cang Wei and Song Wenwei; 26 May 2014; "Beidou to help safeguard fisherman on the high seas"; *Xinhua*.

[165] Xinhua; 17 May 2012; "Beidou Navigation System Installed on More Chinese Fishing Boats".

[166] BeiDou Navigation Systems; December 2019; "Development of the BeiDou Navigation Satellite System (Version 4.0)".

[167] The State Council of the People's Republic of China; 16 June 2016; "Full Text: China's BeiDou Navigation Satellite System".

[168] Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, p. 64; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

[169] Lianping Gao and Ryan Woo; 26 May 2021; "China's Beidou navigation system to serve $156 billion home market by 2025"; *Reuters* (Yahoo Finance reprint); https://finance.yahoo.com/news/chinas-beidou-navigation-system-serve-053827138.html. Accessed 20 July 2021.

[170] Krebs, Gunther; 23 May 2020; "Shenzhou Flight History"; *Gunter's Space Page*; https://space.skyrocket.de/doc_sat/shenzhou_hist.htm. Accessed 2 August 2021.

[171] Krebs, Gunther; 14 September 2020; "Shenzhou 1, 2, 3, 4, 5, 6, 7 (SZ 1, 2, 3, 4, 5, 6, 7)"; *Gunther's Space Page*; https://space.skyrocket.de/doc_sdat/sz-1.htm. Accessed 2 August 2021.

[172] Krebs, Gunther; 14 September 2020; "Shenzhou 8, 9, 10, 11, 12 (SZ 8, 9, 10, 11, 12)"; *Gunther's Space Page*; https://space.skyrocket.de/doc_sdat/sz-8.htm. Accessed 2 August 2021.

[173] Krebs, Gunther; 14 September 2020; "Tiangong-1 (TG-1)"; *Gunther's Space Page*; https://space.skyrocket.de/doc-sdat/tg-1.htm. Accessed 2 August 2021.

[174] Howell, Elizabeth; 26 March 2018; "Tiangong-1: China's First Space Station"; *Space.com*; https://www.space.com/27320-tiangong-1.html. Accessed 3 August 2021.

[175] Krebs, Gunther; 14 September 2020; "Tiangong-2 (TG-2)"; *Gunther's Space Page*; https://space.skyrocket.de/doc-sdat/tg-2.htm. Accessed 2 August 2021.

[176] China Daily; 8 May 2020; "Spacecraft re-entry Model Test Successful".

[177] Graham, William and Gebhardt, Chris; 28 June 2021; "China launches Tianhe module, start of ambitious two-year station construction effort"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2021/04/china-station-construction-begins/. Accessed 20 July 2021.

[178] Graham, William; 29 May 2021; "China launches Tianzhou 2, first cargo mission to new space station"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2021/05/tianzhou-2-launch/. Accessed 20 July 2021.

[179] Xinhua; 16 October 2021; "China Embarks on Longest Ever Crewed Mission for Space Station Construction".

[180] Jones, Morris; 17 November 2011; "Yinghuo Was Worth It"; *Space Daily*; https://www.spacedaily.com/reports/Yinghuo_Was_Worth_It_999.html. Accessed 3 August 2021.

[181] Krebs, Gunther; 11 December 2020; "XPNAV 1 (Maichong Xing Shiyan Weixing)"; https://space.skyrocket.de/doc-sdat/tg-1.htm. Accessed 31 January 2022.

[182] Xiang Bo; 30 December 2019; "China's First Solar Sail Verifies Key Technologies in Orbit;" *Xinhua*; http://www.xinhuanet.com/english/2019-12/30/c_138667092.htm. Accessed 3 August 2021.

[183] David, Leonard; 14 December 2013; "China Lands On The Moon: Historic Robotic Lunar Landing Includes 1st Chinese Rov-

er"; *Space.com*; https://www.space.com/23968-china-moon-rover-historic-lunar-landing.html#:~:text=China%20has%20landed%20its%20first%20robotic%20lander%20on,to%20make%20a%20soft-landing%20on%20Earth%27s%20celestial%20neighbor. Accessed 3 August 2021.

184 Wong, Catherine; 3 January 2019; "China's Chang'e 4 lunar probe sends first photo of far side of the moon after historic soft landing"; *South China Morning Post*; https://www.scmp.com/news/china/article/2180453/chinas-change-4-lunar-spacecraft-poised-touch-down-dark-side-moon. Accessed 3 August 2021.

185 Chang, Kenneth; 7 December 2018; "China's Chang'e-4 Launches on Mission to the Moon's Far Side"; *The New York Times*; https://www.nytimes.com/2018/12/07/science/china-moon-change-4.html. Accessed 2 August 2021.

186 Clark, Stephen; 7 December 2018; "China launches historic mission to land on far side of the moon"; *Spaceflight Now*; https://spaceflightnow.com/2018/12/07/china-launches-historic-mission-to-land-on-far-side-of-the-moon/. Accessed 2 August 2021.

187 Wu Nan; 24 June 2014; "Next stop - Mars: China aims to send rover to Red Planet within six years"; *South China Morning Post*; https://www.scmp.com/news/china/article/1539568/next-stop-mars-china-aims-send-rover-red-planet-within-six-years/. Accessed 3 August 2021.

188 China National Space Administration; 24 April 2020; "China's first Mars mission named Tianwen 1"; http://www.cnsa.gov.cn/english/n6465652/n6465653/c6809448/content.html. Accessed 3 August 2021.

189 Jones, Andrew; 23 July 2020; "Tianwen-1 launches for Mars, marking dawn of Chinese interplanetary exploration"; *Space News*; https://spacenews.com/tianwen-1-launches-for-mars-marking-dawn-of-chinese-interplanetary-exploration/. Accessed 3 August 2021.

190 Huang, Kristin and Chik, Holly; 24 July 2020; "China's Mars Probe Blasts off on Mission Fraught with Risks: Tianwen-1 has Embarked on Ambitious Project to Chart the Red Planet, but it Faces Many Obstacles"; *South China Morning Post*; https://www.scmp.com/news/china/science/article/3094343/china-launches-first-mission-mars. Accessed 3 August 2021.

191 Amos, Jonathan; 16 December 2020; "China's Chang'e-5 Mission Returns Moon Samples"; *BBC*; https://bbc.com/news/science-environment-55323176. Accessed 3 August 2021.

192 Burghardt, Thomas; 23 November 2020; "China launches world's first lunar sample return mission since 1976"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/11/change5-sample-return-launch/. Accessed 3 August 2021.

193 Gebhardt, Chris; 1 December 2020; "China lands on Moon after causing deep confusion by stopping broadcast"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/12/china-preparing-to-land-sample-return-mission-on-the-moon/. Accessed 3 August 2021.

194 AP News; 17 December 2020; "Chinese capsule returns to Earth carrying moon rocks"; https://apnews.com/article/technology-china-moon-da510a5fd9a97505296ddbdb5749c393. Accessed 17 December 2020.

195 Robitski, Dan; 8 October 2020; "China Names 18 More Crewmembers for its Upcoming Space Station"; *Futurism.com*; https://futurism.com/the-byte/china-names-18-crewmembers-upcoming-space-station. Accessed 3 August 2021.

196 Ji QiMing; 2018; "China Space Station and International Cooperation"; *China Manned Space Agency.*

197 Sputnik News; 8 August 2018; "China to launch space station Tiangong in 2022, welcomes foreign astronauts"; https://sputniknews.com/science/201808071067030662-china-to-launch-space-station-tiangong/. Accessed 3 August 2021.

198 Jones, Andrew; 29 April 2020. "Long March 5B rolled out for crewed spacecraft, space station test launch"; *Space News*; https://spacenews.com/long-march-5b-rolled-out-for-crewed-spacecraft-space-station-test-launch/. Accessed 3 August 2021.

199 Jones, Andrew; 11 September 2019. "China's Space Station Core Module Passes Review but Faces Delays"; *Space News*; https://spacenews.com/chinese-space-station-core-module-passes-review-but-faces-delays/. Accessed 3 August 2021.

200 Jones, Andrew; 21 June 2019; "China's Moon, Mars and Space Station Missions May be Facing Delays"; *Space News*; https://spacenews.com/chinas-moon-mars-and-space-station-missions-may-be-facing-delays/. Accessed 3 August 2021.

201 China Daily; 25 November 2020; "(U) Future Probes Already Mapped Out By Administration"; http://www.chinadaily.com.cn/a/202011/25/WS5fbdeec9a31024ad0ba965fa.html. Accessed 3 August 2021.

202 China Daily; 25 November 2020; "(U) Future Probes Already Mapped Out By Administration"; http://www.chinadaily.com.cn/a/202011/25/WS5fbdeec9a31024ad0ba965fa.html. Accessed 3 August 2021.

203 China Daily; 25 November 2020; "(U) Future Probes Already Mapped Out By Administration"; http://www.chinadaily.com.cn/a/202011/25/WS5fbdeec9a31024ad0ba965fa.html. Accessed 3 August 2021.

204 Mo Hong'e; 13 March 2018; "China to launch Chang'e 4 this year, eyeing lunar base in 2025"; *ECNS Wire*; http://ecns.cn/cns-wire/2018/03-13/295615.shtml. Accessed 3 August 2021.

205 Liu Jia; 3 May 2016; "Senior Officer Expects Moon Visit by 2036"; *Chinese Academy of Sciences*; http://english.cas.cn/newsroom/china_research/201605/t20160503_162635.shtml. Accessed 3 August 2021.

206 Mo Hong'e; 13 March 2018; "China to launch Chang'e 4 this year, eyeing lunar base in 2025"; *ECNS Wire*; http://ecns.cn/cns-wire/2018/03-13/295615.shtml. Accessed 3 August 2021.

207 Liu Jia; 3 May 2016; "Senior Officer Expects Moon Visit by 2036"; *Chinese Academy of Sciences*; http://english.cas.cn/newsroom/china_research/201605/t20160503_162635.shtml. Accessed 3 August 2021.

208 Xinhua; 25 April 2018; "China Outlines Roadmap for Deep Space Exploration"; http://www.xinhuanet.com/en-

glish/2018-04/25/c_137136188.htm. Accessed 3 August 2021.

[209] Xinhua; 25 April 2018; "China Outlines Roadmap for Deep Space Exploration"; http://www.xinhuanet.com/english/2018-04/25/c_137136188.htm. Accessed 3 August 2021.

[210] Jones, Andrew; 26 April 2021; "China, Russia open moon base project to international partners, early details emerge"; *Space News*; https://spacenews.com/china-russia-open-moon-base-project-to-international-partners-early-details-emerge/. Accessed 20 July 2021.

[211] The State Council of the People's Republic Of China; 28 January 2022; Full Text: China's Space Program: A 2021 Perspective; http://www.xinhuanet.com/english/20220128/eb9fb038ebfe4a3d93887b9f120ef74a/c.html. Accessed 28 January 2022.

[212] Xinhua; 25 April 2018; "China Outlines Roadmap for Deep Space Exploration"; http://www.xinhuanet.com/english/2018-04/25/c_137136188.htm. Accessed 3 August 2021.

[213] Chang, Kenneth; 7 December 2018; "China's Chang'e-4 Launches on Mission to the Moon's Far Side"; The *New York Times*; https://www.nytimes.com/2018/12/07/science/china-moon-change-4.html. Accessed 2 August 2021.

[214] Clark, Stephen; 7 December 2018; "China launches historic mission to land on far side of the moon"; *Spaceflight Now*; https://spaceflightnow.com/2018/12/07/china-launches-historic-mission-to-land-on-far-side-of-the-moon/. Accessed 2 August 2021.

[215] GlobalSecurity.org; "Chinese Space Launch Vehicles"; https://www.globalsecurity.org/space/world/china/launch-intro.htm. Accessed 26 July 2021.

[216] GlobalSecurity.org; "Chinese Space Launch Vehicles"; https://www.globalsecurity.org/space/world/china/launch-intro.htm. Accessed 26 July 2021.

[217] Jones, Andrew; 5 July 2018; "China reveals details for super-heavy-lift Long March 9 and reusable Long March 8 rockets"; *Space News*; https://spacenews.com/china-reveals-details-for-super-heavy-lift-long-march-9-and-reusable-long-march-8-rockets/. Accessed 3 August 2021.

[218] China Daily; 1 August 2019; "New Port Will Host Sea Based Space Launches"; http://www.chinadaily.com.cn/a/201908/01/WS5d4238f8a310d830564021f8.html. Accessed 3 August 2021.

[219] Wood, P., Stone, A., and Lee, T.A.; 1 March 2021; "China's Ground Segment: Building the Pillar of a Great Space Power", pp. 66, 75, 79-81; *China Aerospace Studies Institute*; https://airuniversity.af.edu/portals/10/casi/documents/research/space/2021-03-01 chinas ground segment.pdf?ver=z4ogy_mrxadurwvt-r9j6w%3d%3d. Accessed 2 August 2021.

[220] U.S. Geological Survey; "The Aerospace Information Research Institute (AIR)"; https://landsat.usgs.gov/snc. Accessed 27 July 2021.

[221] GlobalSecurity.org; "Chinese Space Launch Vehicles"; https://www.globalsecurity.org/space/world/china/launch-intro.htm. Accessed 26 July 2021.

[222] U.S.-China Economic and Security Review Commission; November 2015; *2015 Report to Congress of the U.S.-China Economic and Security Review Commission*, Chapter 2, Section 2; https://www.uscc.gov/sites/default/files/Annual_Report/Chapters/Chapter%202,%20Section%202%20-%20China's%20Space%20and%20Counterspace%20Programs.pdf. Accessed 3 August 2021.

[223] Barbosa, Rui C.; 9 January 2017; "Chinese Kuaizhou-1A rocket launches several small satellites"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2017/01/chinese-kuaizhou-1a-launches-several-small-satellites/. Accessed 3 August 2021.

[224] Xinhua; 5 June 2020; "China Plans to Develop New Solid Fueled Carrier Rocket"; http://www.xinhuanet.com/english/2020-06/05/c_139116817.htm. Accessed 3 August 2021.

[225] Herbert, Natalie; February 2021; "Achieving the PLA's Strategic Support Force talent needs through MCF"; *China Aerospace Studies Institute*; https://airuniversity.af.edu/portals/10/casi/documents/research/casi articles/2021-02-01 achieving the plassf talent needs through mcf.pdf?ver=r2p5iwlumz_bvmqohmtwuw%3d%3d. Accessed 2 August 2021.

[226] National Institute for Defense Studies, Japan; November 2020; *NIDS China Security Report 2021: China's Military Strategy in the New Era*, p. 59; https://nids.mod.go.jp. Accessed 27 July 2021.

[227] Asia-Pacific Space Cooperation Organization (APSCO) and Chinese Academy of Science National Astronomical Observatories (NAOC); 13 January 2016; *APOSOS Program Review: Annual Report of APOSOS Project, 2015*.

[228] APSCO; *Asia-Pacific Space Cooperation Organization Brochure*, p. 5.

[229] Xinhua News; 15 November 2018; "China to Enhance Space Science, Technology Sharing in Asia-Pacific".

[230] Wood, P., Stone, A., and Lee, T.A.; 1 March 2021; "China's Ground Segment: Building the Pillar of a Great Space Power", pp. 75, 79-81; *China Aerospace Studies Institute; https://airuniversity.af.edu/portals/10/casi/documents/research/space/2021-03-01 chinas ground segment.pdf?ver=z4ogy_mrxadurwvt-r9j6w%3d%3d. Accessed 2 August 2021.*

[231] Griesbach, Jacob and Vallado, David; 4 August 2011; "Simulating Space Surveillance Networks", pp. 8-9; *Proceedings from the American Astronautical Society (AAS) Conference*; https://www.agi.com/getmedia/8e3d8763-08c9-465d-a500-cba8b1300050/Simulating-Space-Surveillance-Networks.pdf?ext=.pdf. Accessed 26 July 2021.

[232] National Military Standard of the People's Republic of China; 25 May 2009; GJB 6776-2009: *Space Objects Orbits Cataloging Method*.

[233] Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, pp. 73, 83-84; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

234 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, pp. 82-83; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

235 Wang, X. and Zheng, K.; 1 May 2015; "Deception Jamming Power Against SAR"; *Electronic Information Warfare Technology, Vol. 30, No. 3*, pp. 35-38, 53.

236 Hou, W., Ji, Z., Lu, C., and Leng, K.; March 2017; "Research on SAR deception jamming on engineering design"; *Aerospace Electronic Warfare, No. 3*, pp. 34-37.

237 Lin, J., Feng, T., Chen, B., and Jiang, C.; March 2010; "Study on Countermeasure against Satellite Adaptive Null-Steering Technique"; *Aerospace Electronic Warfare, Vol. 26, No. 3*, pp. 1-4.

238 Wang, H.; "Analysis on Anti-jamming Measures of Mobile User Objective System"; *Radio Communications Technology*, Vol. 35, No. 2; 2009, pp. 46-49.

239 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, pp. 82-83, 118; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 13 January 2022.

240 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 13.

241 CrowdStrike Global Intelligence Team; May 2014; *CrowdStrike Intelligence Report: PUTTER PANDA*, p. 5; https://cdn0.vox-cdn.com/assets/4589853/crowdstrike-intelligence-report-putter-panda.original.pdf. Accessed 2 August 2021.

242 Office of the Secretary of Defense; 16 May 2018; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2018*, pp. 53, 88; https://media.defense.gov/2018/Aug/16/2001955282/-1/-1/1/2018-CHINA-MILITARY-POWER-REPORT.PDF. Accessed 27 July 2021.

243 Office of Director of National Intelligence; 11 December 2020; "Support to U.S. Space Command Messaging".

244 Li Ying, Zhou Bingyu; 1 April 2002; "Ground High Power Laser Anti-Satellite Reconnaissance Technology"; *53rd Institute of Electronic Research*.

245 Gao Guiqing, Xiang Jin, Li Yongxiang, Zhou Yong; February 2010; "Efficiency research on laser jamming photoelectric detector in early-warning satellite of infrared"; *Laser & Infrared, Vol. 40 No. 2*.

246 Wang Shiyong, Fu Youyu, Guo Jin; January 2002; "Evaluation of high energy laser effecting on remote distance photoelectron sensor system"; *Optical Technique, Vol. 28, No 1*.

247 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 13.

248 PLA Strategic Strike Force in 21st Century; September 2009; "Rise of Great Power – East Asia Rising: Focus on People's Liberation Army in New Century"; Lbac Consultant.

249 Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. I-13.

250 18 Space Control Squadron; "Box Score"; Space-Track.org; https://www.space-track.org/#boxscore. Accessed 19 March 2022.

251 Office of the Director of National Intelligence; 11 May 2017; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 9.

252 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 13.

253 Office of the Secretary of Defense; April 2015; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, p. 14; https://dod.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf. Accessed 27 July 2021.

254 Office of the Secretary of Defense; 1 September 2020; *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2020*, p. 65; https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF. Accessed 3 August 2021.

255 Jones, Andrew; 29 October 2021; "China launches classified space debris mitigation technology satellite"; *Space News*; https://spacenews.com/china-launches-classified-space-debris-mitigation-technology-satellite/. Accessed 1 November 2021.

256 Jiayu Liu, Qiang Huang, Tao Yang, Xuechao Chen, and Yanbo Wang; 8 February 2018; "Whole-body compliance for multi-arm space robotic capturing of large tumbling target in connection compliant phase"; *Advances in Mechanical Engineering, Vol. 10(4) 1–19*.

257 Gong, Zizheng; October 2018; "Mission Planning and Simulation System Study on Active Debris Removal with Space-based Laser System"; *69th International Astronautical Congress 2018.*

258 Jones, Andrew; 27 January 2022; "China's Shijian-21 Towed Dead Satellite to a High Graveyard Orbit"; *Space News*; https://spacenews.com/chinas-shijian-21-spacecraft-docked-with-and-towed-a-dead-satellite/. Accessed 19 March 2022.

259 Office of Director of National Intelligence; 11 December 2020; "Support to U.S. Space Command Messaging".

260 Qin Hui, Zhao Jian-Kang; November 2006; "Conceptual Research on Space to Ground Release Technologies for Spacecrafts"; *National University of Defense Technology*.

261 Yuan Guoxiong, Bai Tao, and Ren Zhang; 1 September 2005; "A Hybrid Reentry Guidance Method for Space-Based Ground Attack Weapon System"; *Control Technology and Tactical Missile.*

262 Kang Xingwu, Chen Gang, Qiao Yang, and Chen Shilu; 25 March 2008; "A Terminal Guidance Law Applied to Space-to-Surface Precision Attack Weapons"; *Journal of Solid Rocket Technology*.

263 Hu Zhengdong, Ding Hongbo, Cao Yuan, Guo Caifa, Cai Hong; 1 August 2009; “Application of Pseudo-Spectral Method in Rapid Orbit Optimization for Space-To-Ground Kinetic Weapons”; *Aerospace Control, Vol. 27, No. 4*.

264 Duan Junhong, Gao Xiaoguang; July 2009; “Simulation Research on Attacking Process of a Space-based Weapon to Fixed Ground Target”; *Journal of System Simulation*, Vol. 21, No. 14.

265 Zhang Wei, Wu Hua, Wang Zhengjun, and Fang Juan; 1 January 2017; “Research on Attack Mode of Space-to-ground Kinetic Weapon”; *Journal of Tactical Missile Technology*.

266 179614-21.

267 Russian Ministry of Defense; 4 November 2018; “Aerospace Forces successfully launch Soyuz-2 vehicle from Plesetsk Cosmodrome”.

268 Bodner, Matthew; 3 August 2015; “Russian Military Merges Air Force and Space Command”; *Moscow Times Online*.

269 Official website of the Russian Federation president; 12 April 2021; “Meeting On Long Term Priorities Of Space Exploration”.

270 Interfax; 30 August 2019; “Future militarization of space unavoidable – Roscosmos head”.

271 Izvestia; 27 June 2020; “Roscomos Named Crew Dragon’s Weaknesses”.

272 Bodner, Matthew; 4 October 2017; “60 years after Sputnik, Russia is lost in space”; *Space News*; https://spacenews.com/60-years-after-sputnik-russia-is-lost-in-space/. Accessed 2 August 2021.

273 Siddiqi, Asif; 21 March 2017; “Russia’s Space Program Is Struggling Mightily”; *Slate*; https://slate.com/technology/2017/03/russias-space-program-is-in-trouble.html. Accessed 3 August 2021.

274 Defense Intelligence Agency; 28 June 2017; *Russia Military Power: Building a Military to Support Great Power Aspirations*, pp. 35-37, 42; https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Russia%20Military%20Power%20Report%202017.pdf?ver=2017-06-28-144235-937. Accessed 3 August 2021.

275 Interfax-AVN; 5 December 2018; “Peresvet combat laser can fight satellites – Russian Defense Ministry”.

276 Milkavkaz.net; 23 December 2015; “Russia: Aerospace Forces Order of Battle”.

277 Izvestiya; 4 June 2019; “Expert Spots the Russian VKS’s New Missile Interceptor”.

278 Interfax; 4 June 2019 “New missile of Russian missile defense system successfully test-launched at Kazakh firing range – Russian Defense Ministry”.

279 Ramm, Alexei; 19 April 2019; “Targeting Stars: What is Known about the New ASAT Weapon? Project NUDOL”; *Izvestiya*.

280 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*, p. 13.

281 Bozhov, Oleg; 9 August 2016; “How They Will Wage War in the Future: Tanks Rumbled Across the Sky”; *Moskovskiy Komsomolets*.

282 Official website of Russian Federation President; 26 December 2014; “Military Doctrine of the Russian Federation, approved by Russian Federation President V. Putin”.

283 Chekinov, S.G. Col. (Res) and Bogdanov, S.A. Lt. Gen. (Ret); 1 October 2013; “The Nature and Content of a New-Generation War”; *Moscow Military Thought Vol 4. (2013)*.

284 Chekinov, S.G. Col. (Res) and Bogdanov, S.A. Lt. Gen. (Ret); 1 October 2015; “A Forecast for Future Wars: Meditations on What They Will Look Like”; *Military Thought Vol.4 (2015*).

285 Official website of Russian Federation President; 26 December 2014; “Military Doctrine of the Russian Federation, approved by Russian Federation President V. Putin”.

286 Bozhov, Oleg; 9 August 2016; “How They Will Wage War in the Future: Tanks Rumbled Across the Sky”; *Moskovskiy Komsomolets*.

287 Zhongguo Taikong Wang; 17 October 2017; “China Plans To Ban Space Weaponization, Manage Debris, Ensure Research, Work With Russia”.

288 Luzin, Pavel; 25 October 2017; “Space Power: What is Russia’s Military Strategy in Outer Space?” *Warsaw Intersection*.

289 Ministry of Foreign Affairs of the Russian Federation; 6 July 2017; “MFA Website Provides Overview of Policy on Prevention of Placement of Weapons in Outer Space”.

290 Milkavkaz.net; 23 December 2015; “Russia: Aerospace Forces Order of Battle”.

291 Izvestiya; 4 June 2019; “Expert Spots the Russian VKS’s New Missile Interceptor”.

292 Interfax; 4 June 2019; “New missile of Russian missile defense system successfully test-launched at Kazakh firing range – Russian Defense Ministry”.

293 Ramm, Alexei; 19 April 2019; “Targeting Stars: What is Known about the New ASAT Weapon? Project NUDOL”; *Izvestiya*.

294 Office of the Director of National Intelligence; 11 May 2017; *Statement for the Record: Worldwide Threat Assessment of the U.S. Intelligence Community*; p. 9.

295 Vyatkin, Yaroslav; 16 April 2015; “Russian Potential for Combating, Acquiring Prompt Global Strike Capability Examined”; *Argumenty Nedeli*.

296 Ramm, Alexei; 19 April 2019; “Targeting Stars: What is Known about the New ASAT Weapon? Project NUDOL”; *Izvestiya*.

297 Claus, Malcom; 9 November 2018; “New Russian missile likely to be part of anti-satellite system”; *Jane’s Intelligence Review.*

298 O’Connor, Tom; 12 March 2018; “Russia’s Military has Laser Weapons that Can Take out Enemies in Less than a Second”; *Newsweek*; http://www.newsweek.com/russia-military-laser-weapons-take-out-enemies-less-second-841091. Accessed 2 August 2021.

299 Interfax; 19 July 2018; “Space Forces Get Combat Laser System”.

300 Nebehay, Stephanie; 14 August 2018; “U.S. Warns on Russia’s

new space weapons"; *Reuters*; https://www.reuters.com/article/us-russia-usa-space-idUSKBN1KZ0T1. Accessed 3 August 2021.

301 Interfax-AVN; 5 December 2018; "Peresvet combat laser can fight satellites – Russian Defense Ministry".

302 Poblete, Yleem D.S.; 14 August 2018; "United States Remarks at the Conference on Disarmament as Delivered by Assistant Secretary of State for Arms Control, Verification, and Compliance"; *U.S. State Department*; https://eneva.usmission.gov/2018/08/14/remarks-by-assistant-secretary-yleem-d-s-poblete-at-the-conference-on-disarmament/. Accessed 30 July 2021.

303 Interfax; 26 October 2017; "Russia Tests Military Satellite Capable of Approaching other Spacecraft – Newspaper".

304 Hendrickx, Bart; 27 September 2018; "Russia Develops Co-Orbital Anti-Satellite Capability"; *Jane's Intelligence Review*.

305 Hennigan, W.J.; 10 February 2020; "Exclusive: Strange Russian Spacecraft Following U.S. Spy Satellite"; *Time*; https://time.com/5779315/russian-spacecraft-spy-satellite-space-force/. Accessed 3 August 2021.

306 Interfax; 6 December 2019; "Russian military experts stage experiment in separating satellite from universal space platform".

307 Krivoruchek, Aleksey; 5 August 2013; "Skorpion System to Replace GLONASS"; *Izvestiya.*

308 Vozdushno-Kosmicheskaya Oborona; 14 July 2009; "Impact of Information and Space Superiority on High-Tech Military Operations".

309 Official website of Russian Federation President; 26 December 2014; "Military Doctrine of the Russian Federation, approved by Russian Federation President V. Putin".

310 Chekinov, S.G. Col. (Res) and Bogdanov, S.A. Lt. Gen. (Ret); 20 June 2013 "Russia: Asymmetrical Actions to Maintain Russia's Military Security"; *Military Thought Volume 1 (2010)*.

311 Moscow Izvestiya; 14 August 2013; "Russia Building Ground-Based Backup For Glonass".

312 Rossiyskaya Gazeta; 15 October 2017; "Missile Defense Missiles and Visas – The US Refused Russian General Staff Officers Entry into the Country".

313 Bogdanov, Konstantin; 15 June 2018; "The Clowns Are Demolishing the Circus: US Missile Defense and the International Security System in Crisis"; *Izvestiya*.

314 Sputnik News; 30 January 2016; "This is the Achilles' Heel of Washington's Military Power"; https://sputniknews.com/military/201601301033971479-us-space-satellites/. Accessed 3 August 2021.

315 Bozhov, Oleg; 9 August 2016; "How They Will Wage War in the Future: Tanks Rumbled Across the Sky"; *Moskovskiy Komsomolets*.

316 Tuchkov, Vladimir; 28 October 2018; "Star Wars: Will Russia Find an Antidote to the X-37; the Space Arms Race Enters a New Orbit"; *Svobodnaya Pressa*.

317 Tuchkov, Vladimir; 28 October 2018; "Star Wars: Will Russia Find an Antidote to the X-37; the Space Arms Race Enters a New Orbit"; *Svobodnaya Pressa*.

318 Selivanov, V.V. and Ilyin, Y.D. Col.; 31 December 2017; "Choosing Priorities in Developing Kinetic Energy Weapons for Military Conflicts"; *Military Thought, Volume 4 (2017)*.

319 Izvestiya; 14 December 2017; "Space Is a Battlefield: Krasukha-2 Counter-Space Broadband Jamming System, US Space Efforts".

320 Gazeta; 27 August 2016; "Russian Missile Defense Advances, Status of A-235 NUDOL Advanced Missile Defense System".

321 Selivanov, V.V. and Ilyin, Y.D. Col.; 31 December 2017; "Choosing Priorities in Developing Kinetic Energy Weapons for Military Conflicts"; *Military Thought, Volume 4 (2017)*.

322 Chekinov, S.G. Col. (Res) and Bogdanov, S.A. Lt. Gen. (Ret); 31 December 2011 – 30 March 2012 "Strategic Deterrence and Russia's National Security Today"; *Military Thought, Volume 1 (2012)*.

323 Selivanov, V.V. and Ilyin, Y.D. Col.; 31 December 2017 "Choosing Priorities in Developing Kinetic Energy Weapons for Military Conflicts"; *Military Thought, Volume 4 (2017).*

324 Bodner, Matthew; 3 August 2015; "Russian Military Merges Air Force and Space Command"; *The Moscow Times*; https://www.themoscowtimes.com/2015/08/03/russian-military-merges-air-force-and-space-command-a48710. Accessed 3 August 2021.

325 Voyennoye Obozreniye; 25 March 2011; "Russia's Space Troops: Armaments and Facilities"; https://en.topwar.ru/3884-kosmicheskie-vojska-rossii-vooruzhenie-i-obekty.html. Accessed 3 August 2021.

326 Durnovo, Aleksey; 9 December 2014; "Aerospace Defense Troops Space Command's Primary Mission Is to Ensure Russia's Security in Space"; *Ekho Moskvy*.

327 Golts, Alexander; 10 August 2015; "Russia's Aerospace Forces Will Never Take Off"; *The Moscow Times*; https://www.themoscowtimes.com/2015/08/10/russias-aerospace-forces-will-never-take-off-op-ed-a48868. Accessed 3 August 2021.

328 Bodner, Matthew; 3 August 2015; "Russian Military Merges Air Force and Space Command"; *The Moscow Times*; https://www.themoscowtimes.com/2015/08/03/russian-military-merges-air-force-and-space-command-a48710. Accessed 3 August 2021.

329 Wincewicz-Bosy, Marta and Gonciarz, Artur; 16 December 2019; "The Network of the Aerospace Forces of the Russian Federation"; *Scientific Journal of the Military University of Land Forces, Volume 51 Number 4*; pp. 717-732.

330 Russian Ministry of Defense; 31 July 2019; *Space Forces*; http://eng.mil.ru/en/structure/forces/cosmic/structure.htm. Accessed 20 July 2021.

331 RIA Novosti; 2010; "Russian Space Force"; https//sputniknews.com/infographics/20111004167368531/. Accessed 5 August 2020.

332 Russian Ministry of Defense; 31 July 2019; *Space Forces*; http://eng.mil.ru/en/structure/forces/cosmic/structure.htm. Accessed 20 July 2021.

333 A. Kopik; 28 February 2003; "Russian Space Forces"; *Novosti Kosmonavtiki*; web.archive.org/web/20090201000712/http://novo-

sti-kosmonavtiki.ru/content/numbers/243/30.shtml. Accessed 27 July 2021.

[334] Mozhayskiy Military Space Academy Website; 19 February 2019; “Academy named after A.F. Mozhaysky”; http://academy-mozhayskogo.ru/istoricheskaja.spravka. Accessed 20 August 2020.

[335] Russian Ministry of Defense; 31 July 2019; *Space Forces*; http://en.mil.ru/forces/cosmic. Accessed 20 July 2021.

[336] A. Kopik; 28 February 2003; “Russian Space Forces”; *Novosti Kosmonavtiki*; web.archive.org/web/20090201000712/http://novosti-kosmonavtiki.ru/content/numbers/243/30.shtml. Accessed 27 July 2021.

[337] Bodner, Matthew; 23 January 2015; “Putin Approves Roscosmos Merger with Conglomerate”; *Space News*; http://www.spacenews.com/putin-approves-roscosmos-merger-with-conglomerate/. Accessed 3 August 2021.

[338] Interfax; 16 November 2015; “State Space Corporation to Hire 500 Staff”.

[339] State Corporation Roscosmos Website; “State Corporation Organizations”; http://www.roscosmos.ru/24028/. Accessed 3 August 2021.

[340] Interfax; 28 November 2019; “Illegal enrichment schemes existed in Roscosmos enterprise for decades – Head of State Corporation’s Internal Audit Service”.

[341] Luzin, Pavel; 22 June 2021; “Roscosmos Suffers From Russia’s Confrontation With the US”; *Jamestown.org*; https://jamestown.org/program/roscosmos-suffers-from-russias-confrontation-with-the-us/. Accessed 17 December 2021.

[342] Interfax; 1 July 2015; “Russian Deputy PM Admits Sanctions Affect Defence Industry”.

[343] Cheberko, Ivan; 26 September 2016; “Glonass’ Satellites Will Be Built from Russian Components by 2020”; *Izvestiya*.

[344] Svarovskaya, Anastasiya; 3 April 2018; “Russian state-run and private space industry: problems and cooperation”; *Space Watch*.

[345] Cheberko, Ivan; 27 September 2020; “Cosmic Scale of Import Substitution: What’s Going on with GLONASS”; *Vedomosti*.

[346] Interfax; 16 June 2021; “U.S. sanctions on microelectronics supplies affect dozens of Russian satellites – Rogozin”.

[347] Sputnik News; 30 May 2018; “Russian State Space Giant Roscosmos May Curb Space Program Due to Lack of Funds”; https://sputniknews.com/science/201805301064927907-roscosmos-funds-change-state-program/. Accessed 3 August 2021.

[348] Smirnov, Leonid; 5 January 2021; “United States Finds Russia’s Weak Spot”; *Saint Petersburg Rosbalt*.

[349] Cheberko, Ivan; 27 September 2020; “Cosmic Scale of Import Substitution: What’s Going On With GLONASS”; *Vedomosti*.

[350] Fedorov, Yevgeniy; 19 February 2020; “The ‘Era’ Military Technopolis: The Attempt to Make Up for What Has Been Lost in Microelectronics”; *Voyennoye Obozreniye*.

[351] Dokuchayev, Dmitriy; 08 July 2019; “Russian Growth Model Doomed to Failure: Economist Yakov Mirkin’s Assessment of Half Year Results”; *MK Online.*

[352] Borisov, Yuriy Ivanovich; 15 October 2018; “Yuriy Borisov: The Director Corps Should not Have the Incentive That All of Their Debts Will Be Written Off. The Deputy Prime Minister Talked About the Solutions to the Problem of the OPK’s Debt Load, About the Situation in Aircraft Manufacturing, and About the Plans to Bring the Electronic Sector Out of the Protracted Crisis”; *Svobodnaya Pressa.*

[353] Polunin, Andrey; 15 October 2018; “Zhirinovskiy’s Frightener: Instead of the S-700 Russia Threatens the West With Fakes. Why We Will Not Be Seeing Even a Modernized Version of the S-500 in the Foreseeable Future”; *Svobodnaya Pressa.*

[354] Interfax-AVN; 27 May 2019; “Roscosmos to spend over 3 bln rubles within 3 years on operating remote sensing satellites”.

[355] Ramm, Alexei and Kretsul, Roman; 8 May 2019; “All Liana Space Reconnaissance System Satellites Will Be Placed Into Orbit by 1 January”; *Izvestiya.*

[356] Kotlyar, Mikhail; 6 July 2020; “Unified Space System Communications, Surveillance Satellites To Be Deployed by 2024”; *RBK Online.*

[357] Tuchkov, Vladimir; 10 March 2020; “Domestic Space Reconnaissance is on Top of the Game Again”; *Izvestiya.*

[358] Izvestiya; 22 September 2017; “Military Expert Anton Lavrov Documents Need for Optical Reconnaissance Satellite Array”.

[359] TASS; 17 November 2015; “Russia involves 10 reconnaissance satellites in Syria operation – General Staff”; http://tass.com/science/837273. Accessed 3 August 2021.

[360] Kommersant; 28 July 2016; “Defense Ministry Orders New Space-Based Electro-Optical Reconnaissance System”.

[361] Interfax; 29 April 2014; “Ban on U.S. high-tech exports won’t hurt Russian companies – Siluanov”.

[362] Interfax; 29 April 2014; “U.S. Sanctions against Russia will hit ESA – Rogozin”.

[363] Zak, Anatoly; 22 February 2019; “The Meridian military communications satellite”; *Russian Space Web*; http://www.russianspaceweb.com/meridian.html. Accessed 3 August 2021.

[364] Gonets Satellite Company; 2018; “‘Gonets Satellite Company’ Public Corporation”.

[365] Zak, Anatoly; 15 June 2019; “Yamal Satellite Series”; *Russian Space Web*; http://www.russianspaceweb.com/yamal.html. Accessed 3 August 2021.

[366] State Corporation Roscomos; 5 June 2020; “Russia – Reshetnev Company: Express AMU7 Satellite was Assembled”.

[367] Zak, Anatoly; 23 April 2020; “Russian communications satellites”; *Russian Space Web*; http://www.russianspaceweb.com/spacecraft_comsats.html. Accessed 3 August 2021.

368 Defense Intelligence Agency; 28 June 2017; *Russia Military Power: Building a Military to Support Great Power Aspirations*, pp. 35-37; https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Russia%20Military%20Power%20Report%202017.pdf?ver=2017-06-28-144235-937. Accessed 3 August 2021.

369 Aronov, Dmitry Dr. and Zheltonogov, Egor; 5 October 2018; "GLONASS Status Update"; *Geyser Telecom.*

370 ISS Reshetnev; 12 October 2018; "Glonass-K Project"; https://www.iss-reshetnev.ru/projects. Accessed 3 August 2021.

371 Revnivykh, Ivan; 12 October 2016; "GLONASS Programme Update"; *International Committee on Global Navigation Satellite Systems (ICG): Annual Meeting 2016*; http://www.unoosa.org/pdf/icg/2016/icg11/01.pdf. Accessed 3 August 2021.

372 Serov, Sergei; 31 August 2020; "Eliminating Targets: Air Bombs are Quickly Becoming Smarter"; *Rossiyskaya Gazeta.*

373 Surovtsev, Oleg; 20 November 2020; "Secrets of Mastery of 'Gods of War': Interview with Colonel Sergey Ivantey, chief of the Eastern Military District Missile Troops and Artillery"; *Suvorovskiy Natisk.*

374 Strazh Baltiki; 20 November 2020; "Khrizantemas in Battle Order".

375 NASA; "Yuri Gagarin: First Man in Space"; https://www.nasa.gov/mission_pages/shuttle/sts1/gagarin_anniversary.html. Accessed 3 August 2021.

376 Zak, Anatoly; 30 July 2020; "Robotic Missions to Mars"; *Russian Space Web*; http://www.russianspaceweb.com/spacecraft_planetary_mars.html. Accessed 2 August 2021.

377 Pavlushchenko, Katya; 30 April 2021; "Roscosmos discusses ISS withdrawal strategy and new space station for mid-2020s"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2021/04/roscosmos-future-for-mid-2020s/. Accessed 2 May 2021.

378 Interfax; 1 July 2020; "Russia working on own communications channel with ISS".

379 Interfax; 2 July 2020; "Russian Segment of ISS to be Provided with Independent Channel of Communication with Earth – Roscosmos CEO Rogozin".

380 Izvestiya; 31 May 2020; "Roscosmos Representative Spoke About the Plans to Test New Rockets in 2020".

381 Grush, Loren; 12 October 2020; "Head of Russian space program calls for more international cooperation in NASA's Moon plans"; *The Verge*; https://www.theverge.com/2020/10/12/21512712/nasa-roscosmos-russia-dmitry-rogozin-artemis-moon-interntational-cooperation. Accessed 17 December 2020.

382 Interfax; 22 August 2019; "Russia's lunar program to be revealed by end of this fall – Rogozin".

383 Interfax; 14 September 2019; "Russia's lunar program to be completed in 2040 – Roscomos".

384 Atkinson, Ian; 19 August 2020; "Russia's Nauka ISS module arrives at Baikonur for final launch preparations"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2020/08/nauka-arrives-baikonur-final-preps/. Accessed 3 August 2021.

385 Cox, Thomas; 27 June 2020; "The 'Science' Module Will Be Launched To The ISS In The Second Quarter Of 2021"; *List23.com*; https://list23.com/2397-the-quot-science-quot-module-will-be-launched-to-the-iss-in-the-second-quarter-of-2021/. Accessed 19 April 2021.

386 Pultarova, Tereza; 21 July 2021; "Russia launches huge Nauka science module to space station after years of delays"; *Space.com*; https://www.space.com/russia-launches-nauka-space-station-research-module. Accessed 21 July 2021.

387 Whittington, Mark; 6 September 2020; "Russia makes bid to become a space power with Luna-25 mission to the moon"; *The Hill*; https://www.msn.com/en-us/news/politics/russia-makes-bid-to-become-a-space-power-with-luna-25-mission-to-the-moon/ar-BB18L8O9. Accessed 3 August 2021.

388 Roskosmos; 6 November 2021; "Development of an Instrument for Geological Exploration of the Moon From Orbit".

389 Harding, Pete; 26 November 2021; "Russian assembly complete: Roscosmos attaches new docking node to station"; *NASA Spaceflight*; https://www.nasaspaceflight.com/2021/11/prichal-launch/#more-82189. Accessed 26 November 2021.

390 Zak, Anatoly; 1 September 2019; "ExoMars-2020 (formerly ExoMars-2018)"; *Russian Space Web;* http://russianspaceweb.com/exomars2018.html. Accessed 3 August 2021.

391 Amos, Jonathan; 12 March 2020; "ExoMars Rosalind Franklin: Rover mission delayed until 2022"; *BBC News;* https://www.bbc.com/news/science-environment-51844030. Accessed 2 August 2021.

392 Zak, Anatoly; 23 July 2019; "Luna-Grunt sample return mission (Luna-28)"; *Russian Space Web;* http://russianspaceweb.com/luna_grunt.html. Accessed 3 August 2021.

393 Globalsecurity.org; February 2019; "Russian Lunar Landing Programs and Plans"; https://www.globalsecurity.org/space/world/russia/lunar.htm. Accessed 3 August 2021.

394 Roskosmos; 6 November 2021; "Development of an Instrument for Geological Exploration of the Moon From Orbit".

395 Roskosmos; 6 November 2021; "Development of an Instrument for Geological Exploration of the Moon From Orbit".

396 Roskosmos; 6 November 2021; "Development of an Instrument for Geological Exploration of the Moon From Orbit".

397 Globalsecurity.org; February 2019; "Russian Lunar Landing Programs and Plans"; https://www.globalsecurity.org/space/world/russia/lunar.htm. Accessed 3 August 2021.

398 Interfax; 18 January 2019; "Russian scientists plan to send research satellite to Mars, Phobos after 2026".

399 Jones, Andrew; 26 April 2021; "China, Russia open moon base project to international partners, early details emerge"; *Space News;* https://spacenews.com/china-rus sia-open-moon-

base-project-tointernational-partners-early-details-emerge/. Accessed 2 May 2021.

400 Ministry of Defence of the Russian Federation; 4 October 2017; "Titov Main Test and Space Systems Control Centre marks 60th anniversary".

401 WAM; 24 September 2019; "Mohamed bun Zayed learns about final preparations for First Emirati Astronaut's Expedition to ISS".

402 Grush, Loren; 12 October 2020; "Head of Russian space program calls for more international cooperation in NASA's Moon plans"; *The Verge*; https://www.theverge.com/2020/10/12/21512712/nasa-roscosmos-russia-dmitry-rogozin-artemis-moon-interntational-cooperation. Accessed 17 December 2021.

403 Jones, Andrew; 26 April 2021; "China, Russia open moon base project to international partners, early details emerge"; *Space News*; https://spacenews.com/china-russia-open-moon-base-project-to-international-partners-early-details-emerge/. Accessed 2 May 2021.

404 Jones, Andrew; 9 March 2021; "China, Russia enter MOU on international lunar research station"; *Space News*; https://spacenews.com/china-russia-enter-mou-on-international-lunar-research-station/. Accessed 20 March 2021.

405 Roberts, Thomas G.; 13 March 2019; "Spaceports of the World", pp. 43, 45; *Center for Strategic and International Studies, Aerospace Security Project;* https://www.researchgate.net/profile/Thomas_Roberts24/publication/332211453_Spaceports_of_the_World/links/5ca6590a4585157bd322dc39/Spaceports-of-the-World.pdf. Accessed 3 August 2021.

406 Bratsky, Jan; 8 May 2021; "Russian complex 'Okno-M' detected increased space Activity"; *Zvezda TV;* https://tvzvezda.ru/news/202158931-66F05.html. Accessed 27 July 2021.

407 Russian Ministry of Defense—Aerospace Defense Forces; "Optical-electronic complex 'Okno'"; http://www.structure.mil.ru/structure/forces/cosmic/weapons/more.htm?id=10342893@morfmilitarymodel. Accessed 27 July 2021.

408 Federation of American Scientists; 30 December 2008; *Sourcebook on the Okno (Fpn 52168), Krona (Fpn 20096) and Krona-N (Fpn 20776) Space Surveillance Sites*; https://fas.org/spp/military/program/track/okno.pdf. Accessed 27 July 2021.

409 IMINT & Analysis; June 2008; "Soviet & Russian Space Surveillance Facilities"; http://geimint.blogspot.com/2008/06/soviet-russian-space-surveillance.html. Accessed 27 July 2021.

410 Podvig, Pavel; 21 June 2011; "Daryal-U radar in Mishelevka demolished"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2011/06/daryal-u_radar_in_mishelevka_d.shtml. Accessed 27 July 2021.

411 Holm, Michael; 2011; "46th independent Radio-Technical Unit"; *Soviet Armed Forces 1945–1991*; http://www.ww2.dk/new/pvo/radar/46ortu.htm. Accessed 27 July 2021.

412 SityShooter; 2011; "Radar 'Dniester' – 'Dnepr-M'"; https://www.webcitation.org/6cc28t10i?url=http://www.panoramio.com/photo/58798723. Accessed 27 July 2021.

413 Podvig, Pavel; 23 December 2009; "Radar in Lekhtusi accepted for service"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2009/12/radar_in_lekhtusi_accepted_for.shtml. Accessed 27 July 2021.

414 Podvig, Pavel; 23 December 2009; "Radar in Lekhtusi accepted for service"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2009/12/radar_in_lekhtusi_accepted_for.shtml. Accessed 27 July 2021.

415 Podvig, Pavel; 14 February 2009; "Two radars at Armavir"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2009/02/two_radars_at_armavir.shtml. Accessed 27 July 2021.

416 RIA Novosti; 15 December 2011; "Russia's Baltic radar to be fully operational by 2014"; http://en.rian.ru/news/20111215/170284350.html. Accessed 27 July 2021.

417 Podvig, Pavel; 21 June 2011; "Daryal-U radar in Mishelevka demolished"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2011/06/daryal-u_radar_in_mishelevka_d.shtml. Accessed 27 July 2021.

418 Lenta; 12 December 2011; "Upgrading early warning radars in the Northwest District will begin in 2015"; http://lenta.ru/news/2011/12/12/modernize/. Accessed 27 July 2021.

419 TASS; 2 June 2013; "Construction of a missile warning radar system began in Altay"; http://www.tasstelecom.ru/news/one/20215. Accessed 2 August 2021.

420 TASS; 2 December 2012' "Three advanced early warning radars enter service in Russia"; http://tass.com/defense/981965. Accessed 2 August 2021.

421 Interfax; 14 January 2013; "RTI General Director Boyev on New Missile Attack Warning System Radars".

422 RIA Novosti; 9 February 2012; "St. Petersburg Radar to be Put on Alert in Feb"; http://en.rian.ru/mlitary_news/20120209/171237484.html. Accessed 27 July 2021.

423 Izvestiya; 11 August 2011; "Russia restores the 'missile umbrella'"; http://vz.ru/news/2011/8/11/513987.html. Accessed 27 July 2021.

424 Air and Space Defense; 1 July 2012; "Warning abdout Attack on our Territory".

425 Arms Trade; 16 June 2015;"TSAMTO/ Of the news / Vladimir Putin appeared at the ceremony of the discovery of international military technical forum 'the army-2015'"; http://www.armstrade.org/includes/periodics/news/2015/0616/165029697/detail.shtml. Accessed 27 July 2021.

426 Russian Military News; 29 September 2016; "Interfax-agency of the Servicemen of Novostei"; http://www.militarynews.ru/story.asp?rid=1&nid=361288. Accessed 27 July 2021.

427 Podvig, Pavel; 22 March 2012; "New Voronezh-M radar in Mishelevka entered trials"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2012/03/new_voronezh-m_radar_in_mishel.shtml. Accessed 27 July 2021.

428 Russian Ministry of Defense; 27 December 2014; "Archived copy"; http://function.mil.ru/news_page/country/more.htm?id=12004148@egnews. Accessed 27 July 2021.

429 Podvig, Pavel; 2 June 2014; "Voronezh-DM radar in Yeniseysk"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2014/06/voronezh-dm_radar_in_yeniseysk.shtml. Accessed 27 July 2021.

430 Podvig, Pavel; 17 September 2014; "Location of the Barnaul early-warning radar"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2014/09/location_of_the_barnaul_early-.shtml. Accessed 27 July 2021.

431 Podvig, Pavel; 19 September 2014; "Voronezh-M early-warning radar in Orsk located"; *Russian Strategic Nuclear Forces;* http://russianforces.org/blog/2014/09/voronezh-m_early-warning_radar.shtml. Accessed 27 July 2021.

432 Revnivykh, Sergey; 16 September 2008; "GLONASS Status and Progress"; *ROSCOMOS;* http://www.navcen.uscg.gov/pdf/cgsicmeetings/48/reports/international subcommittee/%5b24%5d glonass cgsic 16.09.2008.pdf. Accessed 27 July 2021.

433 European Space Agency; 18 September 2014; "GLONASS Ground Segment"; https://gssc.esa.int/navipedia//index.php/GLONASS_Ground_Segment. Accessed 27 July 2021.

434 GlobalSecurity.org; "Russian Space Launch Vehicles"; https://www.globalsecurity.org/space/world/russia/launch.htm. Accessed 3 August 2021.

435 RIA-Novosti; 2012; "Russian Plans to Explore Solar System".

436 Energia Corporation; 29 June 2019; "2018 Energia Annual Report".

437 Gebhardt, Chris; 8 April 2020; "Russia conducts first Soyuz 2.1a human launch; MS-16 crew arrives at Station"; *NASA Spaceflight;* https://www.nasaspaceflight.com/2020/04/soyuz-2-1a-human-launch-ms-16/. Accessed 3 August 2021.

438 Graham, William; 26 December 2019; "Rokot conducts final launch – carries three Gonets-M satellites to orbit"; *NASA Spaceflight;* https://www.nasaspaceflight.com/2019/12/rokot-final-launch-three-gonets-m-satellites/. Accessed 3 August 2021.

439 Foust, Jeff; 24 April 2020; "Sea Launch 'frozen' after ships moved to Russia"; *Space News;* https://spacenews.com/sea-launch-frozen-after-ships-moved-to-russia/. Accessed 3 August 2021.

440 Bodner, Matthew; 10 July 2018; "Energomash raises alarm over U.S. ban on Russian rocket engines"; *Space News;* https://spacenews.com/energomash-raises-alarm-over-u-s-ban-on-russian-rocket-engines/. Accessed 3 August 2021.

441 Agapov, Vladimir; 27 March 2018; "Second Fragmentation of Titan 3C Transtage SSN#2692," p. 5; *IAA Space Debris Committee Meeting*; https://iaaspace.org/wp-content/uploads/iaa/Scientific%20Activity/debrisminutes031816.pdf. Accessed 3 August 2021.

442 Mokhatkin, A., Molotov, I., Voropaev, V., Borovin, S. Andrievsky, N., Dorokhov, N., and Agletdinov, V.; 21 April 2017; "Performance Analysis of the Large Space Debris Tracking Telescope in the North Caucasus After the Second First Light"; *Proceedings of the 7th European Conference on Space Debris, Darmstadt, Germany*; https://conference.sdo.esoc.esa.int/proceedings/sdc7/paper/299/SDC7-paper299.pdf. Accessed 3 August 2021.

443 Schmaltz, S., Molotov, I, Voropaev, V., Krugly, Y., Kouprianov, V., Elenin, L., Graziani, F., Erofeev, D., Kudak, V, and Wolf, A.; 24 January 2019; "ISON'S Sub-Network of Small Aperture Telescopes for Observations of NEOS, Space Debris and Meteors"; *First Near Earth Objects and Debris Detection Conference, Darmstadt, Germany*; https://conference.sdo.esoc.esa.int/proceedings/neosst/paper/NEOSST1-paper442.pdf. Accessed 27 July 2021.

444 NASA Spaceflight Forum; 15 November 2020; "Russian space-related electronic warfare projects"; https://forum.nasaspaceflight.com/index.php?topic=52194.msg2154087#msg2154087. Accessed 5 December 2021.

445 Griesbach, Jacob and Vallado, David; 4 August 2011; "Simulating Space Surveillance Networks," p. 9; Analytical Graphics, Inc.; *Proceedings from the American Astronautical Society (AAS) Conference;* https://www.agi.com/getmedia/8e3d8763-08c9-465d-a500-cba8b1300050/Simulating-Space-Surveillance-Networks.pdf?ext=.pdf. Accessed 26 July 2021.

446 Defense Intelligence Agency; 28 June 2017; *Russia Military Power: Building a Military to Support Great Power Aspirations,* p. 42; https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Russia%20Military%20Power%20Report%202017.pdf?ver=2017-06-28-144235-937. Accessed 3 August 2021.

447 Military News; 1 May 2015; "Radioelectronic Warfare Assets have been Developed that can Hide Topol Launch Positions from Space Surveillance"; http://militarynews.ru/story.asp?rid=1&nid=374975. Accessed 3 August 2021.

448 UAWire; 28 October 2018; "Russia tests satellite jammer system"; https://uawire.org/russia-tests-mobile-anti-satellite-system. Accessed 3 August 2021.

449 Ramm, Alexey; 27 April 2018; "New Systems Will be Able to Effectively Solve Problems Without Human Intervention: Interview with Col. Yuri Gubskov"; *Izvestiya*.

450 Varfolomeeva, Anna; 1 May 2018; "Signaling strength: Russia's real Syria success is electronic warfare against the US"; *Defense Post*; https://www.thedefensepost.com/2018/05/01/russia-syria-electronic-warfare/. Accessed 4 August 2021.

451 Stupples, David; 9 October 2015; "Syria is Becoming a Test Bed for High-Tech Weapons of Electronic Warfare"; *Gizmodo*; https://gizmodo.com/syria-is-becoming-a-test-bed-for-high-tech-weapons-of-e-1735595580. Accessed 20 July 2021.

452 Defense World; 3 February 2020; "Russian Electronic Warfare System Brings Down Hostile Drones in Syria"; https://www.defenseworld.net/news/26265/Russian_Electronic_Warfare_System_Brings_Down_Hostile_Drones_in_Syria. Accessed 3 August 2021.

453 Defense Intelligence Agency; 28 June 2017; *Russia Military Power: Building a Military to Support Great Power Aspirations,*

pp. 37-41; https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Russia%20Military%20Power%20Report%202017.pdf?ver=2017-06-28-144235-937. Accessed 3 August 2021.

454 Office of Director of National Intelligence; 11 December 2020; "Support to U.S. Space Command Messaging".

455 O'Connor, Tom; 12 March 2018; "Russia's Military has Laser Weapons that Can Take out Enemies in Less than a Second"; *Newsweek;* http://www.newsweek.com/russia-military-laser-weapons-take-out-enemies-less-second-841091. Accessed 3 August 2021.

456 Interfax; 19 July 2018; "Space Forces Get Combat Laser System".

457 Nebehay, Stephanie; 14 August 2018; "U.S. Warns on Russia's new space weapons"; *Reuters;* https://www.reuters.com/article/us-russia-usa-space-idUSKBN1KZ0T1. Accessed 3 August 2021.

458 Interfax-AVN; 5 December 2018; "Peresvet combat laser can fight satellites – Russian Defense Ministry".

459 Interfax; 18 December 2019; "Peresvet combat lasers protecting road-mobile strategic missile complexes - General Staff chief".

460 Interfax; 24 December 2019; "Peresvet combat lasers deployed in 5 divisions of Russian Strategic Missile Forces – Shoigu".

461 Azanov, Roman; 24 December 2019; "'Armament Is Not a Chess Game.' What Equipment the Russian Army Received in 2019: TASS on Principal Deliveries of Military Equipment and Arms to the Country's Armed Forces Arms and Branches According to the Year's Results"; *TASS*.

462 Zvezda Television; 29 December 2019; "Russia to deploy airborne Peresvet laser".

463 Gundarova, Lyudmila; 27 May 2021; "Star/Junk Wars: How to Blind the Enemy and Not Blind Yourself"; *Nezavisimoye Voyennoye Obozreniye*; https://nvo.ng.ru. Accessed 20 July 2021.

464 Interfax; 30 December 2019; "Peresvet combat laser to be mounted on aircraft".

465 Office of Director of National Intelligence; 11 December 2020; "Support to U.S. Space Command Messaging".

466 Yezhenedelnik Zvezda; 29 September 2020; "Russian Military Industrial Complex: Debt, Red Tape Impact the Execution of the State Defense Order".

467 Milkavkaz.net; 23 December 2015; "Russia: Aerospace Forces Order of Battle".

468 Izvestiya; 28 May 2019; "An Expert Has Spotted the Russian VKS's New Missile Interceptor".

469 Interfax; 4 June 2019; "New missile of Russian missile defense system successfully test-launched at Kazakh firing range – Russian Defense Ministry".

470 Ramm, Alexei; 19 April 2019; "Targeting Stars: What is Known about the New ASAT Weapon? Project NUDOL"; *Izvestiya.*

471 Dickinson, James H., Gen.; 21 April 2021; United States Space Command Presentation to the Subcommittee on Strategic Forces, House Armed Services Committee, U.S. House of Representatives: Fiscal Year 2022 Priorities and Posture of the United States Space Command, p. 6; https://docs.house.gov/meetings/AS/AS29/20210421/112467/HHRG-117-AS29-Wstate-DickinsonJ-20210421.pdf. Accessed 31 January 2022.

472 Vyatkin, Yaroslav; 16 April 2015; "Russian Potential for Combating, Acquiring Prompt Global Strike Capability Examined"; *Argumenty Nedeli.*

473 Gazeta; 28 July 2018; "In Russia new strategic weapons are being created".

474 U.S. Space Command Public Affairs; 15 November 2021; "Russian direct-ascent anti-satellite missile test creates significant, long-lasting space debris"; https://www.spacecom.mil/news/article-display/article/2842957/russia-direct-ascent-anti-satellite-missile-creates-significant-long-last/#.yzrxfviqul4. Accessed 16 November 2021.

475 Khodarenok, Mikhail; 19 June 2020; "Russia: Defense Industry Source Provides Delivery Schedule for S-500 Prometey, Nudol Systems"; *Gazeta;* https://www.gazeta.ru/army/2020/06/19/13123189.shtml. Accessed 3 August 2021.

476 Ramm, Alexei; 19 April 2019; "Targeting Stars: What is Known about the New ASAT Weapon? Project NUDOL"; *Izvestiya.*

477 Claus, Malcom; 9 November 2018; "New Russian missile likely to be part of anti-satellite system"; *Jane's Intelligence Review.*

478 Mizokami, Kyle; 1 October 2018; "Russia's MiG-31 Spotted with Possible Anti-Satellite Missile"; *Popular Mechanics;* https://www.popularmechanics.com/military/weapons/a23549729/russias-mig-31-spotted-with-possible-anti-satellite-missile/. Accessed 3 August 2021.

479 Ramm, Alexei; 19 April 2019; "Targeting Stars: What is Known about the New ASAT Weapon? Project NUDOL"; *Izvestiya.*

480 Mizokami, Kyle; 16 August 2018; "Is Russia's Mysterious New Satellite a Space Weapon?" *Popular Mechanics;* https://www.popularmechanics.com/military/weapons/a22739471/is-russias-mysterious-new-satellite-a-space-weapon/. Accessed 3 August 2021.

481 Poblete, Yleem D.S.; 14 August 2018; "United States Remarks at the Conference on Disarmament as Delivered by Assistant Secretary of State for Arms Control, Verification, and Compliance"; *U.S. State Department*; https://eneva.usmission.gov/2018/08/14/remarks-by-assistant-secretary-yleem-d-s-poblete-at-the-conference-on-disarmament/. Accessed 30 July 2021.

482 Interfax; 26 October 2017; "Russia Tests Military Satellite Capable of Approaching other Spacecraft – Newspaper".

483 Hendrickx, Bart; 27 September 2018; "Russia Develops Co-Orbital Anti-Satellite Capability"; *Jane's Intelligence Review.*

484 TASS; 6 December 2019; "The Ministry of Defense Conducted an Experiment in Space to Separate a Small Satellite from Another Device".

485 Zak, Anatoly; 26 November 2019; "Soyuz-2-1v launches a secret satellite"; *Russian Space Web;* http://russianspaceweb.com/napryazhenie.html. Accessed 5 August 2020.

486 Hennigan, W.J.; 10 February 2020; "Exclusive: Strange Russian Spacecraft Shadowing U.S. Spy Satellite, General Says"; *Time;* https://time.com/5779315/russian-spacecraft-spy-satellite-space-force/. Accessed 3 August 2021.

487 Interfax; 6 December 2019; "Russian military experts stage experiment in separating satellite from universal space platform".

488 Agence France Presse; 14 August 2018; "Geneva – US dismisses 'hypocritical' draft space weapons treaty"; https://www.shephardmedia.com/news/digital-battlespace/us-dismisses-hypocritical-draft-space-weapons-trea/. Accessed 5 August 2020.

489 U.S. Space Command Public Affairs; 23 July 2020; "Russia conducts space-based anti-satellite weapons test"; https://www.spacecom.mil/MEDIA/NEWS-ARTICLES/Article/2285098/russia-conducts-space-based-anti-satellite-weapons-test/. Accessed 5 August 2020.

490 Hennigan, W.J.; 23 July 2020; "America Really Does Have a Space Force. We Went Inside to See What It Does"; *Time;* https://time.com/5869987/spaceforce/. Accessed 5 August 2020.

491 Office of Director of National Intelligence; 11 December 2020; "Support to U.S. Space Command Messaging".

492 Interfax; 17 September 2019; "Russia developing new inspector-satellite".

493 NASA Spaceflight; 22 April 2020; "Topic:Qased –Noor – Shahrud – April 22, 2020, 03:59 UTC"; https://forum.nasaspaceflight.com/index.php?topic=50687.0. Accessed 3 August 2021.

494 Office of the Supreme Leader; 16 October 2006; "20-Year Vision of the Islamic Republic of Iran 1384-1404".

495 Tehran Times; 9 April 2019; "Space Tech-Domestic Industry Should be Connected – Minister".

496 E'remad ; 16 February 2020; "Ali Rabiei: I negate news on Rouhani's Resignation Until Mordad 1400".

497 Fars News Agency; 21 October 2018; "Official: Iran Among 9 Top Satellite Manufacturers".

498 Tarikhi, Parviz; 2 June 2008; "Iran's Ambition in Space"; *Position Magazine.*

499 Iran Space Research Center; 18 June 2019; "IRSC About Us". Accessed 5 August 2020.

500 Mehr News Agency; 17 August 2019; "SRI to Deliver Home-grown Pars-1 Satellite in Dec".

501 Tehran Times 14 November 2018; "Iran to Involve Private Sector in Space Projects".

502 Iran National Space Administration; 29 March 2019; *Iran Space Agency;* http://www.insa.isti.ir. Accessed 5 August 2020.

503 Tabnak; 13 January 2019; "Glance at Long Row of Iranian Satellites Ready for Launch – Plus Details".

504 Warrick, Joby; 11 June 2021; "Russia is preparing to supply Iran with an advanced satellite system that will boost Tehran's ability to surveil military targets, officials say"; *Washington Post;* https://www.washingtonpost.com/national-security/iran-russia-satellite/2021/06/10/d28978f0-c9ab-11eb-81b1-34796c7393af_story.html. Accessed 20 July 2021.

505 Hendrickx, Bart; 21 June 2021; "Scrutinizing the Russian-Iranian satellite deal"; *The Space Review;* https://www.thespacereview.com/article/4199/1. Accessed 20 July 2021.

506 TASS; 25 August 2015; "Russia to create satellite for remote sensing of the Earth for Iran"; https://tass.ru/kosmos/2210115. Accessed 20 July 2021.

507 VNIIEM; 25 August 2015; http://www.vniiem.ru/ru/index.php?option=com_content&view=article&id=718:2015-08-26-04-14-18&catid=36:2008-03-09-13-50-48&itemid=50. Accessed 20 July 2021.

508 Krebs, Gunther; 12 March 2020; "Safir"; *Gunter's Space Page;* https://space.skyrocket.de/doc_lau/safir.htm. Accessed 3 August 2021.

509 Tabnak; 13 January 2019; "Glance at Long Row of Iranian Satellites Ready for Launch – Plus Details".

510 Mashregh News; 23 March 2020; "What is Iran Pursuing in Space?".

511 Mashregh News; 28 March 2020; "Get Familiar with Iranian Satellite Launch Vehicles".

512 Graham, William; 8 March 2022; "Iran Carries Out Military Launch with Qased Rocket and Noor-2 Satellite"; *NASA Spaceflight*; https://www.NASASpaceflight.com/2022/03/iran-military-qased-noor-2/. Accessed 19 March 2022.

513 Xinhua; 22 April 2020; "Iran 'successfully' puts 1st military satellite in orbit"; http://www.xinhuanet.com/english/2020-04/22/c_138999480.htm. Accessed 3 August 2021.

514 Krebs, Gunter; 12 March 2020; "Simorgh (Safir-2)"; *Gunter's Space Page;* https://space.skyrocket.de/doc_lau/simorgh.htm. Accessed 3 August 2021.

515 Clark, Stephen; 22 April 2020; "Iran Places Military Satellite in Orbit"; *Spaceflight Now;* https://spaceflightnow.com/2020/04/22/iran-places-military-satellite-in-orbit/. Accessed 3 August 2021.

516 Kalbasi, Khorso; 4 February 2020; "Islamic Republic Working on Two Small Satellite Launch Vehicles"; *Financial Tribune;* https://financialtribune.com/articles/sci-tech/102021/islamic-republic-working-on-two-satellite-launch-vehicles. Accessed 24 July 2021.

517 Todd, David; 22 April 2020; "Iran launches new Qased rocket type with Noor military sat aboard"; *Seradata Ltd (Space Equipment Research & Analysis);* https://www.seradata.com/iran-launches-new-qased-rocket-type-with-noor-military-sat-aboard/. Accessed 24 July 2021.

518 Grush, Loren; 22 April 2020; "Iran claims it has successfully launched a military satellite"; *The Verge;* https://www.theverge.com/2020/4/22/21230847/iran-military-satellite-rocket-launch-is-

lamic-revolutionary-guard-corps. Accessed 3 August 2021.

519 Todd, David; 22 April 2020; “Iran launches new Qased rocket type with Noor military sat aboard”; *Seradata Ltd*; https://www.seradata.com/iran-launches-new-qased-rocket-type-with-noor-military-sat-aboard/. Accessed 24 July 2021.

520 Iran Military Forum; 15 February 2020; “Qaem solid propellant space launcher”; https://iran-military.com/index.php?threads/qaem-solid-propellant-space-launcher.1537/. Accessed 24 July 2021.

521 Harrison, Todd, et al; 20 March 2020; “Space Threat Assessment 2020”, p. 30; *Center for Strategic and International Studies;* https://aerospace.csis.org/sta2020. Accessed 22 March 2020.

522 Jane’s Intelligence Review; 14 April 2011; “Republic space – Iran’s satellite programme accelerates”.

523 World Politics Review; 29 September 2016; “Don’t Count Iran’s Nascent Space Capabilities Out”; www.worldpoliticsreview.com/trend-lines/20067/don-t-count-iran-s-nascent-space-capabilities-out. Accessed 3 August 2021.

524 Cohen, Zachary and Liebermann, Oren; 22 June 2021; “Pentagon tracked failed Iranian satellite launch and new images reveal Tehran is set to try again”; CNN; https://www.cnn.com/2021/06/22/politics/iran-failed-satellite-launch/index.html. Accessed 20 July 2021.

525 Fars News; 13 November 2018; “DM: Iran to Give Crushing Response to Enemies Space Threats”.

526 Sadequi, Susan; 16 July 2018; “Iran: Official Says Satellite Jamming Signals, Radio Frequency Radiation Levels not Health Concern”; *IRNA.*

527 Fars News Agency; 26 September 2018; “Iran Unveils New Achievements in Drone Industry”.

528 Harrison, Todd, et al; 20 March 2020; “Space Threat Assessment 2020”, pp. 32-33; *Center for Strategic and International Studies;* https://aerospace.csis.org/sta2020. Accessed 22 March 2020.

529 Iran Electronics Industries; 12 January 2011; “Products”.

530 Fars News Agency; 21 October 2018; “Official: Iran Among 9 Top Satellite Manufacturers”.

531 Harrison, Todd, et al; 20 March 2020; “Space Threat Assessment 2020”, p. 30; *Center for Strategic and International Studies;* https://aerospace.csis.org/sta2020. Accessed 22 March 2020.

532 Jane’s Intelligence Review; 14 April 2011; “Republic space – Iran’s satellite programme accelerates”.

533 World Politics Review; 29 September 2016; “Don’t Count Iran’s Nascent Space Capabilities Out”; www.worldpoliticsreview.com/trend-lines/20067/don-t-count-iran-s-nascent-space-capabilities-out. Accessed 3 August 2021.

534 Spacewatch Global; September 2019; “Iran and APSCO to create a space situational awareness network”; https://spacewatch.global/2016/09/iran-apsco-create-space-situational-awareness-network/. Accessed 3 August 2021.

535 Financial Tribune; 18 September 2017; “Iran Plans to Join 2 APSCO Projects”; https://financialtribune.com/articles/economy-sci-tech/72519/iran-plans-to-join-2-apsco-projects. Accessed 3 August 2021.

536 Asia-Pacific Space Cooperation Organization; “Signing of APSCO Convention”; http://www.apsco.int/. Accessed 3 August 2021.

537 Tehran Times; 23 June 2018; “Iranian Space Agency Seeks Further Co-op With APSCO”.

538 Iran National Space Administration; 29 March 2019; “Imam Ja’far Sadeq Space Monitoring Center.

539 Kooser, Amanda; 2 April 2014. “North Korea Names Space Agency ‘NADA,’ Mimics NASA Logo”; *CNET.com;* https://www.cnet.com/news/north-korea-names-space-agency-nada-mimics-nasa-logo/. Accessed 3 August 2021.

540 Krebs, Gunther; Accessed 8 Dec 20; “Unha-3”; *Gunter’s Space Page;* space.skyrocket.de/doc_lau_unha.htm. Accessed 3 August 2021.

541 Agence France Presse (Yahoo News Reprint); 2 February 2016; “N. Korea confirms Imminent Satellite Launch”; https://news.yahoo.com/n-korea-issues-shipping-warning-satellite-launch-imo-152605329.html. Accessed 3 August 2021.

542 Zwirko, Colin; 11 October 2021; “North Korea boasts of ‘full-scale’ work towards space capabilities“; *North Korea News*; https://www.nknews.org/2021/10/north-korea-boasts-of-full-scale-work-towards-new-space-capabilities/. Accessed 19 October 2021.

543 Dominguez, Gabriel; “Increased Activity spotted at North Korea’s Sohae rocket launch site: 38 North”; *Jane’s Defense Weekly*; 10 October 2016.

544 Bermudez, Joseph and Cha, Victor; 17 December 2019; “December 2019 Update: Tonghae Satellite Launching Ground”; *Beyond Parallel;* https://beyondparallel.csis.org/december-2019-update-tonghae-satellite-launching-ground/. Accessed 3 August 2021.

545 Waterman, Shaun; 23 August 2012; “North Korean Jamming of GPS shows system’s weakness”; *The Washington Times;* https://www.washingtontimes.com/news/2012/aug/23/north-korean-jamming-gps-shows-systems-weakness/. Accessed 5 August 2020.

546 Williams, Martyn; 17 November 2012; “Report: DPRK Jams South Korean Satellite Comms”; *North Korea Tech;* https://www.northkoreatech.org/2012/11/17/report-dprk-jams-south-korean-satellite-comms/. Accessed 6 August 2020.

547 Shim, Elizabeth; 31 March 2016; “North Korea Jamming GPS Signals in South; Can Affect Planes, Cellphones”; *United Press International;* http://www.upi.com/Top_News/World-News/2016/03/31/North-Korea-jamming-GPS-signals-in-South-can-affect-planes-cellphones/2551459443059/. Accessed 5 August 2020.

548 Paganini, Pierluigi; 19 November 2020; “Nation-state Ac-

tors From Russia, China, Iran, and North Korea Target Canada"; *Security Affairs Blog*; https://securityaffairs.co/wordpress/111182/cyber-warfare-2/canada-nation-state-actors.html. Accessed 17 December 2021.

[549] HHS Cybersecurity Program; 25 March 2021; North Korean Cyber Activity; *U.S. Department of Health and Human Services.*

[550] Ciampanu, Catalin; 30 July 2020; "US defense and aerospace sectors targeted in new wave of North Korean attacks"; *Zero Day Net;* https://www.zdnet.com/article/us-defense-and-aerospace-sectors-targeted-in-new-wave-of-north-korean-attacks/. Accessed 27 July 2021.

[551] Min Chao Choy and Weisensee, Nils; 19 June 2020; North Korean hackers targeted aerospace, defense companies via Linkedin: experts; *NK News;* https://www.nknews.org/2020/06/north-korean-hackers-targeted-aerospace-defense-companies-via-linkedin-experts/. Accessed 27 July 2021.

[552] Alyac EST Security; 17 November 2020; "APT Hackers Use Biden Era North Korea Denuclearization Documents for Attack".

[553] Paganini, Pierluigi; 19 November 2020; "Nation-state actors from Russia, China, Iran, and North Korea target Canada"; *Security Affairs;* https://securityaffairs.co/wordpress/author/paganinip. Accessed 27 July 2021.

[554] Canada Centre for Cyber Security; November 2020; "Canada Centre for Cyber Security warns of risks related to state-sponsored programs from China, Russia, Iran, and North Korea"; https://www.canada.ca/en/communications-security/news/2020/11/canadian-centre-for-cyber-security-releases-the-canadian-national-cyber-threat-assessment-2020.html. Accessed 27 July 2021.

[555] U.S. Justice Department; 17 February 2021; "Three North Korean Military Hackers Indicted in Wide-Ranging Scheme to Commit Cyberattacks and Financial Crimes Across the Globe"; https://www.justice.gov/opa/pr/three-north-korean-military-hackers-indicted-wide-ranging-scheme-commit-cyberattacks-and. Accessed 27 July 2021.

[556] Center for Strategic and International Studies; 8 July 2021; "Significant Cyber Incidents"; https://www.csis.org/programs/strategic-technologies-program/significant-cyber-incidents. Accessed 27 July 2021.

[557] Harrison, Todd, et al; 20 March 2020; "Space Threat Assessment 2020", p. 38; *Center for Strategic and International Studies;* https://aerospace.csis.org/sta2020. Accessed 22 March 2020.

[558] Office of the Secretary of Defense; 5 January 2016; *Report to Congress: Military and Security Developments Involving the Democratic People's Republic of Korea 2015*, pp. 4, 10, 13, 19; https://www.hsdl.org/?view&did=790165. Accessed 3 August 2021.

[559] Harrison, Todd, et al; 20 March 2020; "Space Threat Assessment 2020", pp. 35-36; *Center for Strategic and International Studies;* https://aerospace.csis.org/sta2020. Accessed 22 March 2020.

[560] Lotto Persio, Sophia; 30 October 2017; "Star Wars: North Korea Unveils Five-Year-Plan to Conquer Space"; *Newsweek;* https://www.newsweek.com/star-wars-north-koreas-unveils-5-year-plan-conquer-space-695896. Accessed 3 August 2021.

[561] Defense Intelligence Ballistic Missile Analysis Committee/National Air and Space Intelligence Center; 11 January 2021; *Ballistic and Cruise Missile Threat 2020, pp. 2, 27*; https://www.nasic.af.mil/Portals/19/images/Fact%20Sheet%20Images/2017%20Ballistic%20and%20Cruise%20Missile%20Threat_Final_small.pdf?ver=2017-07-21-083234-343. Accessed 3 August 2021.

[562] Jones, Andrew; 22 December 2020; "China launches first Long March 8 from Wenchang spaceport"; *Space News;* https://spacenews.com/china-launches-first-long-march-8-from-wenchang-spaceport/. Accessed 3 August 2021.

[563] Global Times (China); 29 May 2020; "China's liquid rocket engine completes key restart function test".

[564] Jones, Andrew; 4 August 2021; "Mystery Surrounds Chinese Private Rocket Launch Attempt"; *Space News*; https://spacenews.com/mystery-surrounds-chinese-private-launch-attempt/. Accessed 19 March 2022.

[565] Quan Xiaoshu, Yu Fei, and Li Guoli; 08 May 2020; "China Focus: Return Capsule of China's Experimental Manned Spaceship Comes Back Successfully"; *Xinhua.*

[566] China Daily; 15 July 2019; "China Daily: New Recoverable Satellite to Lift Off in 2020"; http://www.chinadaily.com.cn/a/201907/16/WS5d2cb0a7a3105895c2e7d8e3.html. Accessed 3 August 2021.

[567] Levochkin, Petr; 12 April 2019; "Russia: Energomash Chief Designer: We are Ready to Supply Reusable Engines for Russian Rockets"; *Interfax-AVN*.

[568] TASS; 26 August 2019; "Russia Orders Engine for Krylo Reusable Rocket Programme".

[569] Defense Intelligence Agency; 26 April 2021; *Statement of the Record Worldwide Threat Assessment, p. 7.*

[570] Xinhua; 6 September 2020; "China's Reusable Experimental Spacecraft Back to Landing Site".

[571] Xinhua; 4 September 2020; "China Launches Reusable Experimental Spacecraft".

[572] Jane's Strategic Weapon Systems; 9 March 2011; "Satellite Launch Vehicle Programmes: China: Air-launched Satellite Vehicle".

[573] China Hangtian; 21 October 2019; "China: CASC Completes Wind Tunnel Free Separation Test for Two-Stage-to-Orbit Space Plane".

[574] Interfax-AVN; 22 January 2009; "RSC Energia Considers Creating Tourist Space Plane".

[575] Moscow Vesti; 23 April 2010; "Russia's Space Plane Said Much Cheaper Than US Shuttle".

[576] RIA-Novosti; 7 June 2005; "Russia: Space Official Says Buran Space Shuttle Could be Revived".

[577] Moscow Agentstvo Voyennykh Novostey; 27 December 2007; "Russia not to Revive Buran Spacecraft Programme".

[578] Karpukhin, Sergei; 29 May 2019; "Russian Space Tourism

Firm to Send Dummy for First Flight in Returnable Capsule"; *TASS;* https://tass.com/science/1060575. Accessed 3 August 2021.

[579] Space Facts; 6 January 2021; *Astronauts and cosmonauts (sorted by first Mission);* http://wwwspacefacts.de/english/e_first. Accessed 3 August 2021.

[580] Japan Economic Newswire; 1 September 2018; "Japanese Startup aims for Commercial Space Travel in 2023".

[581] NASA; 27 March 2018; "What is a Lagrange Point?"; *NASA Solar System Exploration*; https://solarsystem.nasa.gov/resources/754/what –is-a-lagrange-point/. Accessed 22 July 2021.

[582] Kakaes, Konstantin; 30 January 2017; "International Collaborations in Space Always Reflect Politics on Earth: A Brief History of the Countries that Send People to Space, and Why"; *Slate;* https://www.slate.com/technology/2017/03/a_brief_history_of_the_countries_that_send_people_to_space_and_why.html. Accessed 3 August 2021.

[583] European Space Agency; *Mission Navigator;* https://www.esa.int/ESA/Our_Missions. Accessed 22 March 2021.

[584] Japanese Aerospace Exploration Agency (JAXA); *JAXA: Missions;* https://global.jaxa.jp/projects/index.html. Accessed 22 March 2021.

[585] Indian Space Research Organization (ISRO); *List of Scientific and Exploration Spacecraft;* http://www.isro.gov.in/spacecraft\list-of-scientific-and-exploration-spacecraft. Accessed 22 March 2021.

[586] Trevithick, Joseph; 5 June 2020; "Air Force Is Looking Beyond Traditional Orbits To Get An Upper Hand In Space"; *The War Zone;* https://www.thedrive.com/the-war-zone/33888/air-force-is-looking-beyond-traditional-orbits-to-get-an-upper-hand-in-space. Accessed 3 August 2021.

[587] Secure World Foundation; January 2017; *The United States, China, and Space Security: Issues for the Trump Administration;* https://swfound.org/media/205709/jw_uschinaspacesec_17012017.pdf. Accessed 3 August 2021.

[588] Secure World Foundation; January 2017; *The United States, China, and Space Security: Issues for the Trump Administration;* https://swfound.org/media/205709/jw_uschinaspacesec_17012017.pdf. Accessed 3 August 2021.

[589] 18 Space Control Squadron; Space-Track.org; "Catalog"; https://www.space-track.org/#catalog. Accessed 19 March 2022.

[590] NASA; 2001; *U.S. Government Orbital Debris Mitigation Standard Practices;* https://orbitaldebris.jsc.nasa.gov/library/usg_od_standard_practices.pdf. Accessed 3 August 2021.

[591] Federal Communications Commission; November 2019; *U.S. Government Orbital Debris Mitigation Standard Practices;* https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf. Accessed 3 August 2021.

[592] Inter-Agency Space Debris Coordination Committee (IADC); IADC-02-01; September 2007; *IADC Space Debris Mitigation Guidelines;* https://orbitaldebris.jsc.nasa.gov/library/iadc_mitigation_guidelines_rev_1_sep07.pdf. Accessed 3 August 2021.

[593] National Aeronautics and Space Administration; IG-21-011; 27 January 2021; *NASA's Efforts to Mitigate the Risks Posed by Orbital Debris.* https://oig.nasa.gov/docs/ig-21-011.pdf. Accessed 3 August 2021.

[594] European Space Operations Centre (ESOC); GEN-DB-LOG-00288-OPS-SD, Version 4.0; 27 May 2021; *ESA's Annual Space Environment Report*, pp. 68-71; https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf. Accessed 3 August 2021.

[595] 18 Space Control Squadron; Space-Track.org; "Box Score"; https://www.space-track.org/. Accessed 19 March 2022.

[596] Union of Concerned Scientists (UCS); 1 January 2022; "Satellite Database"; https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database. Accessed 19 March 2022.

[597] McKnight, D., Macdonald, J., Arora, R., Pelton, J., Jenniges, J., and Martinez, P.; S2468-8967(20)30006-9; May 2019; "The Global Risk Continuum (GRC)"; *The Journal of Space Safety Engineering, JSSE 104,* International Association for the Advancement of Space Safety (IAASS) Space Safety Conference, Los Angeles, CA, May 2019.

[598] McKnight, D., Macdonald, J., Arora, R., Pelton, J., Jenniges, J., and Martinez, P.; S2468-8967(20)30006-9; May 2019; "The Global Risk Continuum (GRC)"; *The Journal of Space Safety Engineering, JSSE 104,* International Association for the Advancement of Space Safety (IAASS) Space Safety Conference, Los Angeles, CA, May 2019.

[599] 18 Space Control Squadron; Space-Track.org; "Box Score"; https://www.space-track.org/. Accessed 19 March 2022.

[600] McKnight, D., Matney, M., Walbert, K., Behrend, S. Casey, P., and Speaks, S.; 25 September 2017; "Preliminary Analysis of Two Years of the Massive Collision Monitoring Activity"; *International Astronautical Congress.*

[601] Rossia, A., Petita, A., and McKnight, D.; 8 June 2020; "Short-term space safety analysis of LEO constellations and clusters"; *Acta Astronautica 175.*

[602] Dr. Liou, J.-C.; 9 February 2018; "U.S. Space Debris Environment, Operations, and Research Updates"; *UN Office on Outer Space Activities;* http://www.unoosa.org/documents/pdf/copuos/stsc/2018/tech-14E.pdf. Accessed 5 August 2020.

[603] McFall-Johnsen, Morgan; 4 December 2021; "Russia pushes the International Space Station away from '90s US rocket debris — the 2nd space-junk scare this week"; *Business Insider*; https://www.businessinsider.com/international-space-station-swerves-to-avoid-rocket-debris-2021-12. Accessed 19 March 2022.

[604] McKnight, D. and Kawashima, R.; IAA SG4.23; April 2019; "A Handbook for Post-Mission Disposal of Satellites Less Than 100 kg"; *International Academy of Astronautics (IAA).*

[605] McKnight, D. and Kawashima, R.; IAA SG4.23; April 2019; "A Handbook for Post-Mission Disposal of Satellites Less Than 100 kg"; *International Academy of Astronautics (IAA).*

606 Federal Communications Commission; November 2019; *U.S. Government Orbital Debris Mitigation Standard Practices;* https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf. Accessed 3 August 2021.

607 European Space Operations Centre (ESOC); GEN-DB-LOG-00288-OPS-SD, Version 4.0; 27 May 2021; *ESA's Annual Space Environment Report,* pp. 68-71; https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf. Accessed 3 August 2021.

608 Manis, A., Matney, M., Anz-Meador, P., Gates, D., Kennedy, T., Seago, J., Vavrin, A. and Y.-L. Xu; April 2020; "The New NASA Orbital Debris Engineering Model 3.1"; *NASA Orbital Debris Quarterly News, Vol. 24, No. 2,* p. 2.

609 Aerospace Corporation; September 2020; *Commercial Multi-INT Cheat Sheet.*

610 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community,* p. 13.

611 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community,* p. 13.

612 Beyer, Bill and Nelson, Nicholas; 28 June 2018; "Space Congestion Threatens to 'Darken Skies'"; *National Defense Magazine*; http://www.nationaldefensemagazine.org/articles/2018/6/28/viewpoint-space-congestion-threatens-to-darken-skies. Accessed 4 August 2020.

613 Office of the Director of National Intelligence; 13 February 2018; *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community,* p. 13.

614 Secure World Foundation; January 2017; *The United States, China, and Space Security: Issues for the Trump Administration;* https://swfound.org/media/205709/jw_uschinaspacesec_17012017.pdf. Accessed 3 August 2021.

615 Secure World Foundation; January 2017; *The United States, China, and Space Security: Issues for the Trump Administration;* https://swfound.org/media/205709/jw_uschinaspacesec_17012017.pdf. Accessed 3 August 2021.

616 Matytsin, Valery; 27 January 2017; "Russian specialists proposed creation of satellites to service spacecraft"; *TASS;* https://tass.ru/kosmos/3976581. Accessed 20 July 2021.

617 Sellers, Jerry Jon; *Understanding Space: An Introduction to Astronautics, 4th Edition,* pp. 614-617, 623-624; CEI: United States; 2015.

618 Sellers, Jerry Jon; *Understanding Space: An Introduction to Astronautics, 4th Edition,* pp. 61-62; CEI: United States; 2015.

619 Joint Chiefs of Staff; 26 October 2020; *Joint Publication 3-14: Space Operations* (10 April 2018, Incorporating Change 1), p. II-4.

620 Sellers, Jerry Jon; *Understanding Space: An Introduction to Astronautics, 4th Edition,* pp. 6, 59-60; CEI: United States; 2015.

621 Xinhua; 20 July 2018; "China developing in-orbit satellite transport vehicle".

622 Jones, Andrew; 21 April 2021; "China is developing plans for a 13,000-satellite megaconstellation"; *Space News*; https://spacenews.com/china-is-developing-plans-for-a-13000-satellite-communi- cations-megaconstellation/. Accessed 2 August 2021.

623 Joint Chiefs of Staff; 26 October 2020; Joint Publication 3-14: Space Operations (10 April 2018, Incorporating Change 1), p. x.

624 GPS.GOV; 5 November 2019; "Timing"; http://www.gps.gov/applications/timing/. Accessed 3 August 2021.

625 Hoehn, John R. and Ryder, Samuel D.; R45996; 26 June 2020; "Precision Guided Munitions: Background and Issues for Congress"; *Congressional Research Service.*

626 Gray, Brandon J., Major, USAF; August 2017; "The Post GPS-Only Era: Positioning, Navigation, and Timing (PNT) in 21st Century Warfare"; *Air Command and Staff College*; https://apps.dtic.mil/sti/pdfs/ad1054619.pdf. Accessed 3 August 2021.

627 Quasi-Zenith Satellite System; 2021; "Overview of the Quasi-Zenith Satellite System"; https://qzss.go.jp/en/overview/services/sv01_what.html. Accessed 20 July 2021.

628 Indian Space Research Organization; 2021; "Indian Regional Navigation Satellite System (IRNSS): NavIC"; https://www.isro.gov.in/irnss-programme. Accessed 3 August 2021.

629 European Global Navigation Satellite Systems Agency; 17 February 2021; "Galileo is the European global satellite-based navigation system"; https://www.gsa.europa.eu/european-gnss/galileo/galileo-european-global-satellite-based-navigation-system. Accessed 3 August 2021.

630 Xinhua; 26 May 2021; "China's Beidou-related industry estimated to top 1t yuan by 2025"; http://www.xinhuanet.com/english/2021-05/26/c_139971521.htm. Accessed 20 July 2021.

631 Interfax; 4 May 2021; "Twenty-two GLONASS satellites currently in operation".

632 Foust, Jeff; 8 April 2021; "OneWeb continues to study offering navigation services"; *Space News*; https://spacenews.com/oneweb-continues-to-study-offering-navigation-services/. Accessed 17 December 2021.

633 Joint Chiefs of Staff; 26 October 2020; Joint Publication 3-14: Space Operations (10 April 2018, Incorporating Change 1), p. II-8.

634 Erwin, Sandra; 14 November 2019; "Air Force: SSA is no more; it's 'Space Domain Awareness'"; *Space News*; https://spacenews.com/air-force-ssa-is-no-more-its-space-domain-awareness/. Accessed 3 August 2021.

635 Joint Chiefs of Staff; 26 October 2020; Joint Publication 3-14: Space Operations (10 April 2018, Incorporating Change 1), p. I-3, II-16.

636 Joint Chiefs of Staff; November 2021; *DoD Dictionary of Military and Associated Terms*, p. 71.

637 Joint Chiefs of Staff: November 2021; *DoD Dictionary of Military and Associated Terms*, p. 64.

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