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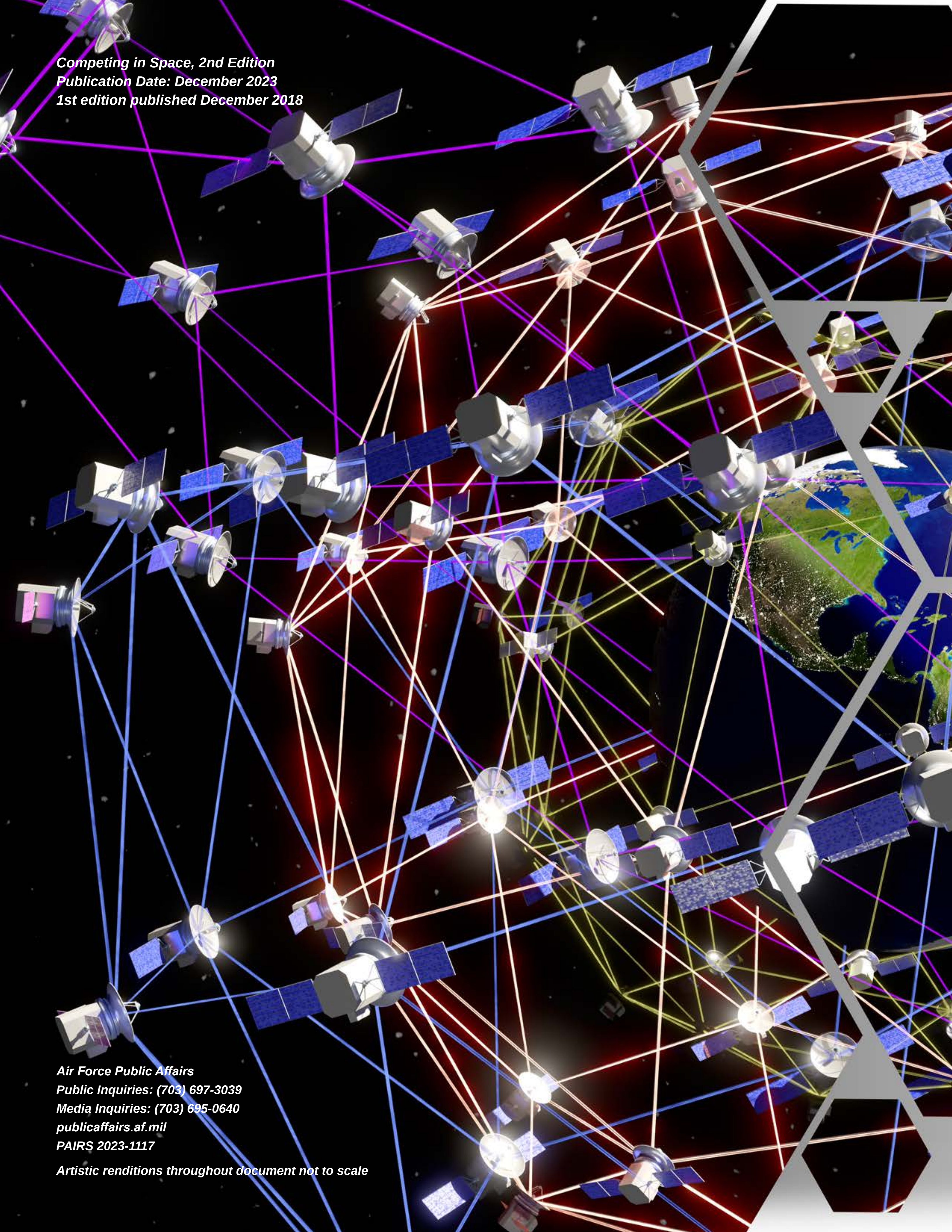
AND THE NATIONAL AIR AND SPACE INTELLIGENCE CENTER

COMPETING IN SPACE

SECOND EDITION



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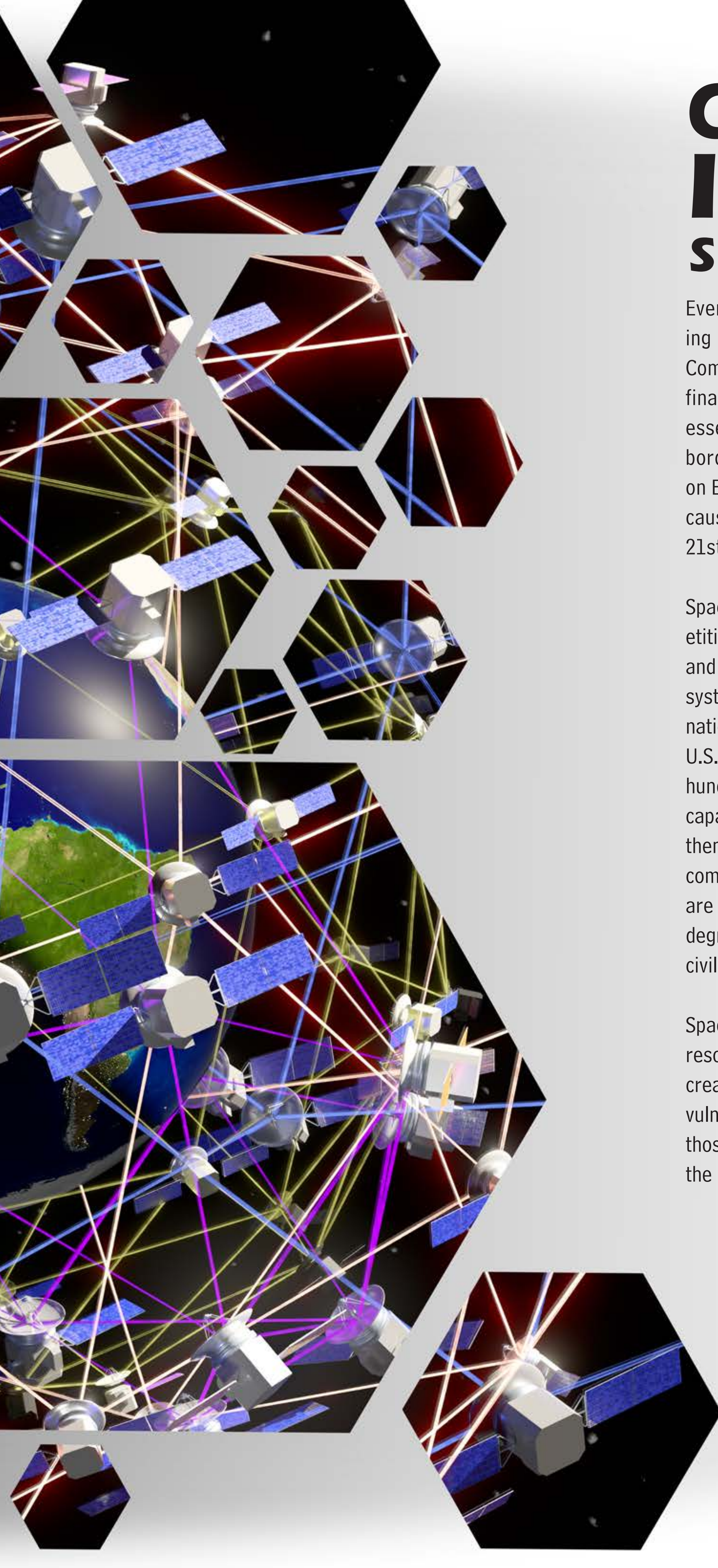


COMPETING IN SPACE
SECOND EDITION

Every day, billions of people rely on spacecraft orbiting hundreds and thousands of miles above Earth. Complex satellite constellations support the world's finances, transportation, and agriculture, providing essential services that transcend international borders and touch the lives of virtually every person on Earth. Major disruptions to satellite services would cause significant, perhaps irreparable, damage to 21st century life.

Space systems have transformed international competition and conflict. Over 80 countries own satellites and many of these countries consider access to space systems and services as important contributors to their national security and military power projection. The U.S.'s key competitors, China and Russia, both operate hundreds of space systems to strengthen warfighting capabilities, boost spheres of influence, and position themselves as leaders in the international space community. At the same time, both of these competitors are developing counterspace capabilities capable of degrading or destroying space systems critical to civilian infrastructure and military operations.

Space promises humanity boundless capabilities, resources, and achievements. However, the world's increasing space use has made the inherent risks and vulnerabilities apparent. This publication identifies those capabilities, trends, and dangers that constitute the present and future of our space-integrated lives.

NATIONAL AIR & SPACE INTELLIGENCE CENTER

NSIC

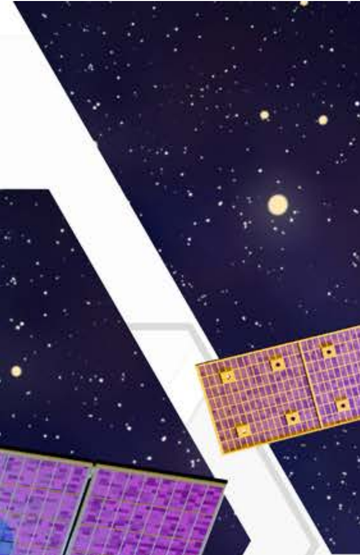
EVERYDAY LIFE

Space services are key enablers of industry, critical infrastructure, and international trade. Navigation satellites provide precise timing references for banks, stock markets, and national power grids, as well as positioning data for cell phones to operate and for trucks, airplanes, and cargo ships to find their way around the world. Remote sensing satellites enable timely warning and monitoring of weather events and natural disasters, and perform mapping and tracking functions for agriculture, environmental protection, resource management, and city planning. Communications satellites supplement terrestrial communications networks and offer people, particularly those in remote or conflict regions, access to telephone, television, and broadband internet.

Space services are increasingly essential to life and security for virtually all people around the globe.

NATIONAL SECURITY

Space services are also key enablers for national defense and military operations. Remote sensing satellites allow tracking and monitoring of adversary installations and movement of forces. Navigation satellite constellations, like the U.S.'s Global Positioning System (GPS), provide critical positioning, navigation, and timing data to improve the effectiveness of guided munitions and deploying forces worldwide. Communications and relay satellites securely transmit data to military forces, particularly in remote regions inaccessible by traditional terrestrial communications. Ballistic missile early warning satellites serve as the initial alarm for detecting ballistic missile launches and are a critical part of national missile defense architectures.



SPACE OPERATIONS

Several of the world's advanced spacefaring nations operate launch vehicles, satellites, and ground-based support infrastructure. Our key competitors, China and Russia, have developed launch vehicles capable of reaching all orbits, substantial satellite constellations for remote sensing, navigation, and communications, and networks of ground sites to launch, control, and support their spacecraft.

Support Infrastructure

EMERGING COMMERCIAL SPACE INDUSTRY

ИННОТЕР

СКАНЭКС

银河航天 GALAXYSPACE

CG SATELLITE

Over ten thousand organizations market space services, spacecraft components, launch services, and satellites worldwide. The growing availability of these services and technologies has opened new actors' eyes to the value of space-derived data. Although state-owned enterprises like China's China Aerospace Science and Technology Corporation and Russia's Roscosmos remain leading exporters of satellites and launch services, a growing number of private and public-private enterprises are developing satellite constellations, launching customers' spacecraft, and selling imagery and communications services.

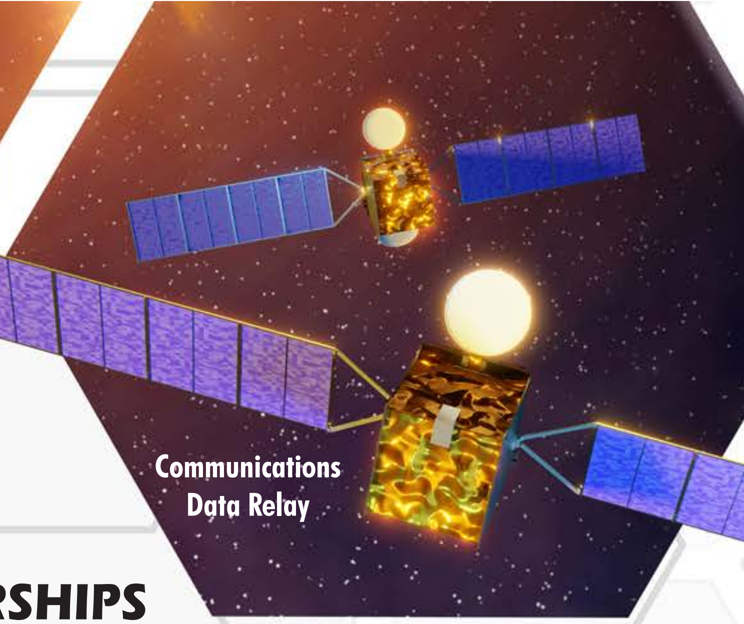
RECENT MILESTONES

2020

China completed the third generation of its version of GPS, BeiDou. The now-global constellation provides high-accuracy satellite navigation services to users worldwide and is used by the Chinese military to enable force movements and precision-guided munitions delivery.

2021

Russia launched its first Arctic-dedicated meteorological satellite. Moscow plans to operate multiple new meteorological, radar, and communications satellites by 2026 to continuously monitor weather conditions in the Arctic, including the Northern Sea Route, for economic and national defense purposes.



COMPETITORS' SPACE PARTNERSHIPS

China and Russia offer launch and satellite services to other countries. Partnerships like these offer non-spacefaring nations the benefits of space use without the expense of developing their own space support infrastructure. China particularly incentivizes its space partnerships by offering technical exchanges, satellite services, and even production of complete satellites at little initial cost. Beyond, or in lieu of, monetary payments, China and Russia can use these opportunities to garner geopolitical influence and bolster scientific prestige.

As part of broader efforts to improve military force capabilities and technological innovation, China and Russia are increasingly integrating civilian, commercial, and academic space expertise into military programs. This was evident in early 2023 when the U.S. issued sanctions and export controls against Chinese and Russia companies for providing satellite imagery support to Russian military operations in Ukraine. Both countries also pursue collaboration with academic and civil organizations abroad to enhance scientific research and expand space surveillance capabilities outside their respective borders.

In late 2022, China and Russia renewed their five-year space partnership agreement. The new agreement includes joint work on satellite navigation and construction of a future International Lunar Research Station on the Moon.

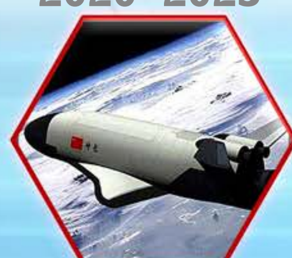
2020–2022

Iran's Islamic Revolutionary Guards Corps (IRGC) launched its first space launch vehicle containing Iran's first military satellite. In 2022, Iran launched a second military satellite, tested a new IRGC launch vehicle, and received the Khayyam remote sensing satellite from Russia.

China constructed the Chinese Space Station, its three-module alternative to the International Space Station, in orbit between April 2021 and October 2022. Beijing plans to maintain a rotating crewed presence on the station for the next decade.

2021–2022

2020–2023



In 2020, China became the third country to operate a spaceplane, after the U.S. and Soviet Union. It launched its second spaceplane in August 2022, which remained in orbit until May 2023.

2018–PRESENT

Since the first edition of "Competing in Space," twenty countries saw their first satellites launched into space.

SPACE GROWTH

Since the first edition of "Competing in Space," the number of active satellites in space has more than tripled, from 1,880 to 7,096 at the end of 2022. While plans for massive mega-constellations made up of hundreds or thousands of satellites cause projections to vary widely, some estimates indicate the number of satellites in orbit may exceed the tens or even hundreds of thousands by 2032.

Increasing commercial availability of launch services and production of small satellites that are cheaper, less complex, and faster to develop are propelling this growth. These factors enable some launch providers to send over a hundred satellites into low Earth orbit on one launch vehicle; for instance, India launched a foreign record of 104 satellites at once in early 2017.

2002
806 Satellites

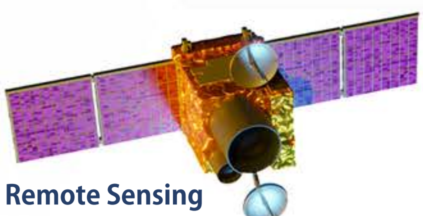
2012
1,091 Satellites

2022
7,096 Satellites

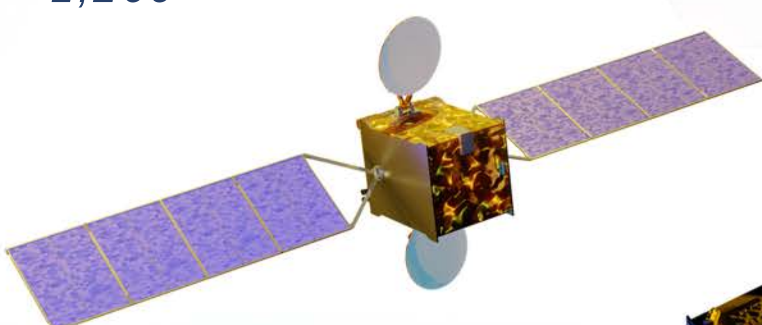
=100 Satellites

7,096 Satellites Worldwide 2022

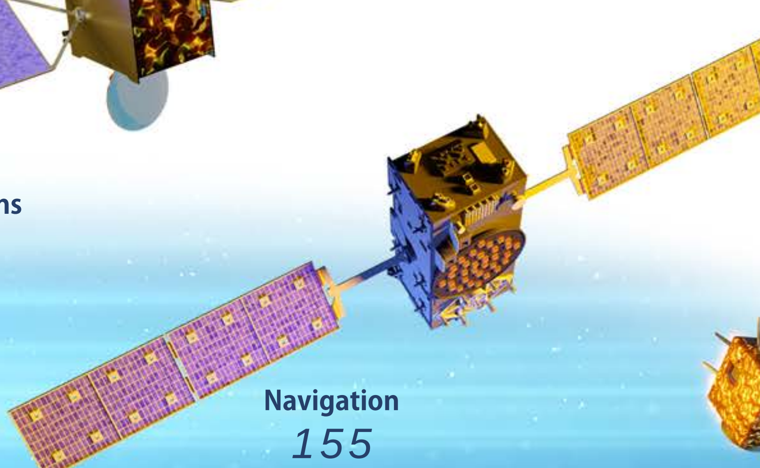
SATELLITES BY MISSION:



Remote Sensing
1,269



Communications
4,969



Navigation
155

Scientific, Technology Development, or Other
703

Satellites by Country:

Russia	China	USA	Rest of World
199	647	4,723	1,527

2032
Tens of Thousands Satellites Worldwide

RUSSIA IN 2022

Amid broader societal problems and growing international isolation, Russian space technology has fallen behind the West. Despite these issues, Moscow hopes to maintain its constellations and develop select next-generation capabilities. Russia successfully orbited all 22 of its launches in 2022 and was the third-most prolific space launch provider behind the U.S. and China. However, Russia's presence on the international launch market all but vanished, with 16 of 19 planned commercial launches cancelled due to its invasion of Ukraine.

LAUNCH CAPABILITIES

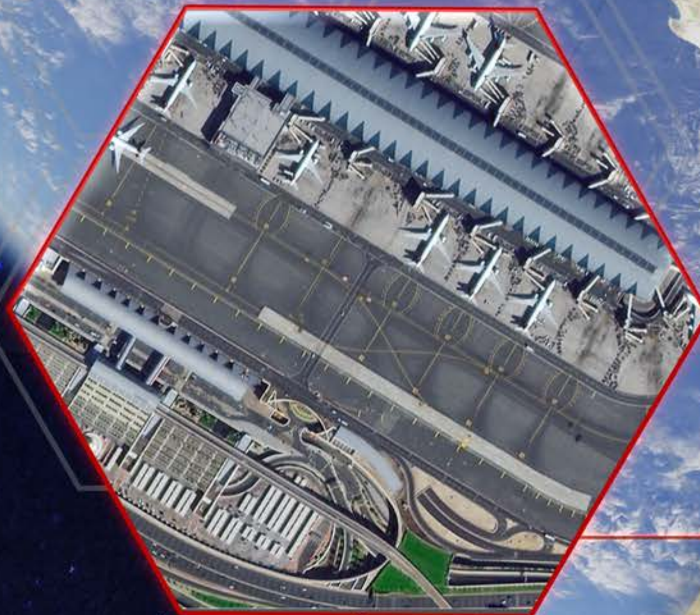
Five countries and one multi-country intergovernmental organization can launch to all Earth orbits. Four additional countries are capable of launching to low Earth orbit.

CHINA IN 2022

Over the past decade, China has rapidly developed into a major international space power, effectively multiplying its number of on-orbit satellites tenfold. In 2022, China successfully conducted 62 of 64 launches, breaking its previous record for launches in a single year and becoming the second-most prolific space launch provider behind the U.S. More than half of the approximately 200 satellites China launched in 2022 were remote sensing satellites.

INCREASING SURVEILLANCE

National, commercial, and academic ventures worldwide are developing and proliferating increasingly sophisticated space-based remote sensing capabilities and space observation sensors. The growing number and variety of these sensors offer greater access to a wide range of data for characterizing systems, events, and facilities. As these capabilities become more commonplace, activities around the world and in space will become more difficult to conduct without being observed.



Monitoring Earth

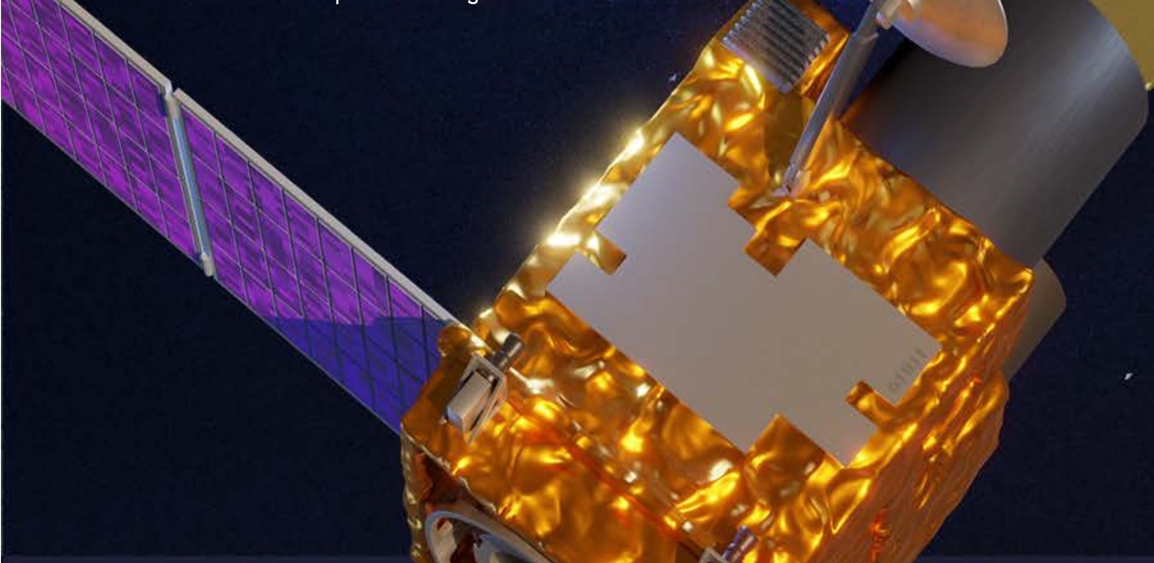
China operates over 300 remote sensing satellites with diverse sensors, improving the Chinese military's ability to observe U.S. aircraft carriers, expeditionary strike groups, and deployed air wings. Russia operates some of the world's most capable individual remote sensing satellites; however, Moscow operates only a limited number of these systems compared to the U.S. and China.

China and Russia have further plans to improve, expand, and diversify these capabilities, which will enhance their ability to readily monitor and target emergent events, force deployments, and sensitive ground locations. Both countries also seek to use space for early warning of ballistic missile launches. Russia has maintained satellites for this purpose since the 1970s and China has recently started developing these capabilities.

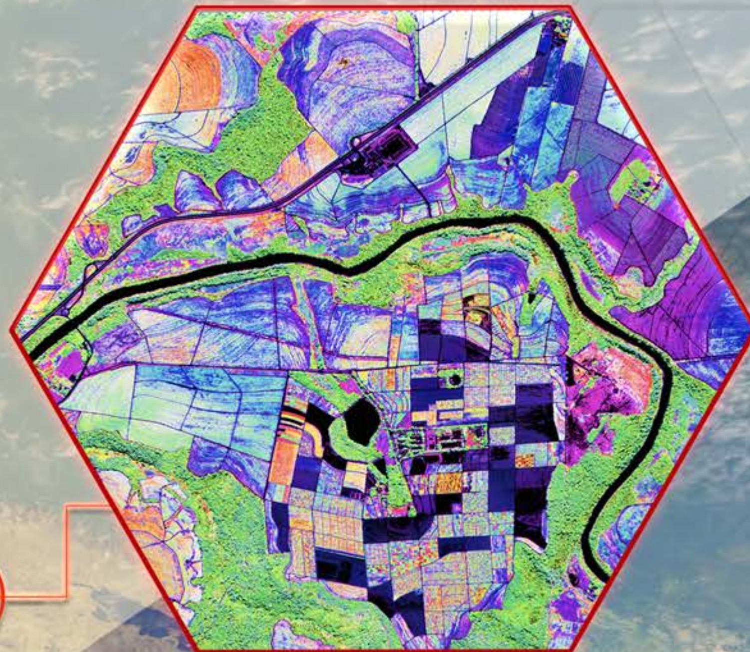
As evidenced by the Russia-Ukraine conflict, commercial remote sensing satellite firms are greatly expanding the public availability of high-quality satellite imagery. In January 2023, the U.S. Department of the Treasury sanctioned a Chinese commercial satellite company, its Luxembourg-based subsidiary, and a Russian company for supplying satellite imagery that enabled Wagner Group, a Russian paramilitary organization, to conduct combat operations against Ukraine.

SPACE-BASED SATELLITE MONITORING

Increasing numbers of satellites with onboard cameras have enabled space-based monitoring of satellites in all orbits.

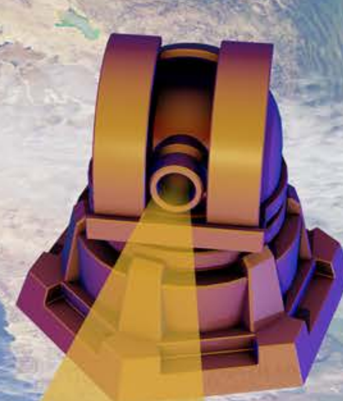


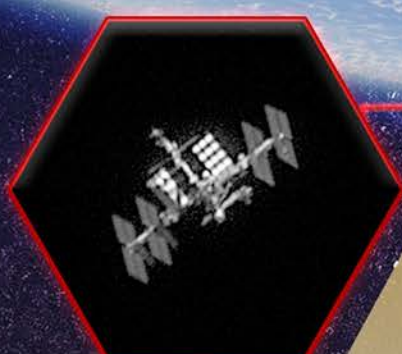
SYNTHETIC APERTURE RADAR IMAGING
- All weather, day or night
- Difficult to interpret



HYPERSPECTRAL IMAGING
- Highly detailed, many applications
- Costly, complex

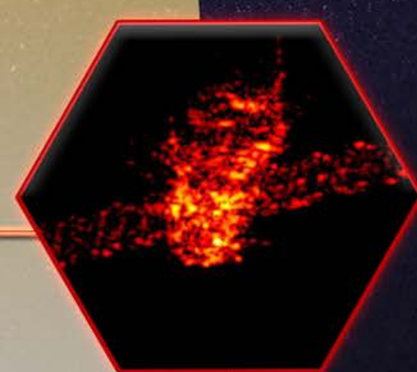
OPTICAL IMAGING
- Easy to conduct/interpret
- Limited to day, clear weather conditions





Monitoring Space

China and Russia maintain networks of diverse sensors to search for, track, and characterize space objects, a capability fundamental to conducting counterspace operations. These countries bolster their respective networks with data from global academic and civilian space monitoring networks, like the Russian-led International Scientific Optical Network and the Chinese Academy of Sciences' future SiTian network, to more frequently track a greater number of space objects.



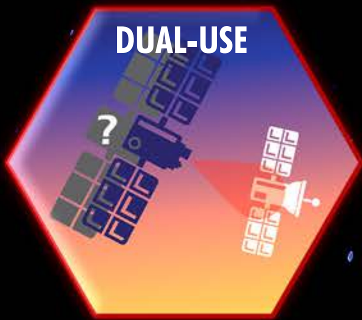
DENYING SPACE

As our world grows increasingly dependent upon space services, potential adversaries are developing technologies and fielding terrestrial and space-based counterspace weapons capable of destroying satellites, disrupting space services, and degrading support infrastructure on the ground.

China and Russia view the U.S. as overly-reliant upon space for military and information superiority. Seeking asymmetric advantages in future conflict, both countries are designing, testing, and demonstrating counterspace weapons to deny, disrupt, or destroy satellites and space services. They often mask or conceal these activities to avoid international condemnation.

The dual-use nature of some spacecraft technologies makes counterspace tests or hostile activity difficult to detect, attribute, or mitigate. For example, sensors to inspect other satellites and robotic arms for servicing other satellites support peaceful missions, but can also be used to target or attack spacecraft.

DUAL-USE



China is developing satellite inspection and repair systems that could function as weapons and it has launched multiple satellites to test orbital maintenance and debris mitigation. In January 2022, China's Shijian-21 towed a defunct Chinese geostationary satellite to a graveyard orbit.

KINETIC KILL VEHICLES

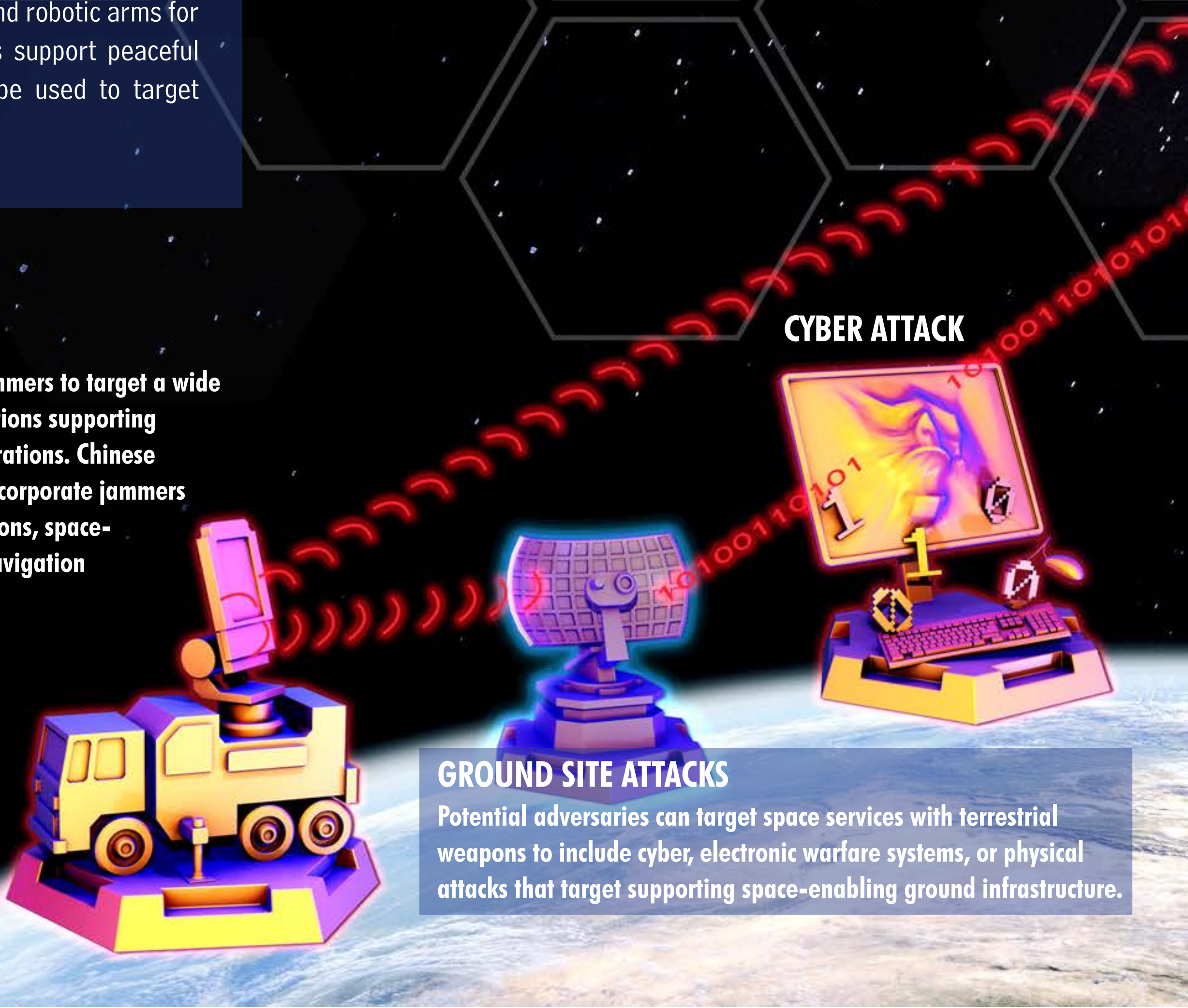
Russia has deployed multiple prototype orbital anti-satellites in low Earth orbit to test kinetic kill capabilities, including COSMOS 2504, COSMOS 2519, and COSMOS 2536. In 2019, a prototype followed a U.S. national security satellite; later, another tested its anti-satellite weapon by ejecting an object near a Russian satellite.

ELECTRONIC WARFARE

China likely is developing jammers to target a wide range of satellite communications supporting government and military operations. Chinese military exercises regularly incorporate jammers against satellite communications, space-based radars, and satellite navigation systems, such as GPS.

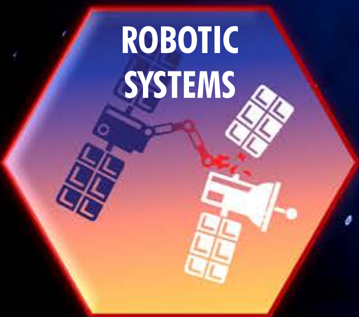
Russia views electronic warfare as essential to gaining and maintaining information superiority and has fielded ground-based electronic attack systems to counter communications, radars, and GPS.

CYBER ATTACK



GROUND SITE ATTACKS

Potential adversaries can target space services with terrestrial weapons to include cyber, electronic warfare systems, or physical attacks that target supporting space-enabling ground infrastructure.



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.

ANTI-SATELLITE MISSILES

More than 2,700 of the original 3,000 trackable debris objects from China's 2007 anti-satellite missile test remain in low Earth orbit. The Chinese military routinely trains with an operational variant of this ground-based missile. In 2013, China launched an object on a ballistic trajectory to an altitude of 30,000km, suggesting it may have a missile capable of destroying satellites in geostationary Earth orbit.

In November 2021, Russia destroyed a Soviet-era satellite in low Earth orbit using Nudol', a mobile, ground-based missile. This test generated over 1,500 pieces of trackable debris and tens of thousands of lethal but nontrackable objects. In 2018, a MiG-31 with a large missile slung beneath the aircraft was observed by the public at a Russian test site. The weapon may be related to the Burevestnik air-launched anti-satellite missile, which will be "capable of destroying targets in near-space."

DIRECTED ENERGY WEAPONS

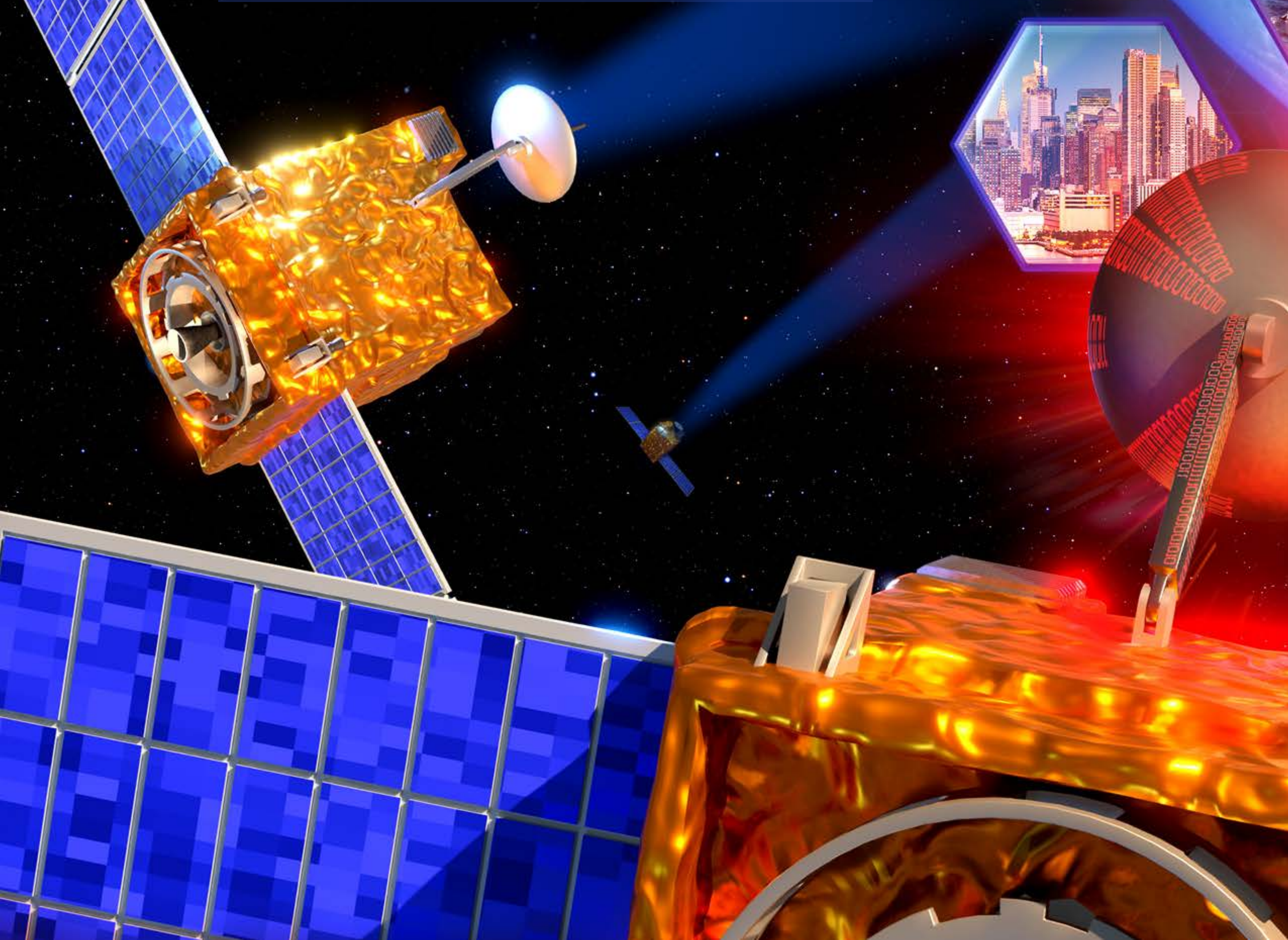
China has multiple ground-based laser systems of varying power levels that could blind or damage satellite sensors. By the mid-to-late 2020s, Beijing may have higher-power systems capable of damaging satellites.

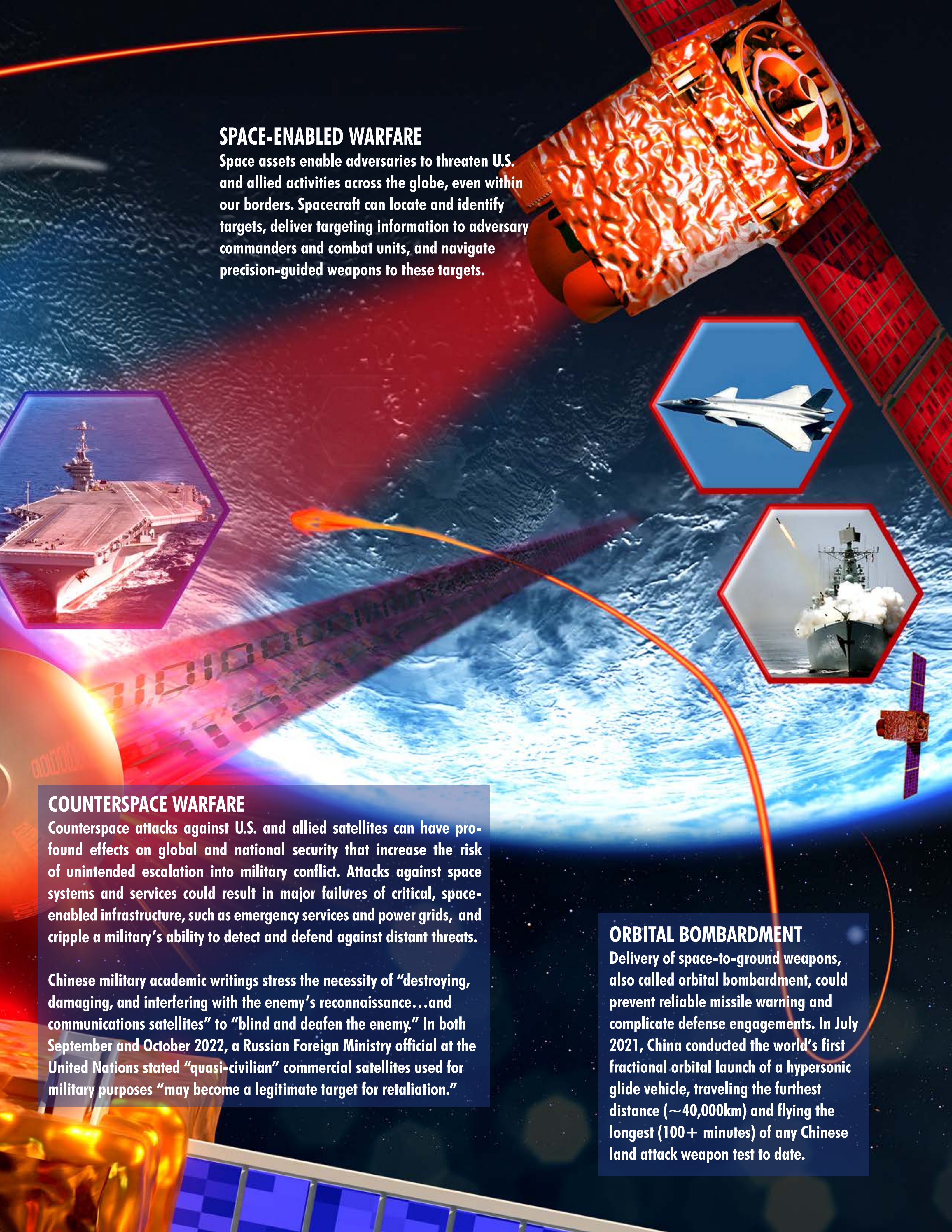
Russia has several ground-based lasers that could jam and blind satellite sensors. Beginning in 2018, Russia deployed Peresvet – a laser system designed to mask missile deployments by blinding satellite sensors – to five strategic missile divisions. Russia likely will field more powerful lasers in the mid-to-late 2020s.

MULTI-DOMAIN WARFARE

Space technologies are critical enablers of modern warfare. Through satellites far above the traditional battlefield, space-enabled actors can collect, transmit, and relay data crucial for achieving military advantages and expanding multi-domain warfare over great distances. Satellites provide nations new means to target and deliver munitions, conduct information operations to influence civilians and service members, and control their military forces nearly anywhere in the world. The emergence of counterspace weapons has introduced methods to deny military and civilian use of space services.

China and Russia view space capabilities as essential for winning future conflicts. In 2015, both countries began significant military reforms to modernize their use of space and counterspace assets. Today, China's Strategic Support Force and Russia's Space Forces are integrating space and counterspace capabilities into military operations and exercises, expanding personnel training and testing for space-enabled systems, and refining delivery of targeting data to precision weapon systems.





SPACE-ENABLED WARFARE

Space assets enable adversaries to threaten U.S. and allied activities across the globe, even within our borders. Spacecraft can locate and identify targets, deliver targeting information to adversary commanders and combat units, and navigate precision-guided weapons to these targets.

COUNTERSPACE WARFARE

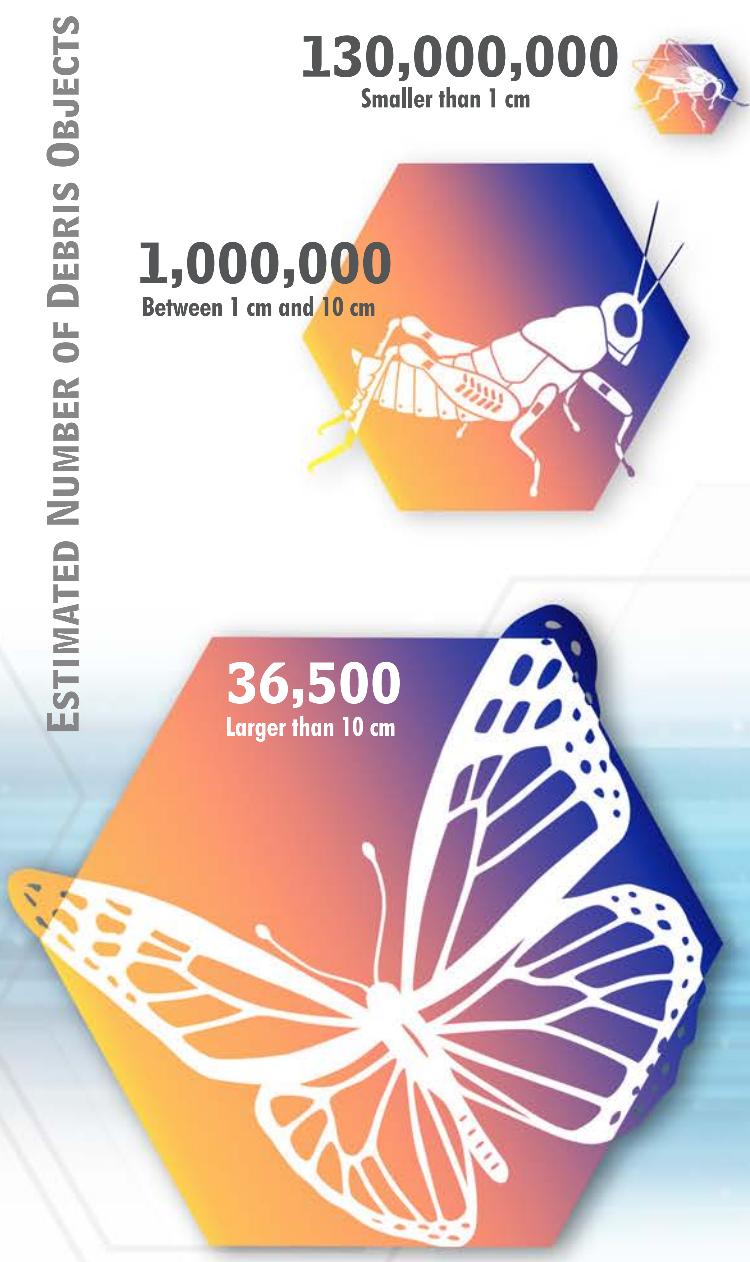
Counterspace attacks against U.S. and allied satellites can have profound effects on global and national security that increase the risk of unintended escalation into military conflict. Attacks against space systems and services could result in major failures of critical, space-enabled infrastructure, such as emergency services and power grids, and cripple a military's ability to detect and defend against distant threats.

Chinese military academic writings stress the necessity of "destroying, damaging, and interfering with the enemy's reconnaissance…and communications satellites" to "blind and deafen the enemy." In both September and October 2022, a Russian Foreign Ministry official at the United Nations stated "quasi-civilian" commercial satellites used for military purposes "may become a legitimate target for retaliation."

ORBITAL BOMBARDMENT

Delivery of space-to-ground weapons, also called orbital bombardment, could prevent reliable missile warning and complicate defense engagements. In July 2021, China conducted the world's first fractional orbital launch of a hypersonic glide vehicle, traveling the furthest distance (~40,000km) and flying the longest (100+ minutes) of any Chinese land attack weapon test to date.

RISKS IN THE SPACE ENVIRONMENT

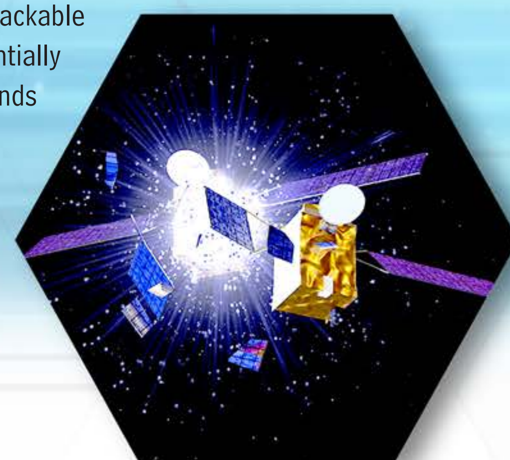


Orbital Debris

Imagine if a fly colliding with your windshield could destroy your car. Space debris smaller than a fly can cause catastrophic damage to spacecraft. As launch activity, satellite breakups, and unsafe use of space continues, the risk of spacecraft colliding with debris will continue to grow.

Global space monitoring networks are currently only capable of tracking debris larger than 10 cm, leaving the overwhelming majority of space objects untracked. As of December 2022, just 32,290 of an estimated 130 million objects in Earth's orbit have been catalogued. In early 2021, International Space Station (ISS) operators discovered a sizable hole in the station's robotic arm created by untracked debris, which highlights the danger these hidden objects can pose.

Kinetic anti-satellite weapons have the potential to create substantial amounts of debris. China's 2007 anti-satellite missile test created the largest single-collision debris field ever, with over 3,000 pieces of trackable debris. Multiple spacecraft, including the ISS, have maneuvered to avoid the debris. Russia's 2021 anti-satellite missile test generated over 1,500 pieces of trackable orbital debris and potentially hundreds of thousands of smaller objects.



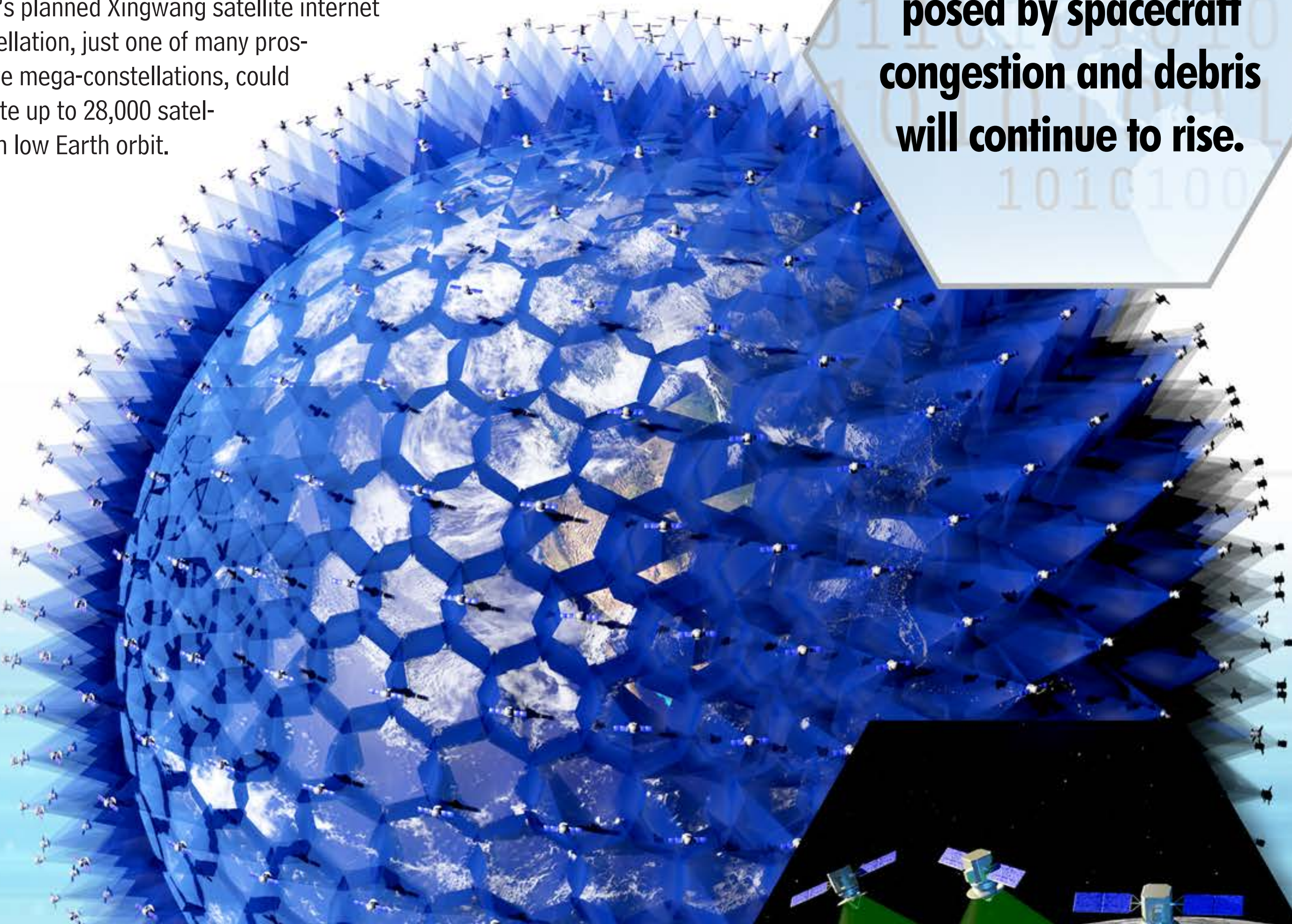
Space Norms

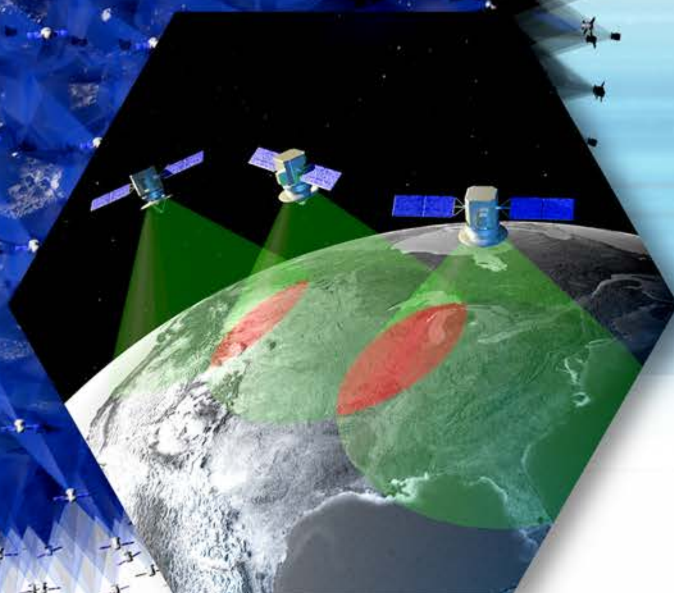
International norms have not kept pace with the dramatic evolution of space use over the past several decades. Despite the substantial increase in new space operators, technologies, and spacecraft, the international community has not achieved consensus on major norms, rules, or principles governing activities in space since the 1970s. China and Russia continue to endorse a draft treaty on weapons in space, though it fails to address a variety of anti-satellite weapons and lacks meaningful verification mechanisms.

Mega-Constellations

Planned mega-constellations of hundreds or thousands of satellites will complicate spacecraft tracking, signal interference mitigation, and collision avoidance. China's planned Xingwang satellite internet constellation, just one of many prospective mega-constellations, could operate up to 28,000 satellites in low Earth orbit.

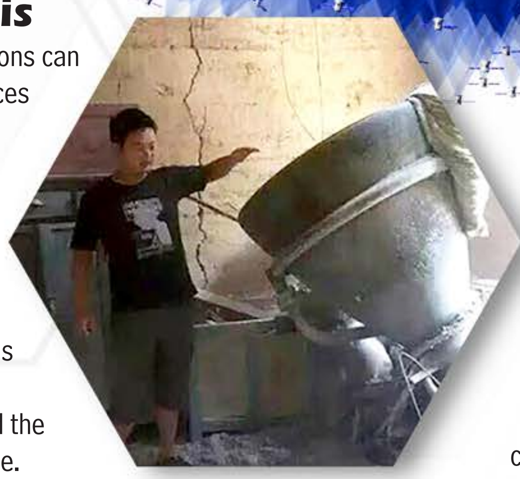
The risks posed by spacecraft congestion and debris will continue to rise.





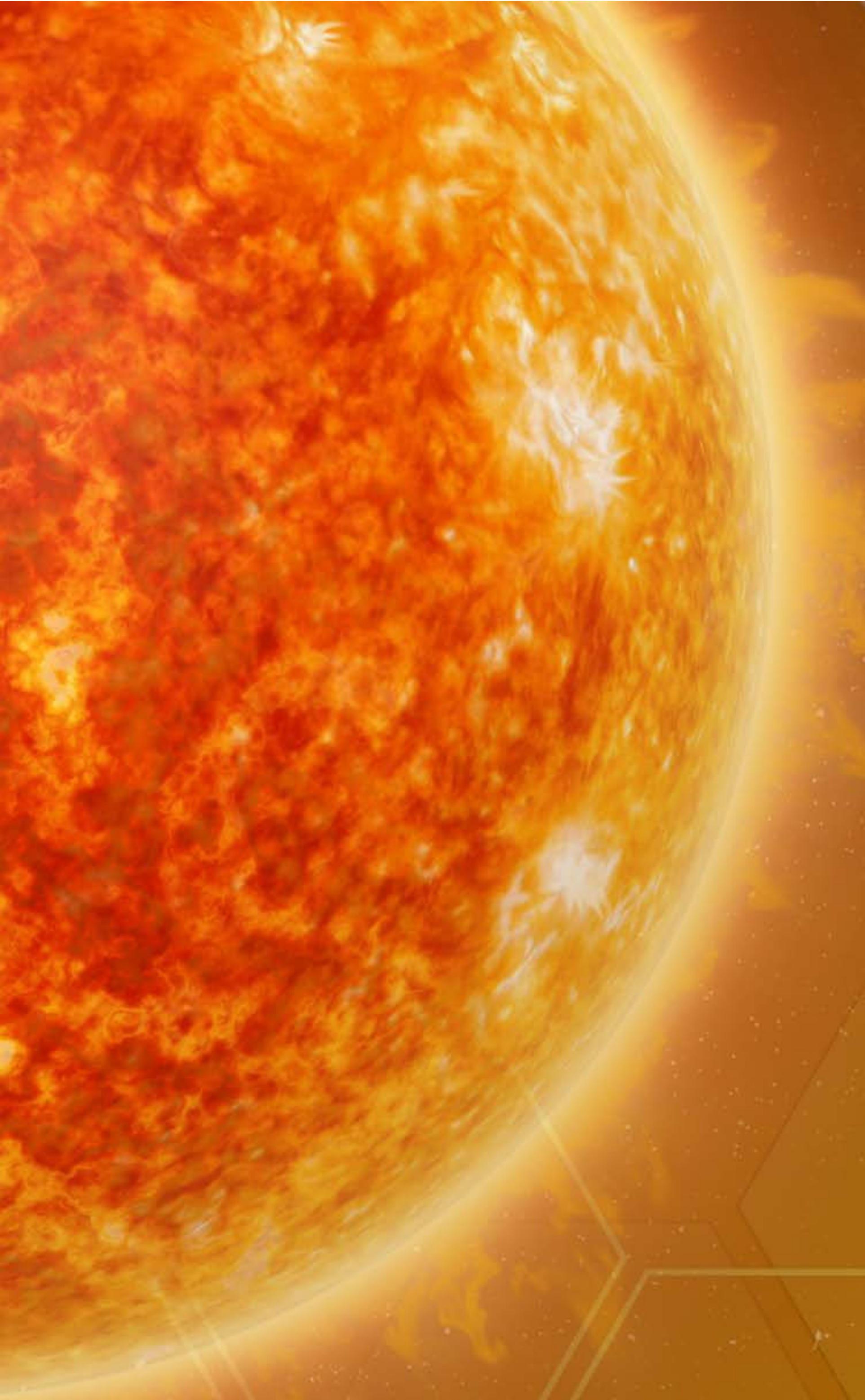
Falling Debris

Debris from space missions can threaten people and places on Earth. Launches over populated areas drop debris and toxic fuel on roads and people's homes. Reentry of large, uncontrolled space objects into Earth's atmosphere must be monitored to understand the risks to people worldwide.



Signal Interference

Similar to adversarial electronic warfare operations, inadvertent signal interference from satellites or ground systems can degrade or deny satellite services. While the International Telecommunications Union regulates frequencies to avoid interference, conflicts between systems using the same frequencies can disrupt space services and require costly or complicated changes to satellite operations.



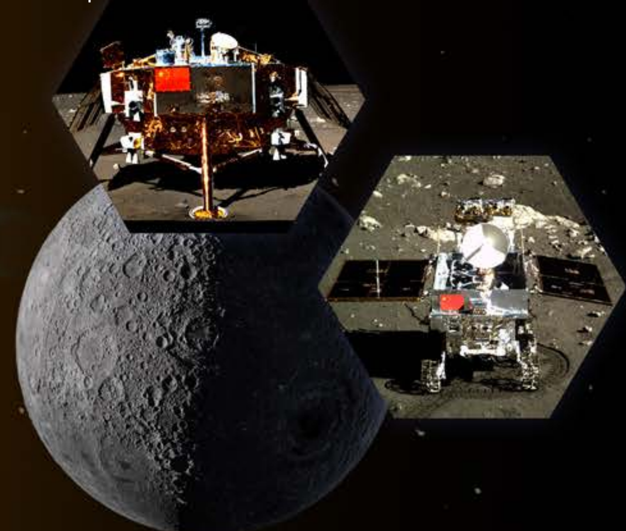
DEEP SPACE EXPLORATION

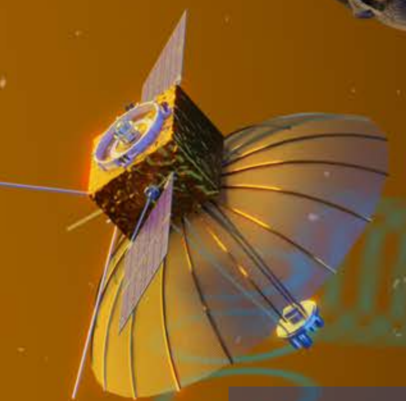
Spacefaring nations are once again taking significant steps beyond Earth's immediate orbit. Deep space exploration promises substantial rewards: scientific breakthroughs for prestige and technological advancement; economic windfalls from resources on asteroids, the Moon, and other celestial bodies; and even potential strategic advantage in specialized orbits or high value locations.

Organizations around the world have proposed over 50 deep space missions in the coming decades, with more than a dozen countries planning to visit the Moon, Lagrange points, other planets, and beyond. China and Russia both have multiple planned robotic missions to the Moon, including the jointly-developed International Lunar Research Station on the lunar surface in the 2030s. China's plans also include its first crewed Moon mission in the 2030s and several robotic scientific missions to Mars, asteroids, and deep space. Russia's plans include its own crewed Moon mission in the 2030s and robotic scientific missions to Venus, Mars, and deep space.

Moon

Between 2018 and May 2023, China, India, Israel, Italy, Japan, South Korea, and the United Arab Emirates (UAE) launched lunar scientific missions; China landed its lunar far-side rover in 2019 and completed a separate sample return mission, Chang'e-5, in 2020. After returning the sample to Earth, Chang'e-5 transited to the L1 Sun-Earth Lagrange Point in 2021, and in early 2022, became the first spacecraft to enter a stable distant retrograde orbit around the Moon. In late 2023, India's Chandrayaan-3 became the world's first spacecraft to successfully land near the lunar south pole.





Lagrange Points

Lagrange points, areas where gravity between two celestial bodies is balanced, allow spacecraft to expend considerably less fuel to remain in stable positions over long periods of time. These regions are uniquely valuable for long-term missions, such as surveillance, space environment monitoring, or data relay, in deep space. China operates its Queqiao relay satellite at the L2 Earth-Moon Lagrange point to communicate with the Yutu-2 lunar far-side rover and Russia operates the Spektr-RG deep space telescope at the L2 Sun-Earth Lagrange point.

SELECT FUTURE MISSIONS

2020s

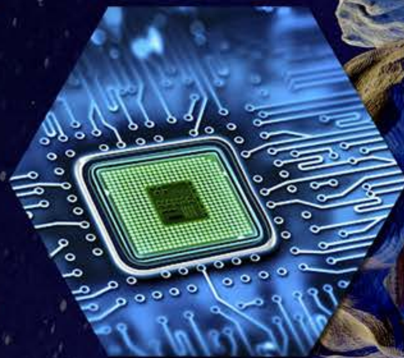
- **Luna-26 orbiter, Luna-27 surface drill, Luna-28 sample return**
- **Queqiao-2 relay satellite, Chang'e-6 sample return, Chang'e-7 & Chang'e-8 polar missions**
- **Beresheet 2 landers**
- **LUPEX lander**

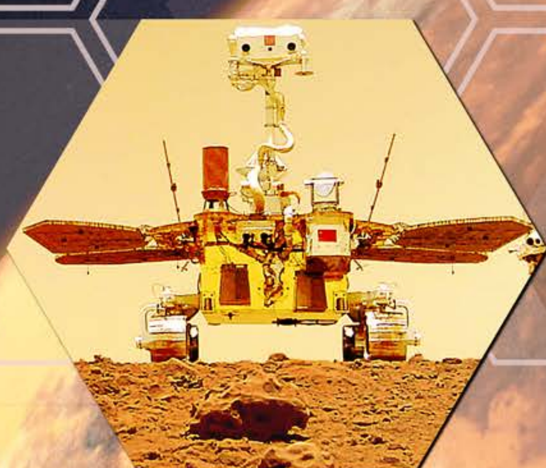
2030s

- **Crewed landing**
- **Crewed landing**
- **International Lunar Research Station**

Resource Exploitation

Countless celestial bodies beyond Earth have vast resources that could fundamentally change resource scarcity and humanity's role in outer space. Helium-3 deposits on the Moon may offer a safe, non-radioactive source of nuclear energy in the future, and massive rare metal deposits on nearby asteroids could supply manufacturers in many industries here on Earth. Lunar and Martian soil can be processed into cement for permanent structures, like long-term human habitats, while water and oxygen in the soil can be used for life support and rocket fuel production.





Mars

Between 2019 and 2021, China and the UAE launched spacecraft into Mars orbit; China also became the second country, after the U.S., to operate a Mars rover.

SELECT FUTURE MISSIONS

2020s	esa ExoMars lander
2030s	Tianwen-3 sample return

Asteroids

In 2020, Japan successfully returned the second asteroid sample ever collected, following the 2010 return of its previous asteroid sample mission.

SELECT FUTURE MISSIONS

2020s

- **DESTINY+ asteroid flyby**
- **Tianwen-2 sample return**
- **Planetary defense test asteroid impactor**

Space Exploration

In April 2023, the European Space Agency launched the Jupiter Icy Moons Explorer (Juice). After its eight year journey to Jupiter, the Juice spacecraft will assess three of Jupiter's moons for conditions suitable for supporting life.

SELECT FUTURE MISSIONS

2020s

- **Shukrayaan-1 Venus orbiter**

2030s

- **Tianwen-4 Jovian system and Uranus explorer**

EMERGING TECHNOLOGIES AND MISSIONS

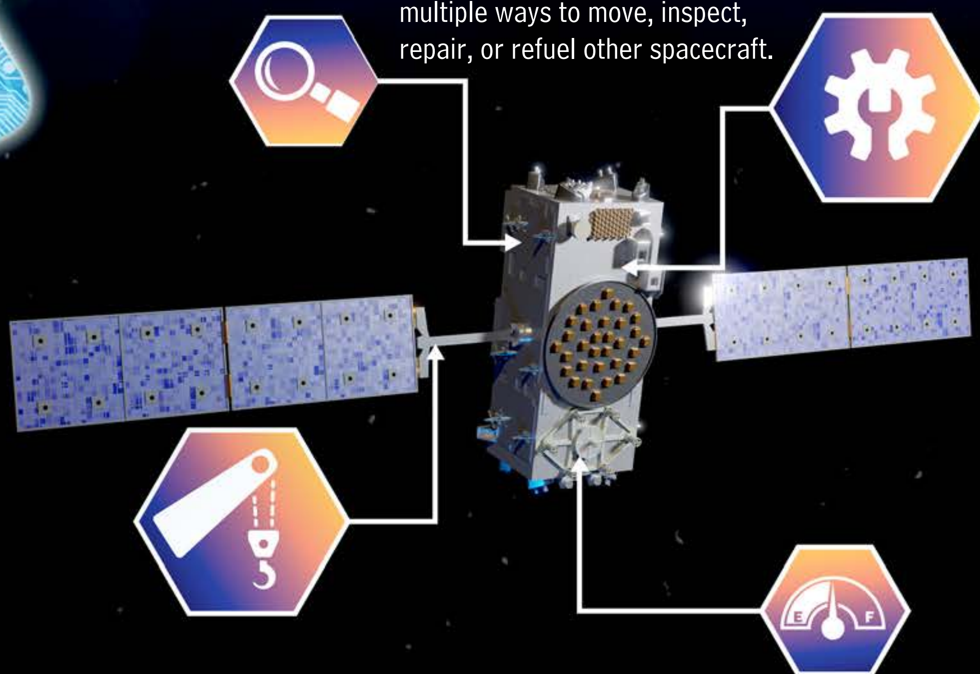
Researchers worldwide are developing novel technologies with the potential to dramatically improve and alter future space capabilities over the next twenty years. The convergence of technologies like artificial intelligence, 3D printing, and robotics will enhance and expand nations' capabilities to perform a wide range of complex missions throughout space. Many of these technologies could have both peaceful and military applications.

Artificial Intelligence

Artificial intelligence will reduce or eliminate the number of human decisions required by spacecraft, enabling them to rapidly or autonomously navigate in space, process information, monitor objects, target and strike adversaries, and operate in large satellite swarms.

On-Orbit Servicing

Servicing satellites will offer multiple ways to move, inspect, repair, or refuel other spacecraft.



Moon/Mars Construction

Construction capabilities on the Moon and Mars will facilitate development of long-term laboratories, observatories, and habitats.

Robotics

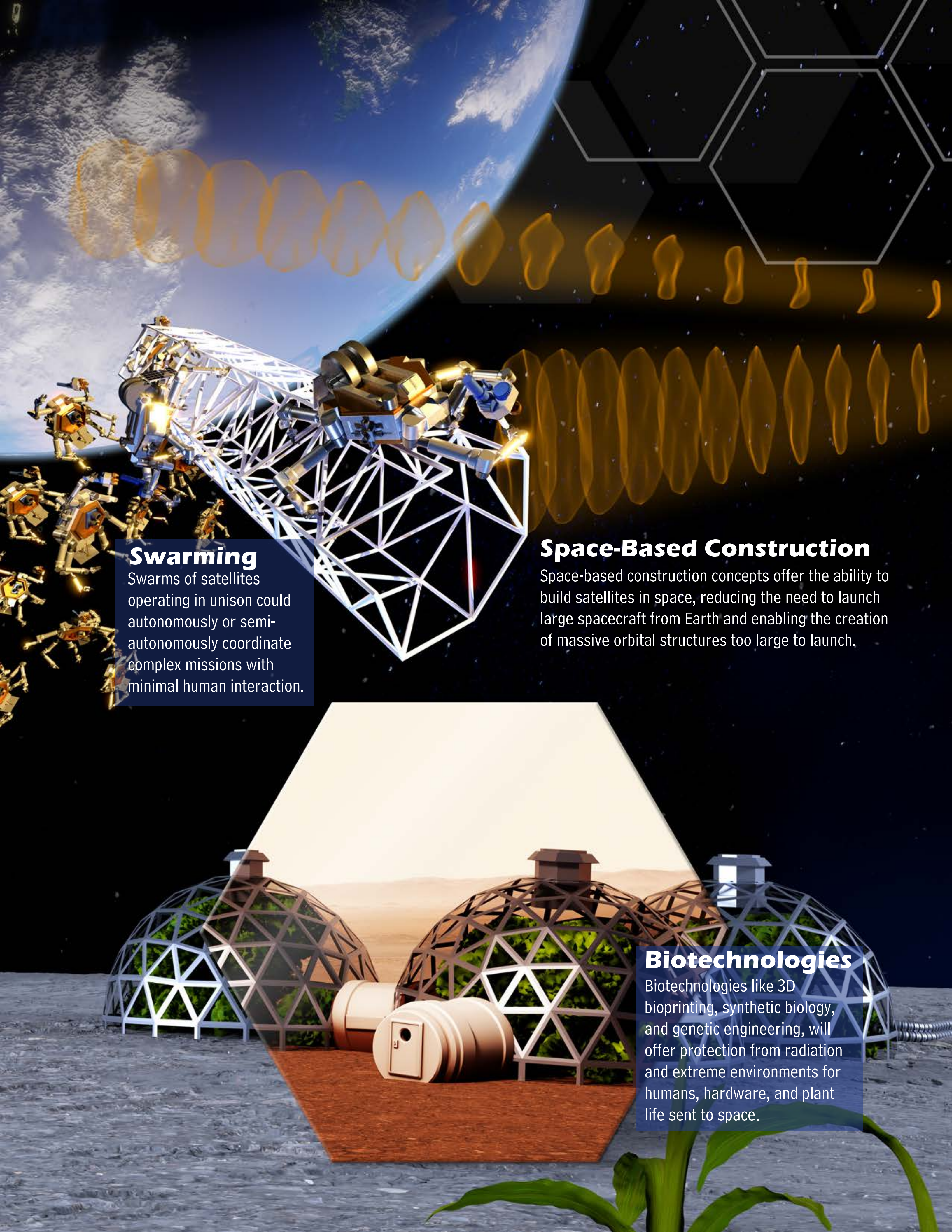
Breakthroughs in robotics will enable countless applications, including satellite repair, debris removal, and mining in space.

3D Printing

3D printing will allow satellite operators to manufacture satellites and construct human habitats in space, potentially reducing launch costs and dependence on supplies from Earth.

Debris Removal

Debris removal concepts offer new opportunities to capture and move orbital objects.



Swarming

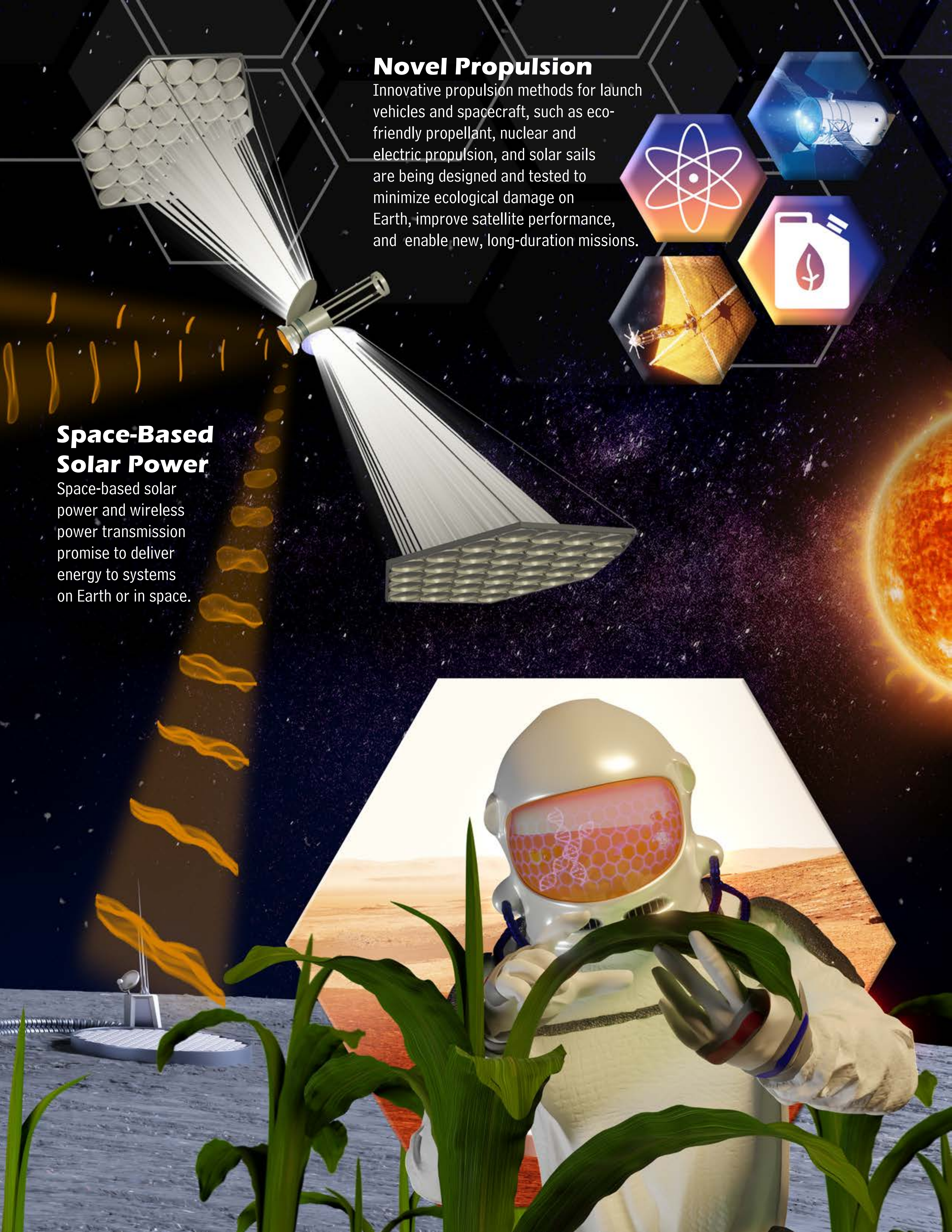
Swarms of satellites operating in unison could autonomously or semi-autonomously coordinate complex missions with minimal human interaction.

Space-Based Construction

Space-based construction concepts offer the ability to build satellites in space, reducing the need to launch large spacecraft from Earth and enabling the creation of massive orbital structures too large to launch.

Biotechnologies

Biotechnologies like 3D bioprinting, synthetic biology, and genetic engineering, will offer protection from radiation and extreme environments for humans, hardware, and plant life sent to space.



Novel Propulsion

Innovative propulsion methods for launch vehicles and spacecraft, such as eco-friendly propellant, nuclear and electric propulsion, and solar sails are being designed and tested to minimize ecological damage on Earth, improve satellite performance, and enable new, long-duration missions.

Space-Based Solar Power

Space-based solar power and wireless power transmission promise to deliver energy to systems on Earth or in space.

PRESERVING SPACE ACCESS

Our future will be defined by innovations in the space domain. We will increasingly value satellites and the services they provide to improve our local communities, grow our economies, advance scientific progress, and keep us safe. However, space developments will continue to introduce new challenges to global security and prosperity.

The expanding utility of space systems has extended the boundaries of conflict and exacerbated the world's vulnerability to dangers in the space environment. Actors seeking to challenge international order will have access to systems capable of devastating and lasting impacts on our progress on Earth and in space.

As humanity expands its space presence, understanding the threats and risks of operating in space will be fundamental to preserving access and peaceful competition for generations to come.