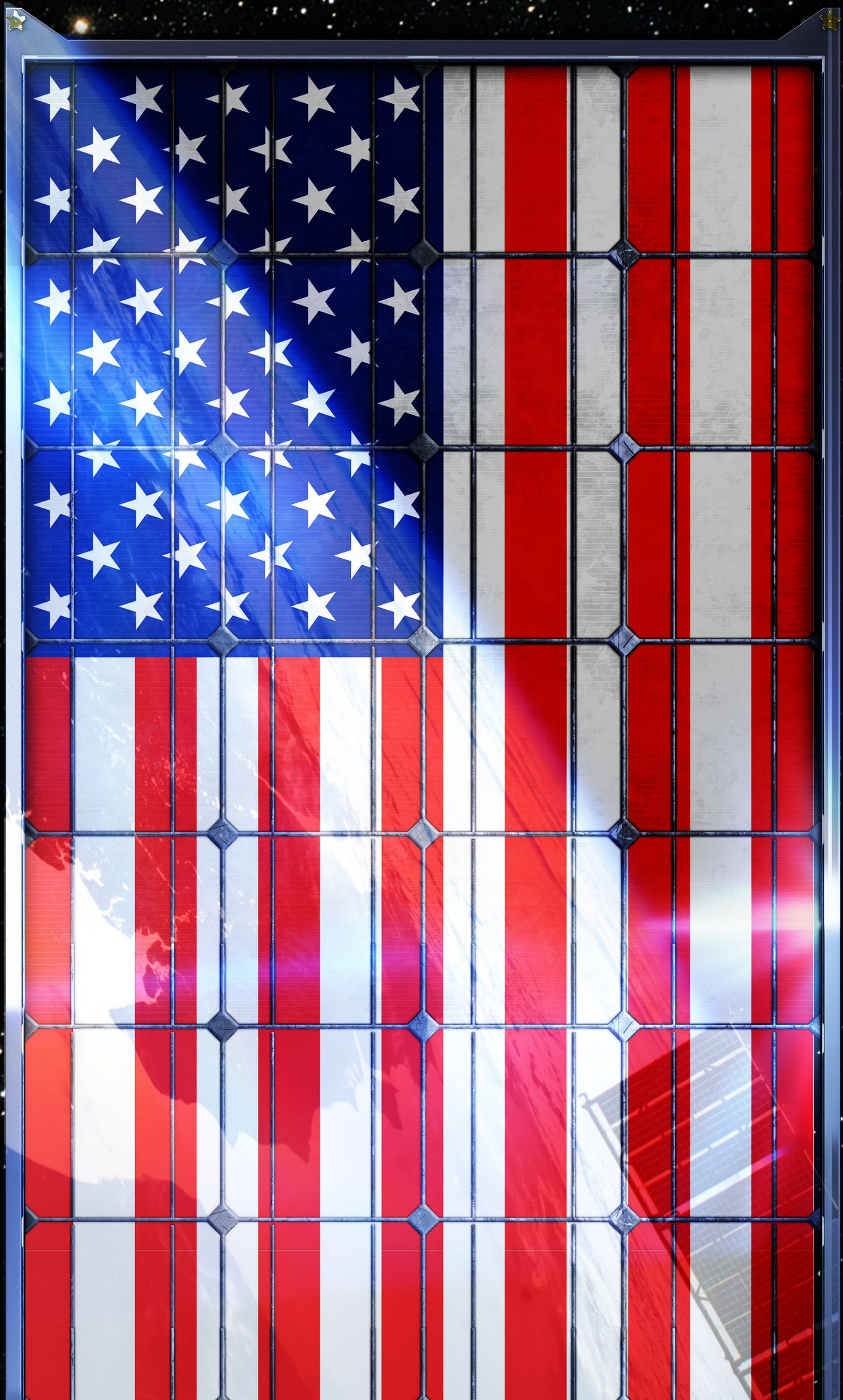
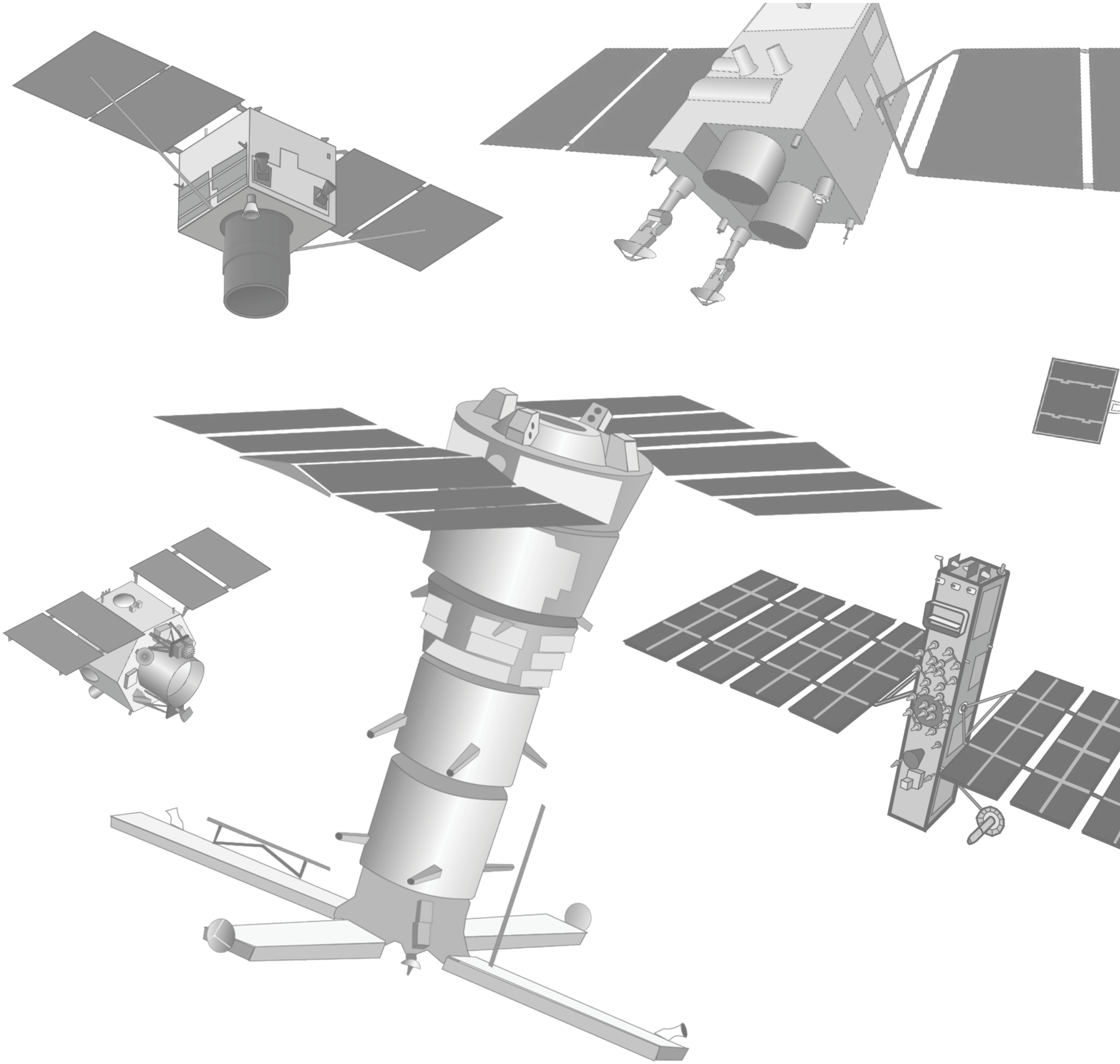
A PRODUCT OF THE NATIONAL AIR AND SPACE INTELLIGENCE CENTER

COMPETING IN SPACE





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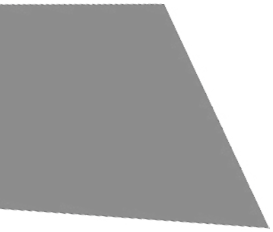
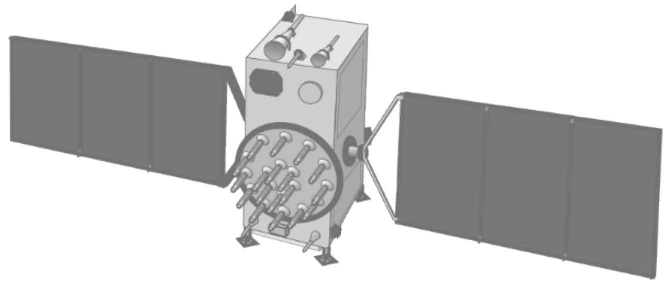
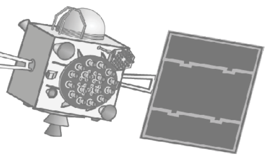
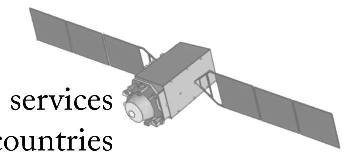




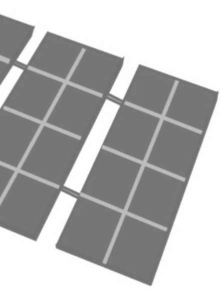
COMPETING IN SPACE



After the Cold War, the United States dominated space. Over the past two decades, an emergent China and a resurgent Russia developed advanced technologies that eroded our advantage. Foreign competitors are integrating advanced space and counterspace technologies into warfighting strategies to challenge U.S. superiority and position themselves as space powers.

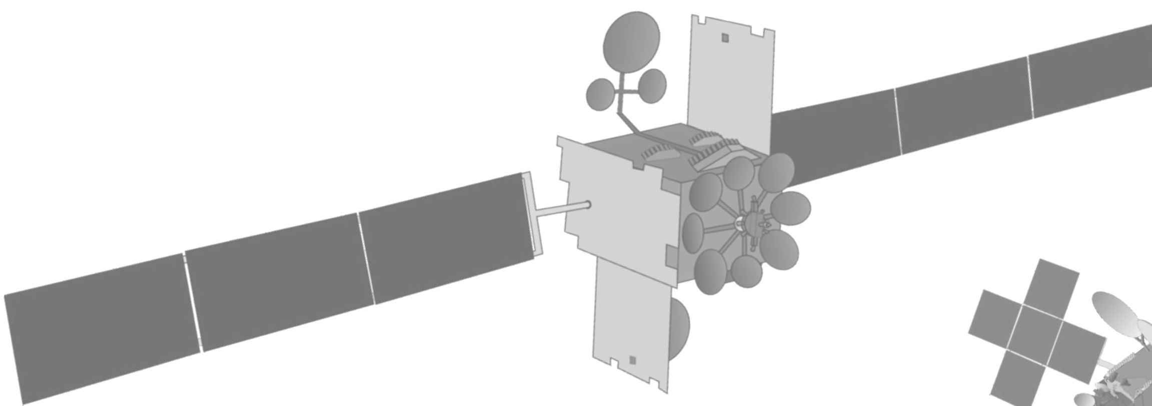


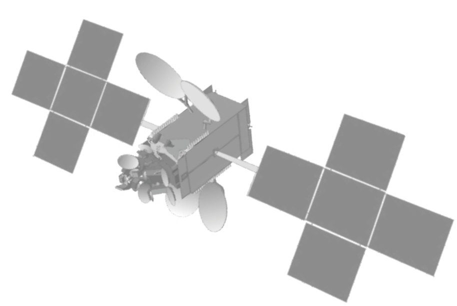
Rising demand and declining cost for high-quality space-based services have increased the number of systems in space and the number of countries or multinational organizations that can access space capabilities. The number of foreign reconnaissance and remote sensing satellites has tripled from 100 to 300. Foreign satellite communications, navigation, and launch services are increasingly available to competitors. China and Russia remain leaders in space launch and space-based services.



Potential adversaries are developing and proliferating anti-satellite capabilities supported by an array of sensors to characterize and target space systems. Multiple attack options (e.g., cyber, electronic, or directed-energy weapons; anti-satellite missiles; or space-based weapons) enable potential adversaries to achieve a range of damaging effects.

This publication identifies developing trends in the space domain, details growing challenges posed by foreign space assets, characterizes threats to U.S. and allied use of space, and presents an outlook for the evolution of these trends.





*Space systems shown throughout this document are not to scale

Space is Contested, Congested, and Competitive

Competitors are developing technologies that contest U.S. and allied space systems and services. Reduced costs of space technologies and launch services have supported explosive growth in the number of objects in space and enabled numerous countries to acquire advanced technologies, boosting their own space industries and countering U.S. competitive advantage.

Space-Based Capabilities are Vulnerable

The global economy and civilian population are dependent on space systems. U.S. and allied militaries use space systems to connect, warn, guide, and inform decisions across the entire spectrum of conflict. Adversaries are aware of the advantages space services provide and actively seek capabilities to deny them.

Space is Increasingly Militarized

Both China and Russia are developing new space capabilities to achieve military goals and reduce their reliance on U.S. space systems. Through military reforms, China and Russia have organized new military forces devoted to the employment of space and counterspace capabilities and regularly integrate them into military exercises. Meanwhile, these countries continue to develop, test, and proliferate sophisticated anti-satellite weapons to hold U.S. and allied space assets at risk.

International Norms Remain Elusive

Over the past decade, international forums have pursued legal frameworks for responsible conduct in space. To date, the international community has not achieved a global consensus on new laws or norms despite efforts to increase transparency in space operations, avoid deliberate debris-generating events (e.g., anti-satellite weapon tests, orbital collisions), and prevent the placement of weapons in space.

China and Russia continue to endorse a draft "Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects (PPWT)." While this draft promotes "no first placement" of weapons in space, it fails to address a variety of anti-satellite weapons and lacks meaningful verification mechanisms. Furthermore, despite publicly insisting that space is a peaceful domain, these competitors are continuing development of several anti-satellite weapons.

Technology Proliferation Driving the Increase in Competitive Space Actors

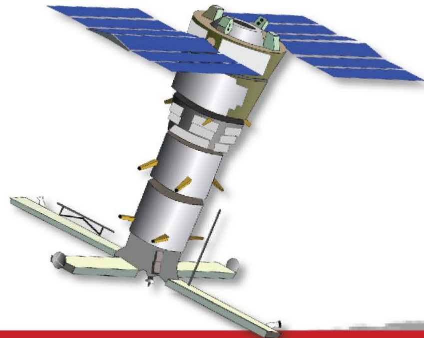
Historically, high cost and technical complexity limited space access to a select few space powers. Over the past few decades increased commercialization and affordability of space technologies means satellites are no longer restricted to a few space powers. Today, over 50 countries and multinational organizations own or operate space assets, while China and Russia maintain the largest foreign space system fleets.

TRENDS IN SPACE

Space technologies play a fundamental role in the day-to-day affairs of the public, businesses, governments, and militaries worldwide. Satellite remote sensing, communications, and navigation systems enable real-time access to information necessary to connect people, operate a global economy, respond to natural disasters, and support military operations. While technological advancement in the space domain has created new opportunities, it has also created new risks and vulnerabilities across these sectors. For the U.S. and its allies, maintaining the leading edge in warfighting requires understanding evolving trends in the space domain.

Countries or Multinational Organizations that Own or Operate Space Assets on Orbit

38 COUNTRIES

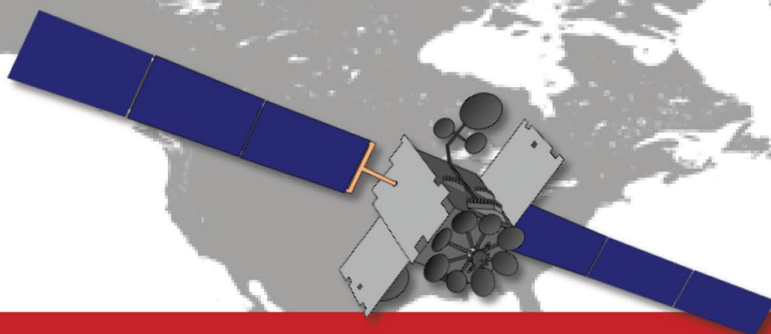


Intelligence, Surveillance, Reconnaissance, and Remote Sensing

SATELLITES
353
122
23
168

666

45 COUNTRIES



Communications

SATELLITES
391
38
81
280

790

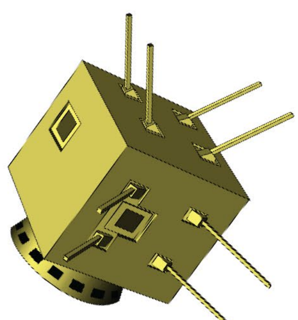
6 COUNTRIES

Navigation

SATELLITES
31
28
28
34

121

38 COUNTRIES

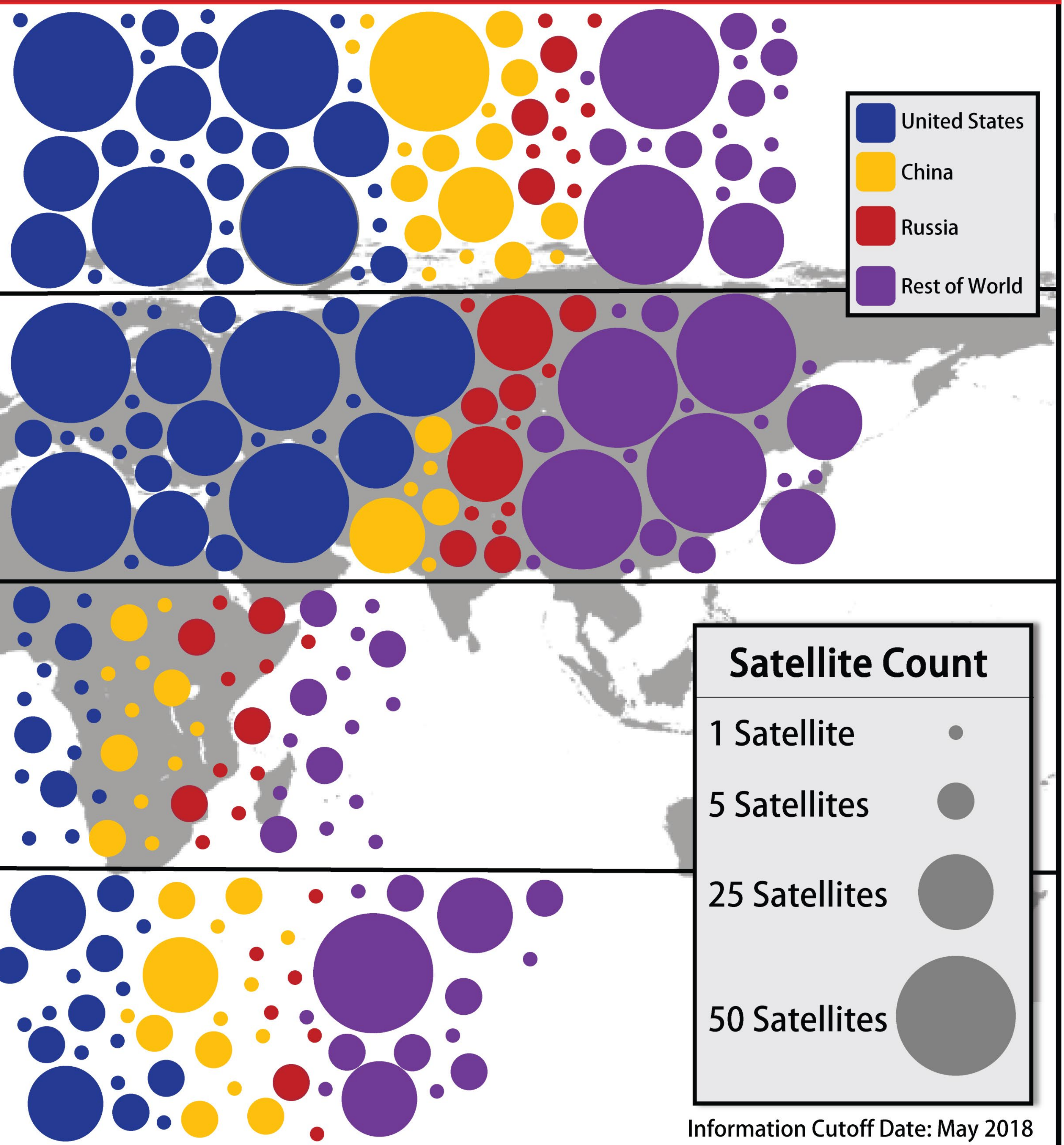


Scientific, Technology Development, or Other

SATELLITES
94
62
11
136

303

SPACE ASSETS ON ORBIT



Data does not include countries or multinational organizations without indigenous satellites that use space services secured via commercial agreements, governmental partnerships, or non-traditional means.

SPACE APPLICATIONS

Space-based remote sensing, communications, and navigation systems are used for a variety of commercial, civil, and military applications. Our competitors have recognized the benefits of investment in space technologies, from the international prestige that comes with technological and spaceflight achievements, to the economic rewards inherent with being a space services provider. Additionally, the U.S. military's unparalleled advantages in space-integrated warfare across multiple theaters has spurred foreign countries to pursue and adopt their own space-integrated military capabilities.

Reconnaissance and Remote Sensing

Reconnaissance and remote sensing satellites collect images, electronic emissions, and other data across the globe to meet a variety of customer needs. There are a number of civil and commercial applications for remote sensing data, 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 remote sensing satellites numbered nearly 100 -- by mid-2018, that number reached over 300.

In addition to civil and commercial uses, these satellites provide military and intelligence collection capabilities. They have reduced the ability of all countries to perform sensitive military activities undetected. The images on the right show Chinese commercial imagery of several sensitive U.S. locations.

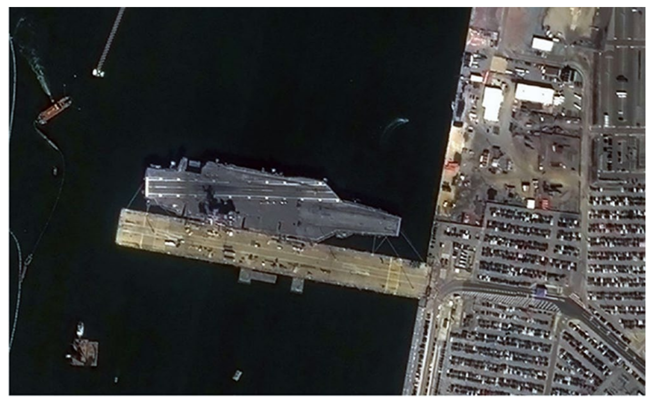
China and Russia have the largest remote sensing satellite fleets outside the U.S. Additionally, the Chinese People's Liberation Army (PLA) and the Russian Ministry of Defense are reportedly capable of employing their respective civil and commercial remote sensing satellites to supplement military-dedicated capabilities.

As of May 2018, the Chinese reconnaissance and remote sensing fleet consisted of more than 120 satellites designed to collect data for civil, commercial, or military owners and operators. Reportedly, the PLA owns and operates about half of these systems, most of which could support monitoring, tracking, and targeting of U.S. forces. These satellites also allow the PLA to maintain situational awareness of China's regional rivals (e.g., India and Japan) and potential regional flashpoints (e.g., Korea, Taiwan, and the East and South China Seas).

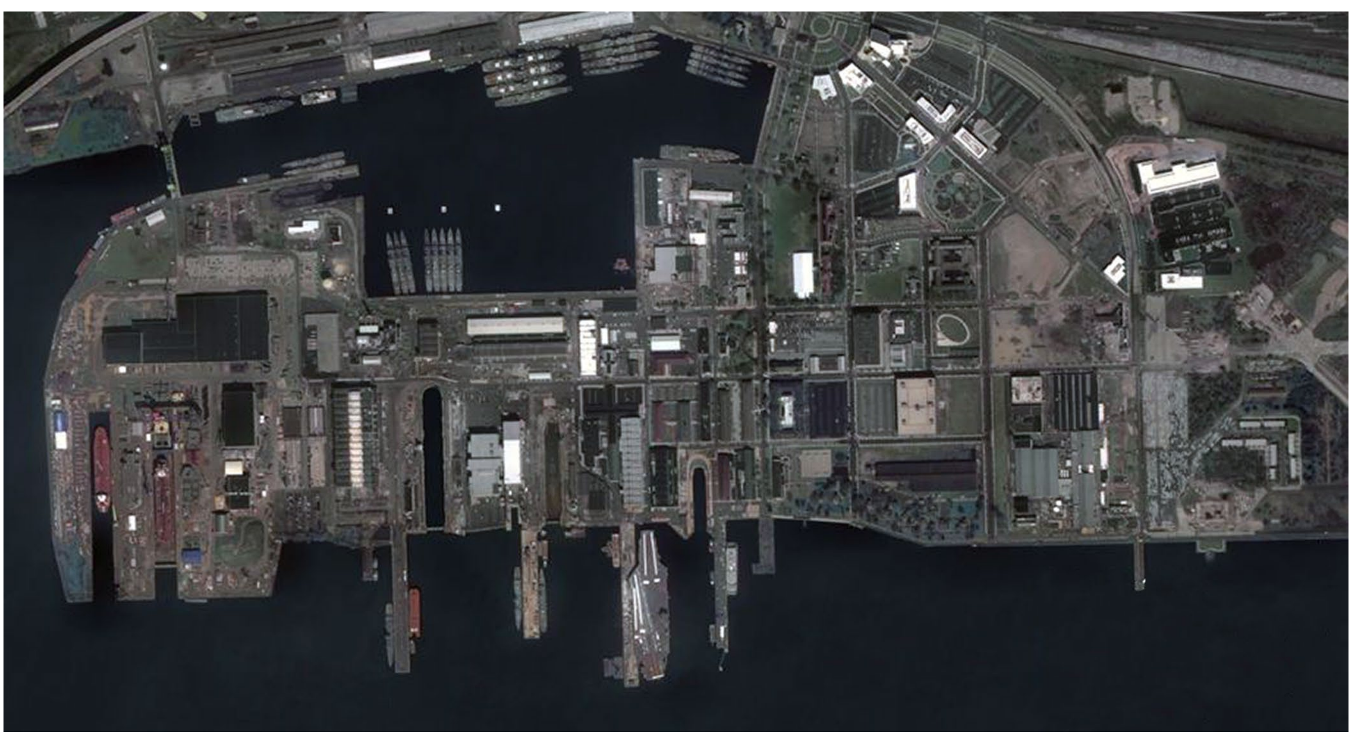
Russia has sought to sustain its reconnaissance and remote sensing satellite fleet despite funding shortfalls, economic sanctions, and technological setbacks since the end of the Cold War. This fleet contains at least 20 satellites, half reportedly owned and operated by the Russian Ministry of Defense. Despite possessing fewer satellites, it is widely accepted that the capabilities of individual Russian reconnaissance and remote sensing satellites exceed the individual capabilities of Chinese satellites. For Russia, these systems reportedly support ongoing military operations in Syria, but can also monitor U.S. and allied forces operating globally.

U.S. commercial satellite imagery companies are bound by a variety of regulatory mechanisms. Foreign commercial imagery companies, some of which are wholly or partially state-owned, are under different regulations. Some foreign satellite imagery companies may sell images or information about U.S. or allied national security interests to hostile non-state actors or foreign powers.

Aircraft at Nellis Air Force Base, NV



U.S. Aircraft Carrier at Naval Station Norfolk, VA



Naval Inactive Ship Maintenance Facility in Philadelphia, PA

Satellite Communications

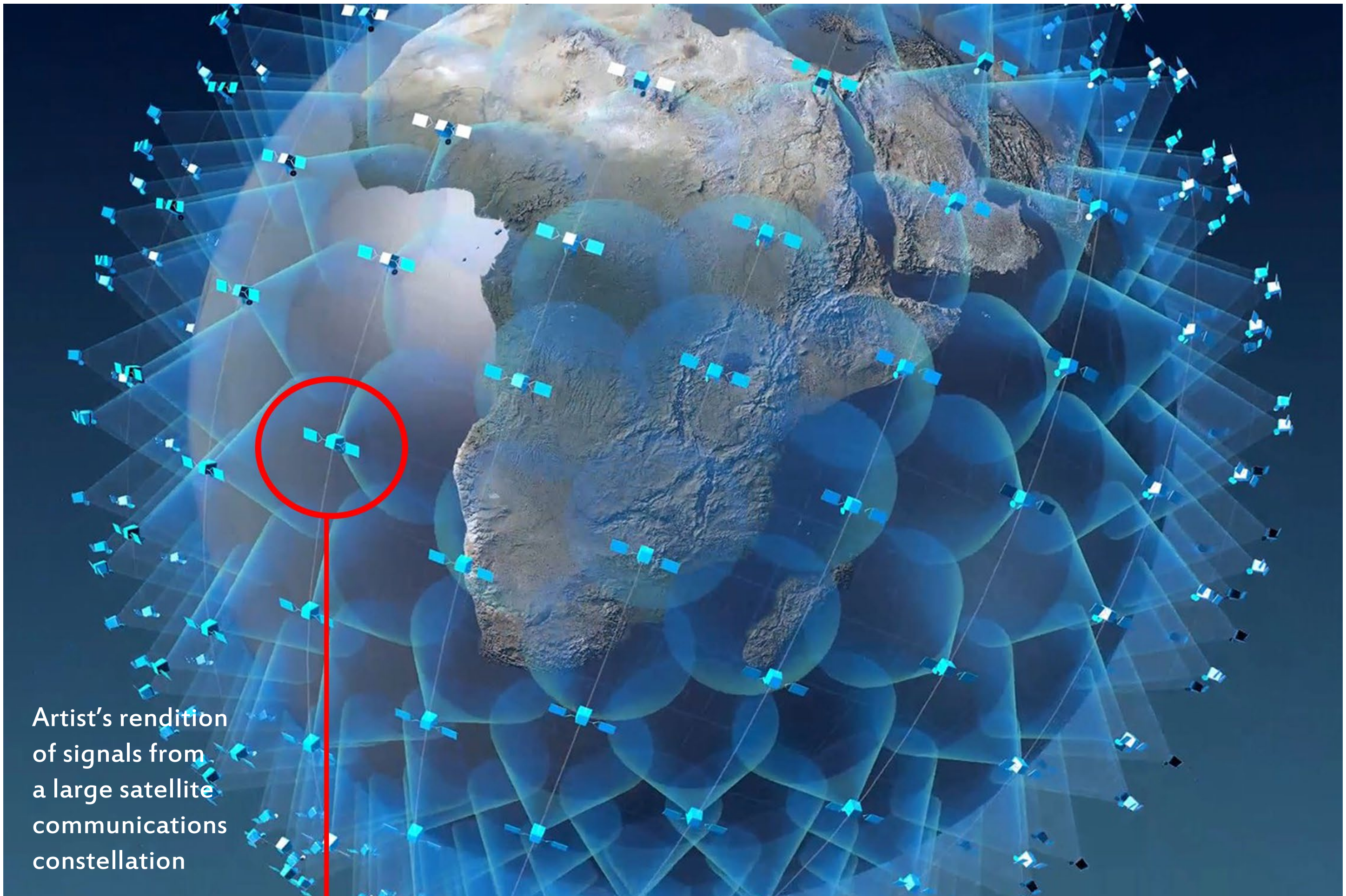
Global communications networks rely on satellite communications systems for worldwide voice communications, television broadcast, broadband internet, mobile services, and data transfer. Satellite communications systems are rapidly deployable, expandable, and affordable, and the demand for services continues to rise worldwide.

Today, most communications satellites operate in geosynchronous orbit more than 22,200 miles 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, satellite communications service providers have proposed future constellations of thousands of satellites in low and medium orbits. Better technology promises greater affordability, efficiency, and flexibility for civil, government, and military users worldwide.

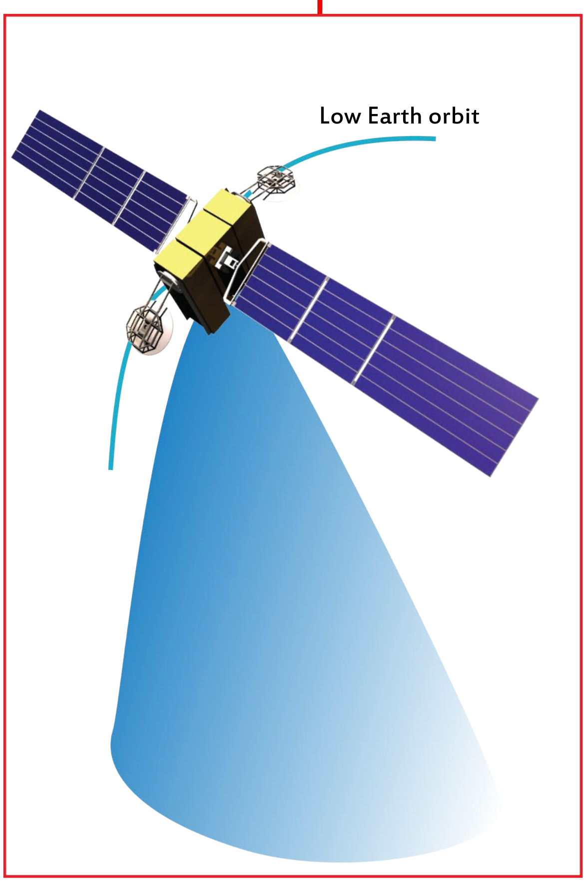
Many countries operate satellite communications systems and lease commercial services for official government communications worldwide. Competitors to the U.S. rely on these systems for military command and control, particularly in places inaccessible by terrestrial communications.

China plans to expand services beyond Asia by providing satellite communications to users worldwide and exporting domestically developed systems. China is testing multiple next-generation capabilities, such as the world's first quantum communications satellite, and plans to develop at least three new constellations.

Russia maintains a satellite communications fleet that provides resilient services to civil, government, and military users within its borders and worldwide. Russia has taken steps to modernize its satellite communications systems, but continues to lag behind other worldwide providers.



Artist's rendition of signals from a large satellite communications constellation



The low cost of launching and operating satellites in low Earth orbit makes it particularly attractive for space service providers. Several proposed large constellations of communications satellites in low Earth orbit, combined with the rapid growth of intelligence, surveillance, and reconnaissance assets in this orbit, threaten to congest the space environment nearest to Earth. This congestion presents a higher potential for orbital collisions and increases the need for timely and thorough space situational awareness.

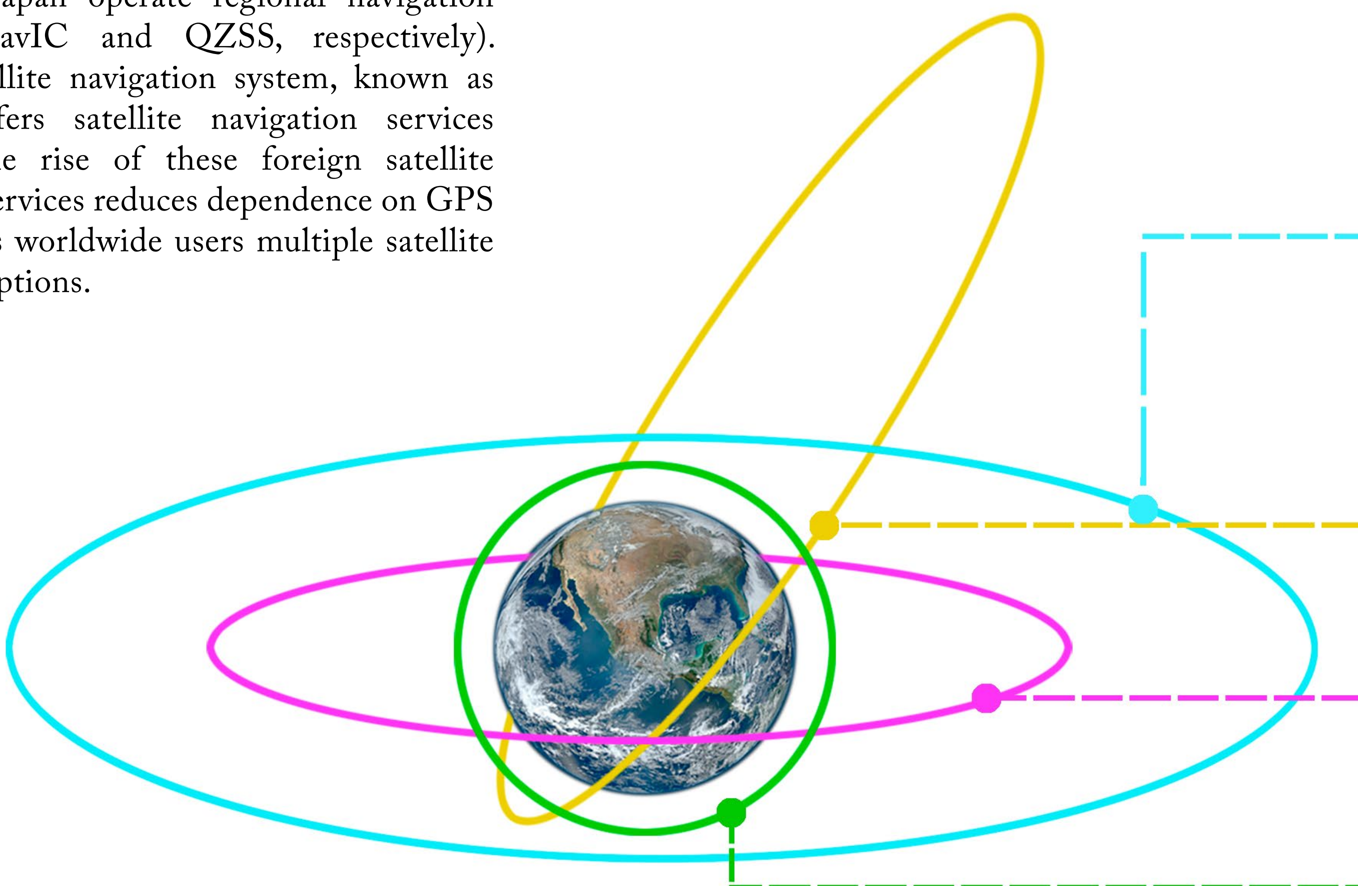
Satellite Navigation

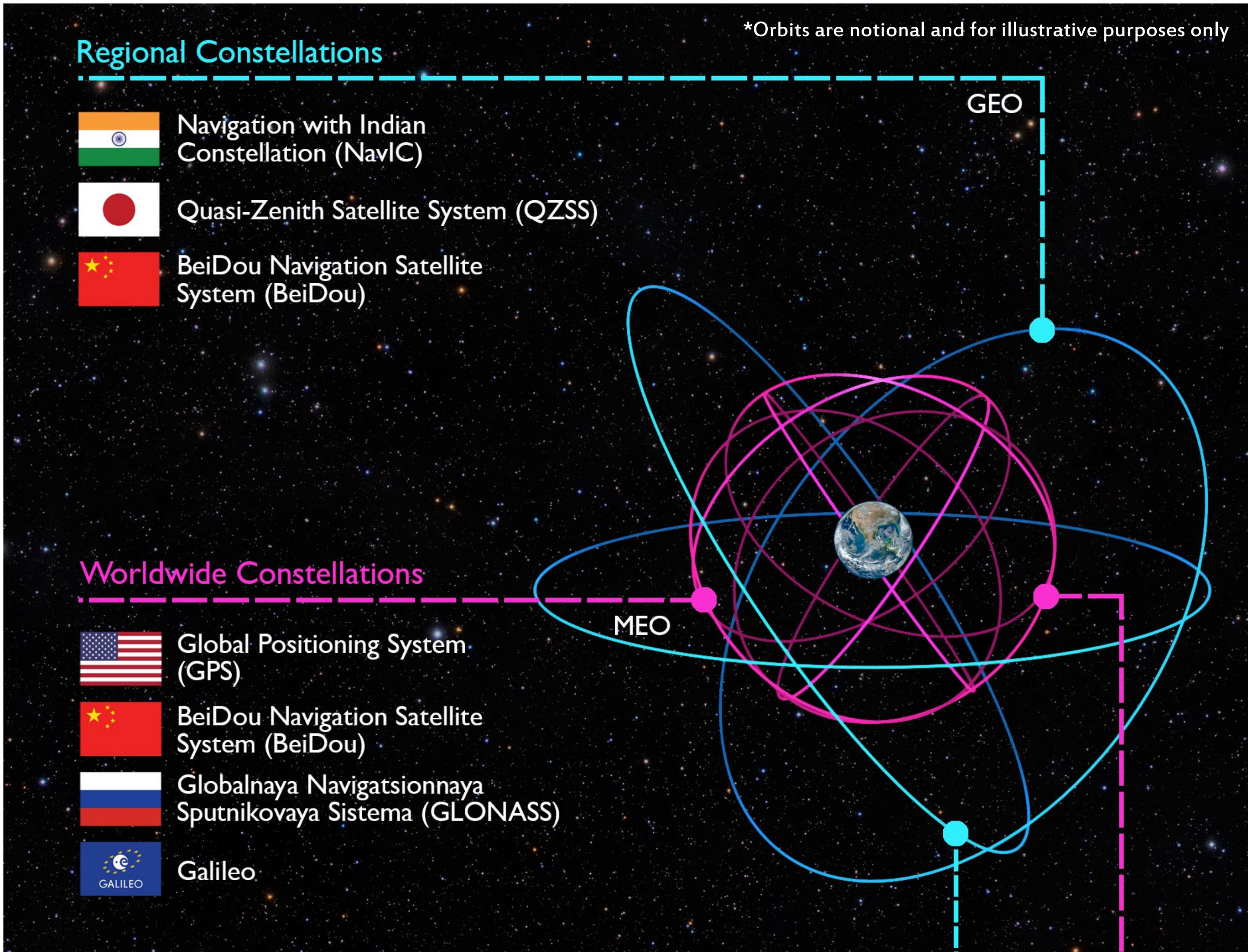
The 1991 Gulf War and subsequent U.S. military operations illustrated the value of the U.S. GPS satellite navigation system for troop movement, force tracking, and precision munition delivery. This prompted other countries to develop their own satellite navigation systems. Today, satellite navigation services are critical to military and civilian users worldwide, with applications in navigation, munitions guidance, communications, agriculture, banking, and power supply. Advances in satellite navigation technology offer foreign countries improved military situational awareness and accuracy in precision-guided munitions.

Russia and the European Union currently operate worldwide satellite navigation systems (GLONASS and Galileo, respectively), while India and Japan operate regional navigation systems (NavIC and QZSS, respectively). China's satellite navigation system, known as BeiDou, offers satellite navigation services in Asia. The rise of these foreign satellite navigation services reduces dependence on GPS and provides worldwide users multiple satellite navigation options.

In 2017, China began deployment of its next-generation, worldwide BeiDou constellation, scheduled for full operation in 2020. The BeiDou constellation also offers text messaging and user tracking through its Short Message Service, to enable mass communications for specific BeiDou users and provide additional command and control capabilities for the Chinese military.

Russia's GLONASS constellation provides worldwide satellite navigation services. Following the constellation's deterioration in the late 1990s, Russia committed to reconstituting GLONASS during the 2000s. With full capacity regained in 2011, Russia now launches satellites as needed to maintain the constellation while developing next generation GLONASS satellites.





Geosynchronous Earth orbit (GEO): 35,786 km (22,200 mi)

- Continuous coverage over a very large region, may be inclined for coverage of high latitudes
- Satellites over the equator appear to hover above a single spot on the Earth's surface
- Primarily used by communications satellites

Highly elliptical orbit (HEO): Approximately 40,000 km (25,000 mi) at highest point

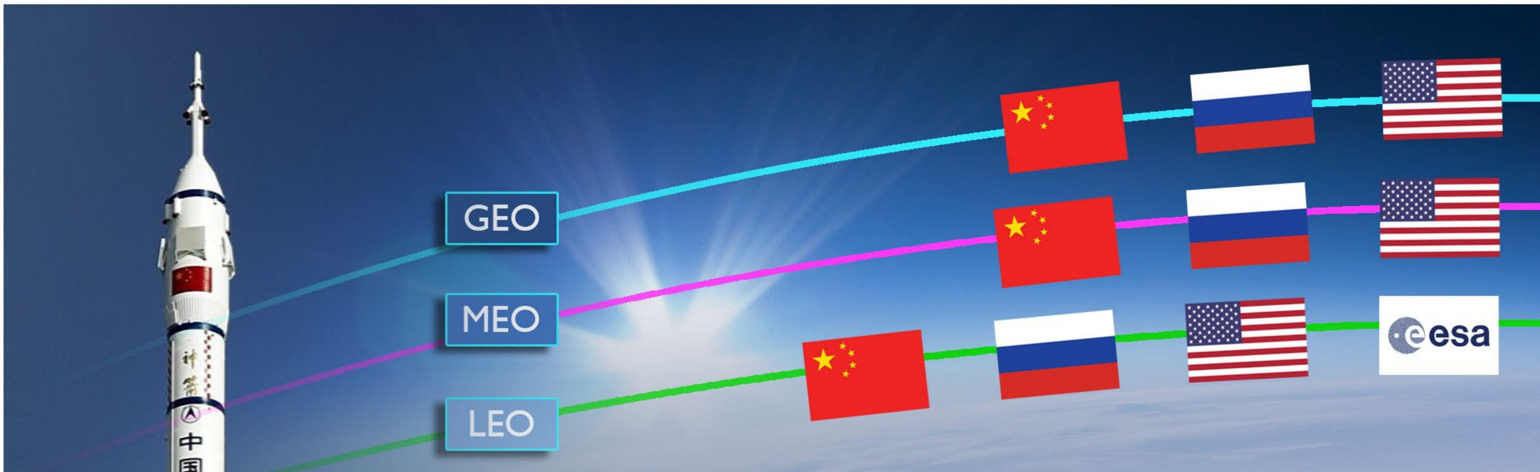
- Provides coverage of high latitudes and Arctic region
- Primarily used by communications satellites

Medium Earth orbit (MEO): 2,000 to 35,000 km (1,200 to 22,000 mi)

- Intermittent coverage over a large region; requires multiple satellites for persistent coverage
- Almost solely used by navigation satellites

Low Earth orbit (LEO): Up to 2,000 km (1,200 mi)

- Revolves around the Earth in ~ 90 minutes with very limited coverage
- Often used by remote sensing and scientific satellites

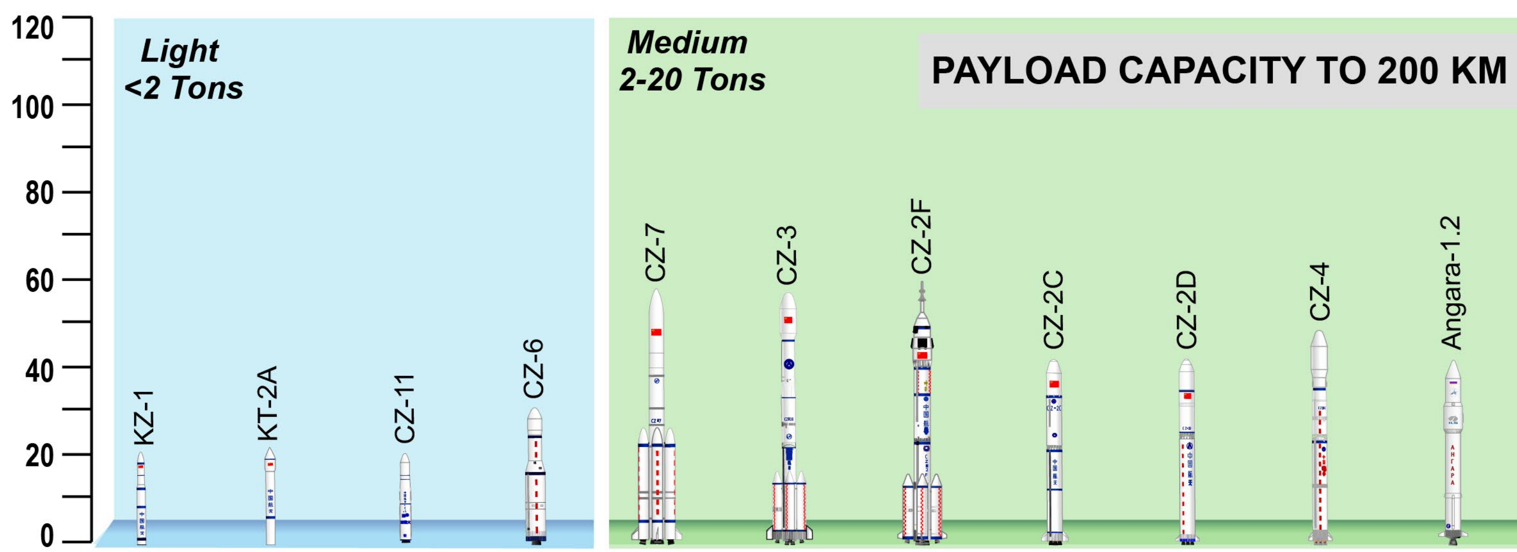


Space Launch

Since the start of the "Space Race" in 1957, the number of countries capable of placing satellites in space has grown beyond the U.S. and former Soviet Union. Today, nine countries and one international organization can independently launch spacecraft: China, India, Iran, Israel, Japan, Russia, North Korea, South Korea, the U.S., and the European Space Agency.

Many countries developed space launch capabilities to compete in the international market or to advance national security strategies that require domestic access to space. Iran and North Korea maintain independent space launch capabilities that could also test ballistic missile technologies. The graphic above indicates the global spacefaring nations' capabilities to launch satellites into different orbits.

China and Russia are updating their space launch capabilities to increase responsiveness, reduce launch timelines, improve manufacturing efficiencies, and support future human spaceflight and deep space exploration missions. The graphic below depicts Chinese and Russian light-, medium-, heavy-, and proposed super heavy-lift space launch vehicles.

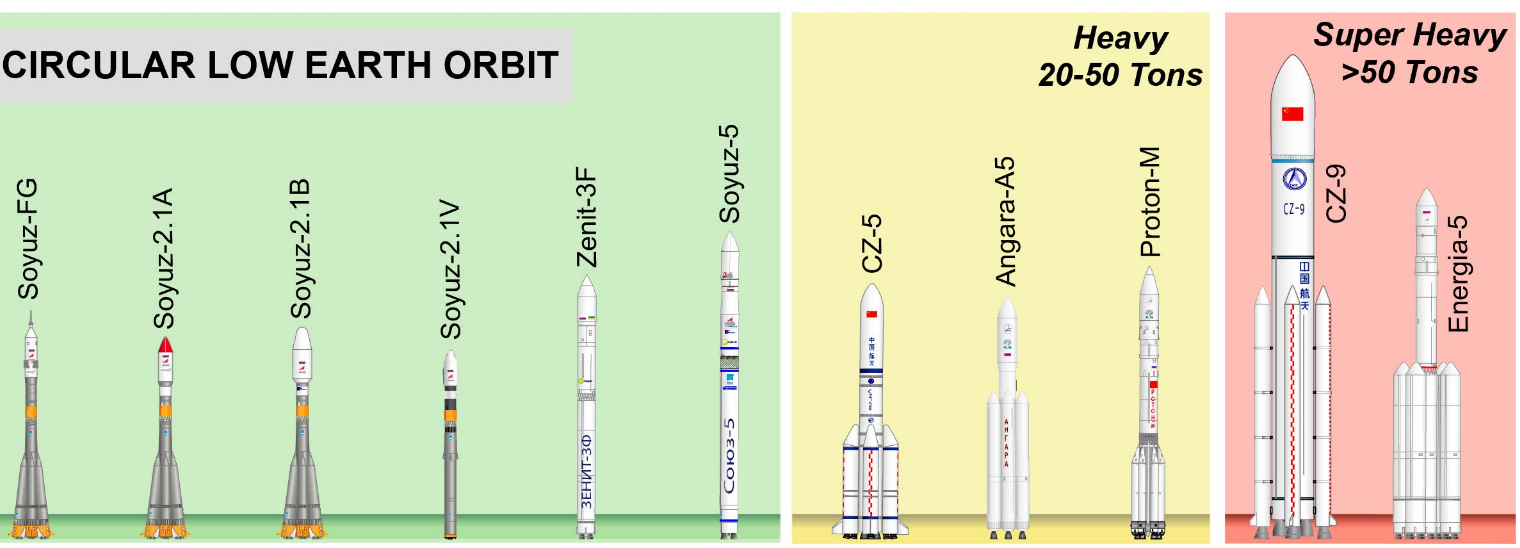


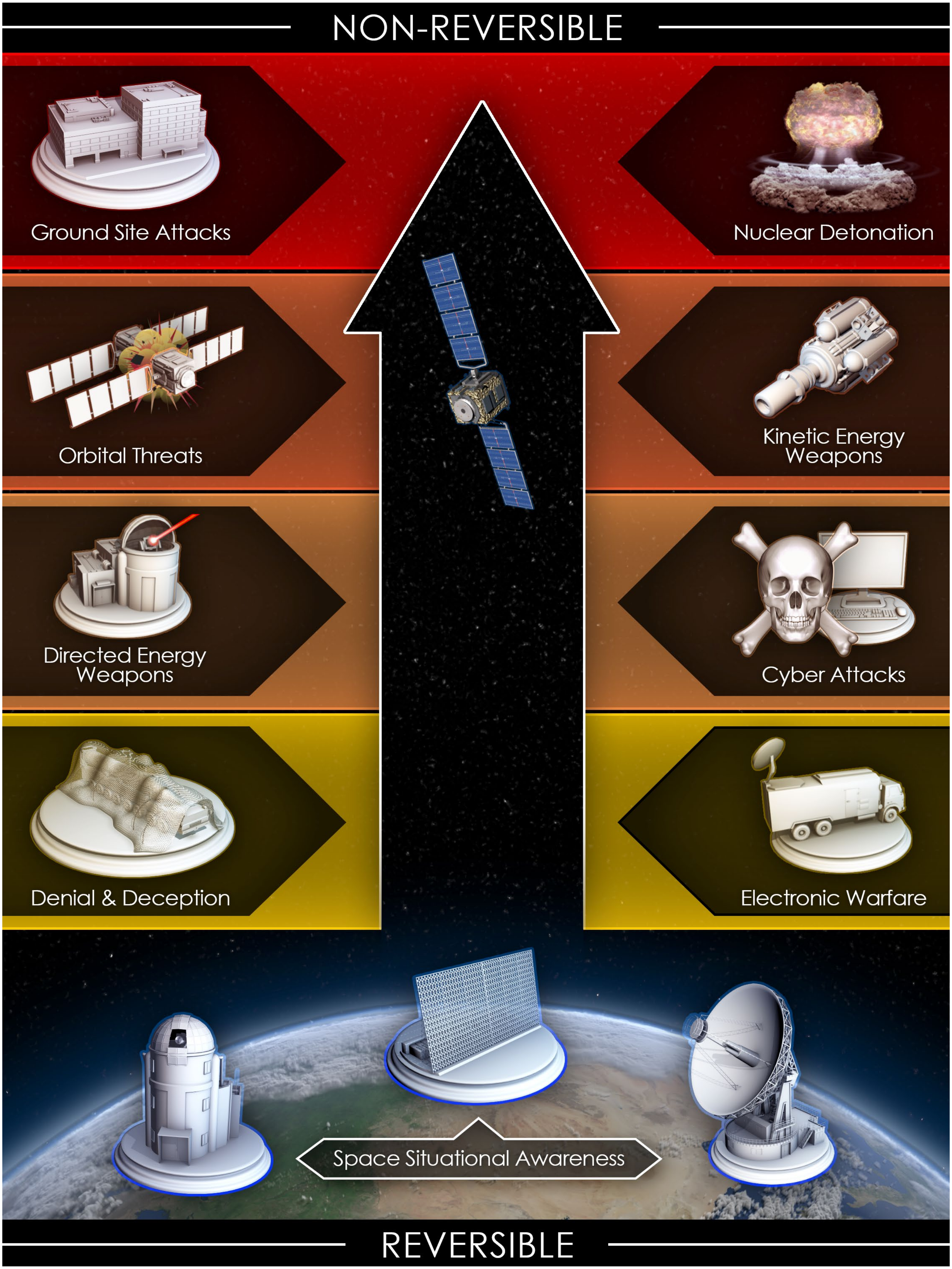
Capabilities

China and Russia are updating their medium- and heavy-lift launch fleets to include new, modular launch vehicles with common designs that increase manufacturing efficiency, launch vehicle reliability, and overall cost savings for space launches.

China has developed and fielded light, quick response space launch vehicles capable of expedited launches. Compared to medium- and heavy-lift launch vehicles, quick response systems require little launch infrastructure, can relocate by road or rail, can be stored launch-ready for longer periods, but are only capable of launching small satellite payloads into low orbits. China designed quick response space launch vehicles to increase its attractiveness as a commercial small satellite launch provider and to rapidly reconstitute space capabilities in low Earth orbit during disasters or conflicts.

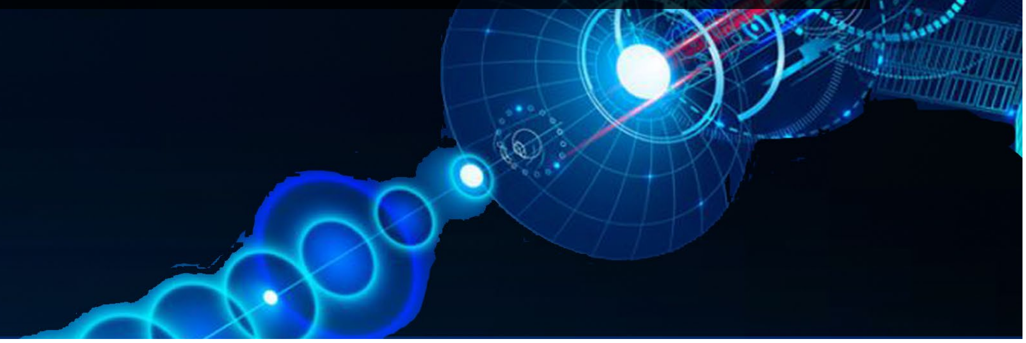
China and Russia are currently in the early stages of developing super heavy-lift space launch vehicles similar to the U.S. Space Launch System. These super heavy-lift vehicles could support future Chinese and Russian crewed lunar and Mars exploration missions.




NON-REVERSIBLE
Ground Site Attacks
Nuclear Detonation
Orbital Threats
Kinetic Energy Weapons
Directed Energy Weapons
Cyber Attacks
Denial & Deception
Electronic Warfare
Space Situational Awareness
REVERSIBLE

DENYING SPACE

Society increasingly depends on the services provided by satellites. What if GPS and other services were unreliable or unavailable? Police, firefighters, and paramedics, who rely on satellite navigation, would be slow or unable to respond in an emergency. Live news from across the country or the other side of the planet would no longer be available. Long-distance telephone, satellite television, and internet would be unavailable. Retail stores and gas stations could not communicate with banks to complete transactions. Many critical services and daily conveniences we rely on could be affected by weapons targeting our space services.



Potential adversaries are developing and proliferating a variety of weapons that could disrupt or deny civil and military space services. Although many of these weapons are intended to degrade space services temporarily, others can damage or destroy satellites permanently.

- Adversaries may jam global navigation and communications satellites used for command and control of naval, ground, and air forces, to include manned and unmanned vehicles.
- Weapons designed to target intelligence, surveillance, and reconnaissance capabilities may deny the ability to locate, monitor, track, and target the enemy. For example, lasers can temporarily or permanently blind imagery satellites and other strategic sensors.
- Adversaries may use anti-satellite missiles to shoot down satellites in low Earth orbit. China used an anti-satellite missile against its own defunct weather satellite in 2007. The result of a missile shooting down a satellite can produce debris that may threaten satellites in nearby orbits.
- A number of foreign countries are believed to be testing on-orbit, space-based anti-satellite technologies and concepts. China and Russia continue to conduct sophisticated on-orbit activities that may advance counterspace capabilities.
- Physical attacks against ground sites and infrastructure that support space operations can also threaten satellite services. Cyber capabilities could target space systems and supporting infrastructure.

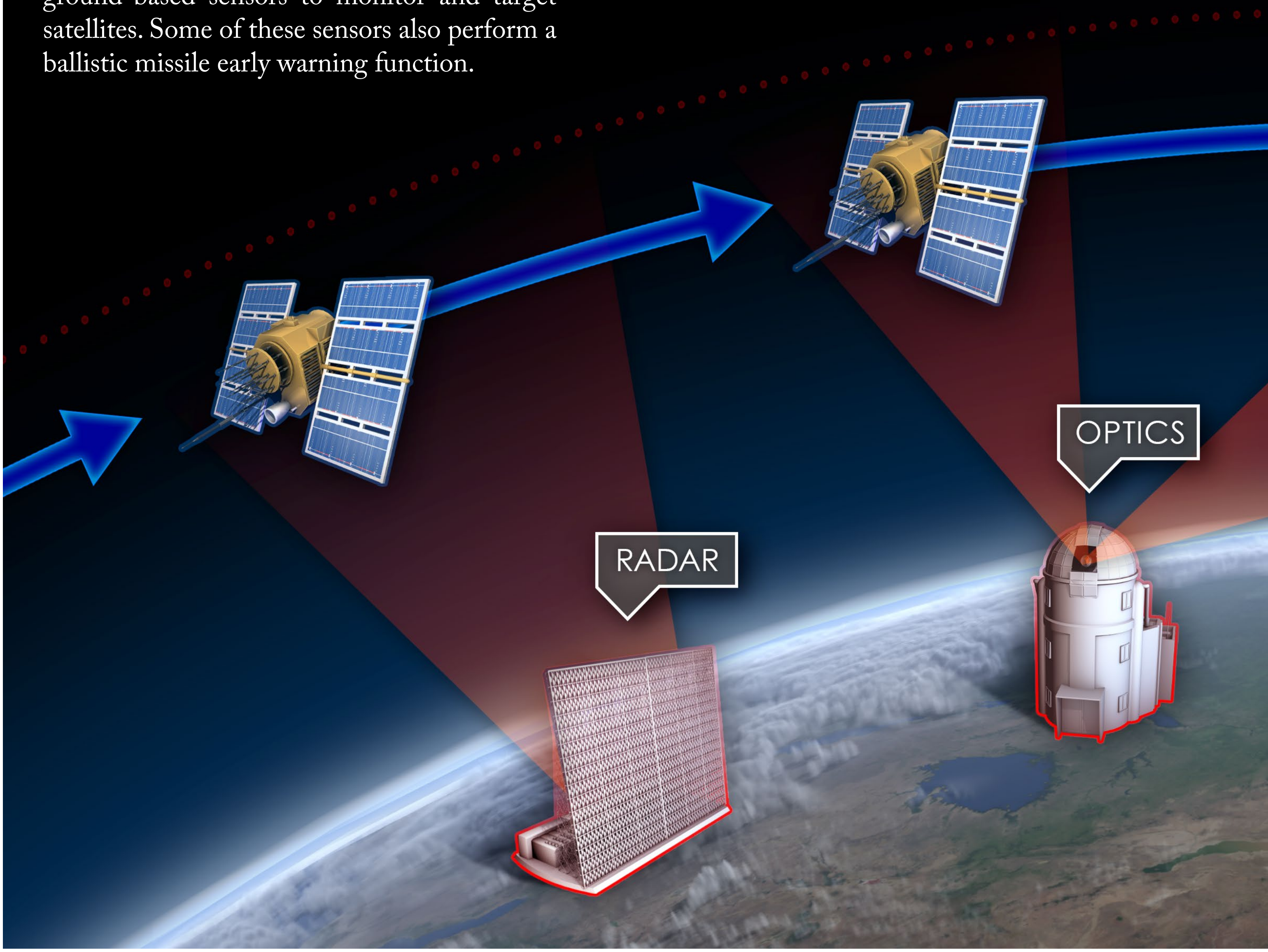
Space Situational Awareness

Terrestrial and space-based sensors search the sky for foreign satellites, chart their orbits, and determine the function and operational status. This is a continuous process, first in a sequence of steps that a potential adversary will use to target satellites, launch counterspace weapons, and assess the effectiveness of an attack. This image depicts the various categories of sensors used for space situational awareness (e.g., ground-based radars, telescopes, signals intercept antennas, and space-based sensors).

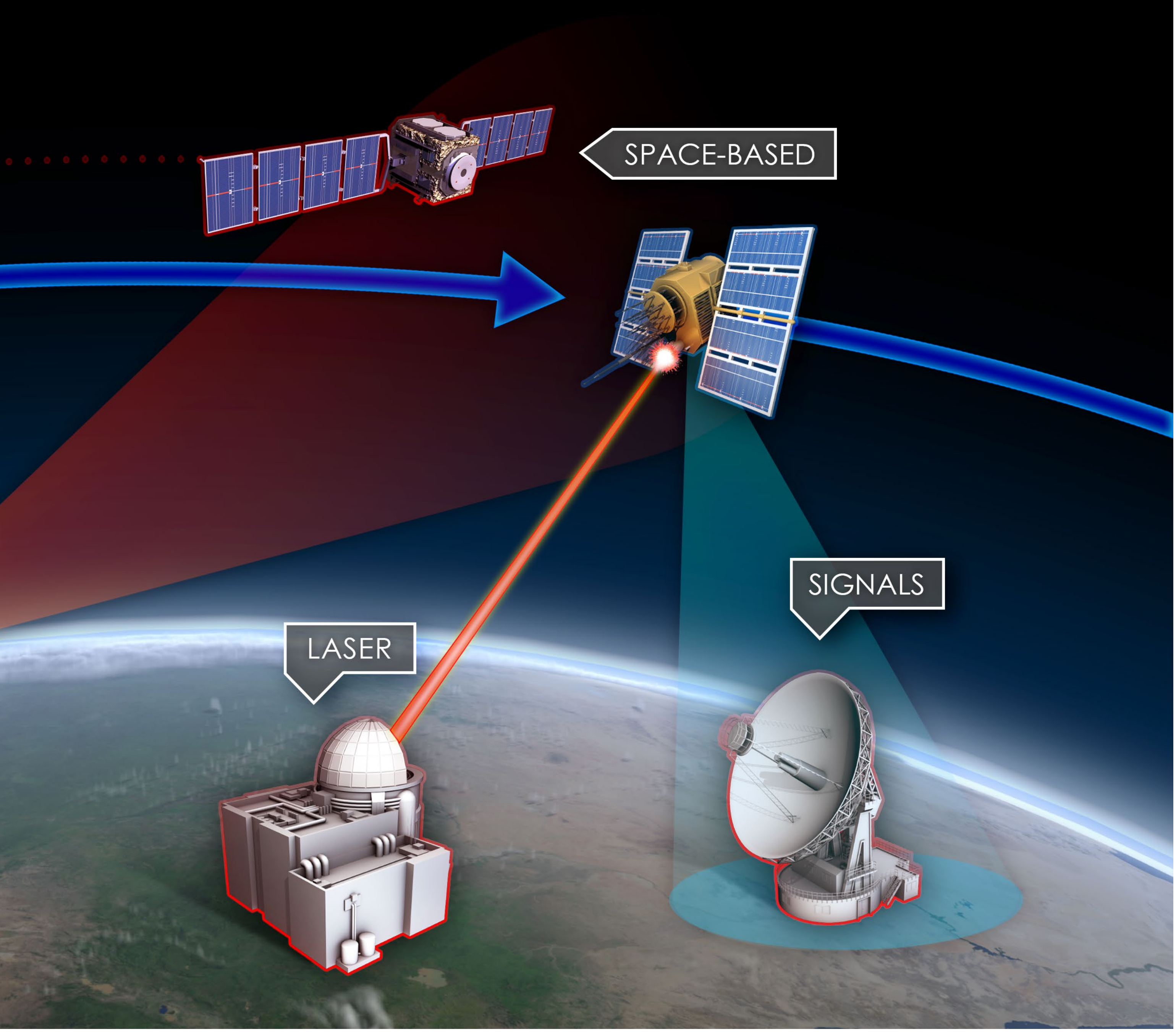
China and Russia both have large networks of ground-based sensors to monitor and target satellites. Some of these sensors also perform a ballistic missile early warning function.

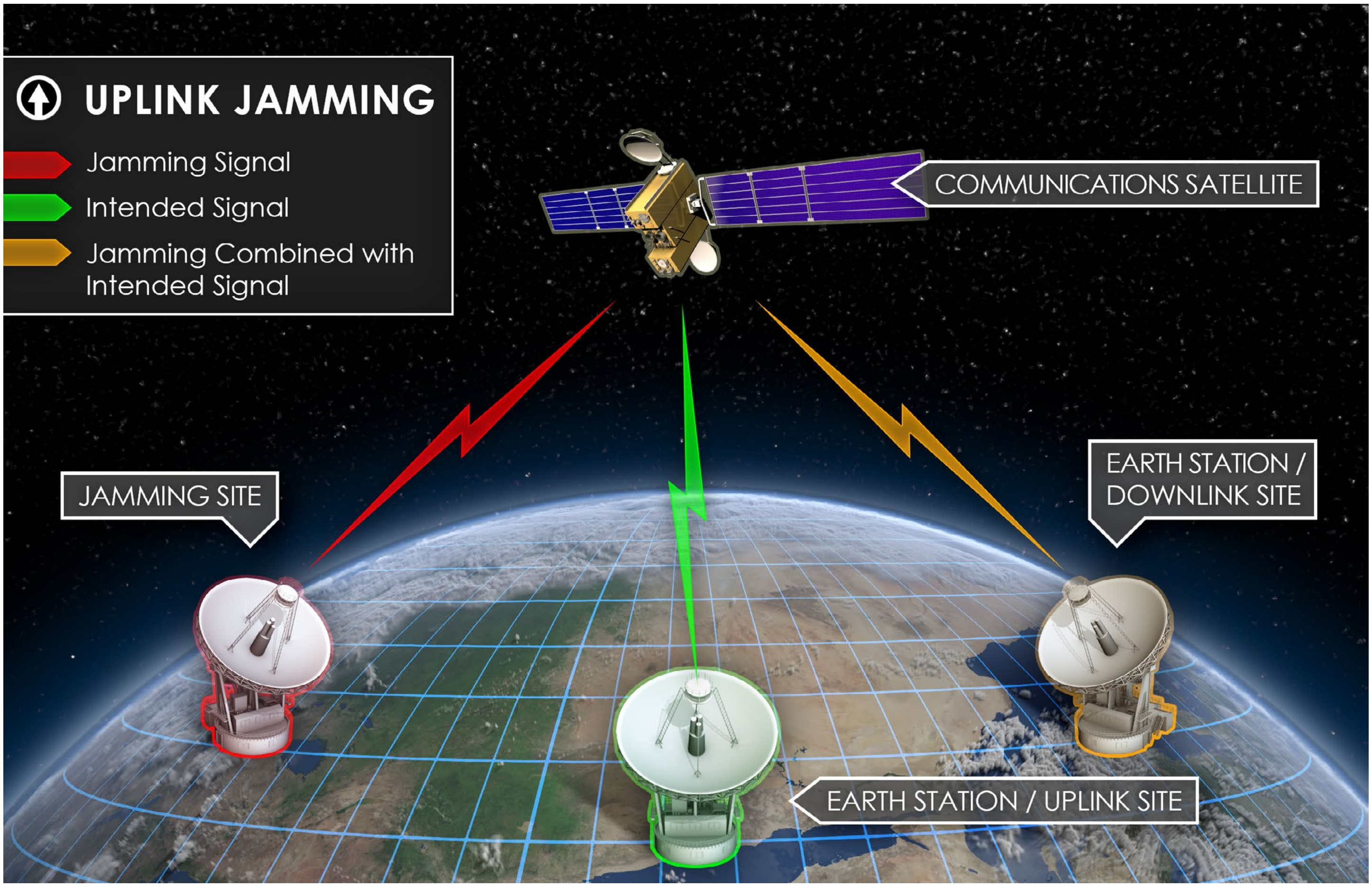
Space object surveillance and identification sensors can also enable foreign denial and deception programs. For instance, knowing when reconnaissance and remote sensing satellites pass overhead allows adversaries to coordinate the concealment of sensitive military capabilities or operations on the ground.

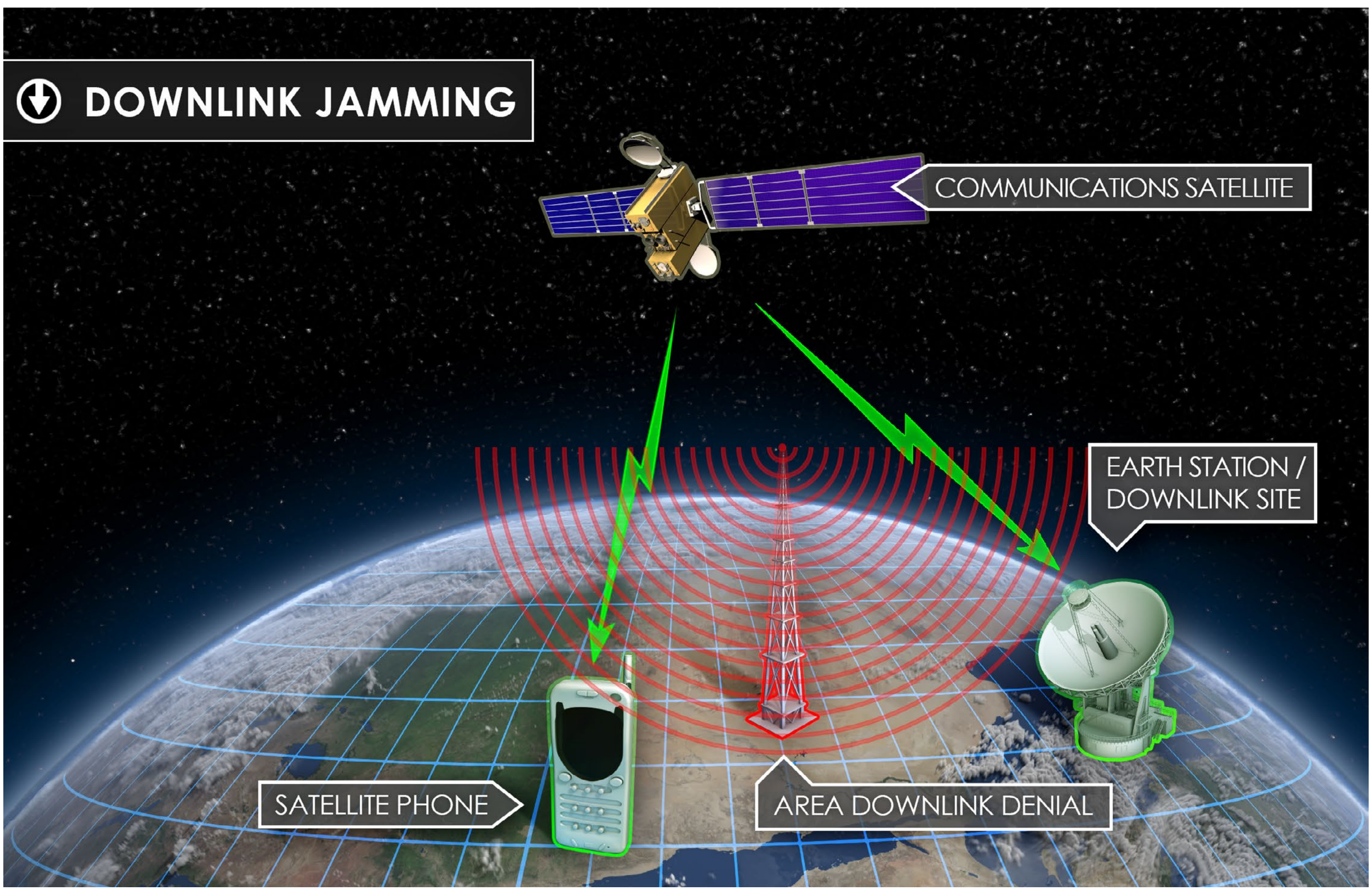
Countries without advanced space tracking sensors can attain basic space situational awareness by purchasing commercially available telescopes.



A worldwide association of amateur satellite observers uses the Internet to distribute satellite orbital information and track suspected reconnaissance satellites.




UPLINK JAMMING
Jamming Signal
Intended Signal
Jamming Combined with Intended Signal
COMMUNICATIONS SATELLITE
JAMMING SITE
EARTH STATION / DOWNLINK SITE
EARTH STATION / UPLINK SITE


DOWNLINK JAMMING
COMMUNICATIONS SATELLITE
EARTH STATION / DOWNLINK SITE
SATELLITE PHONE
AREA DOWNLINK DENIAL

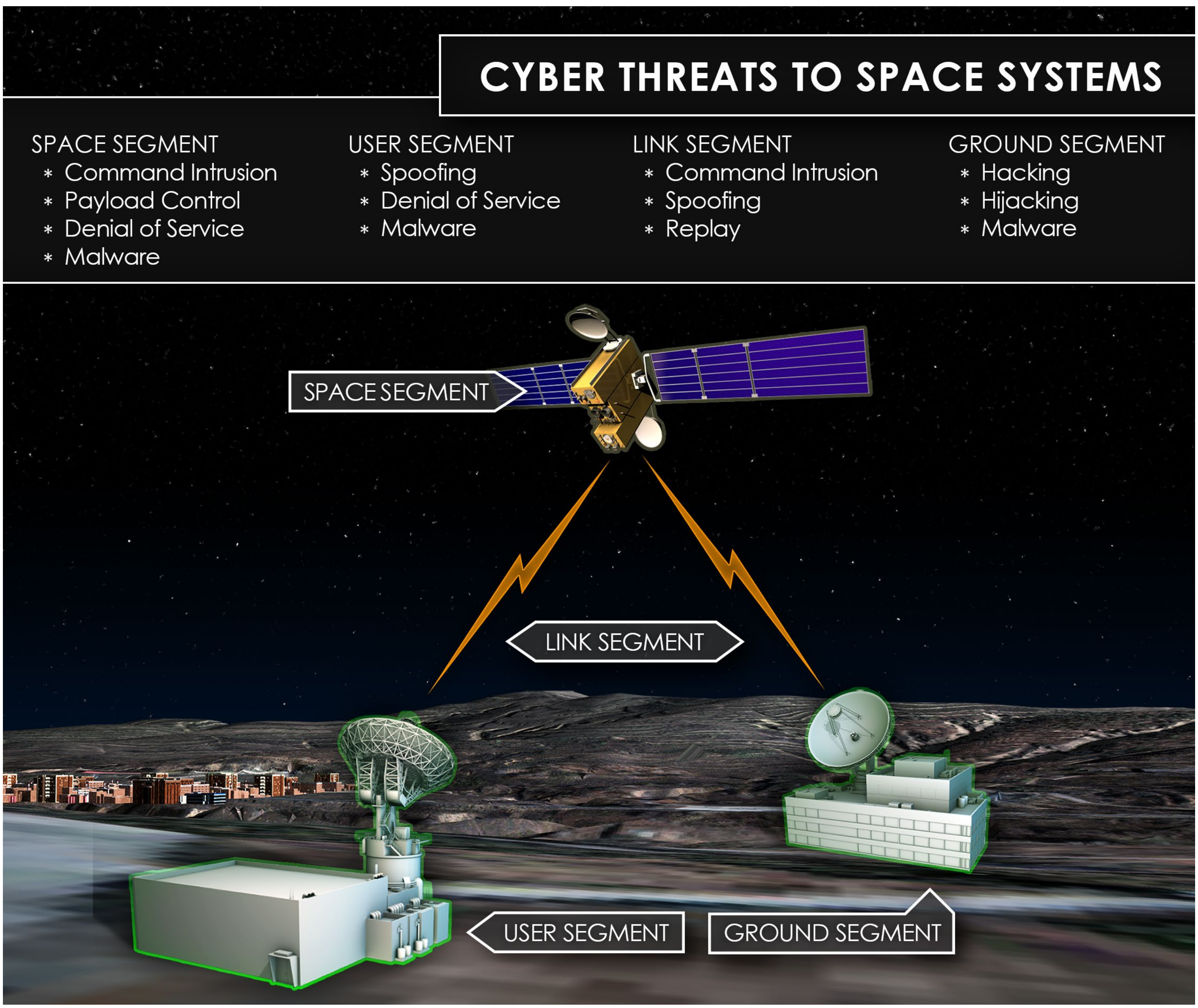
Cyber and Electronic Threats

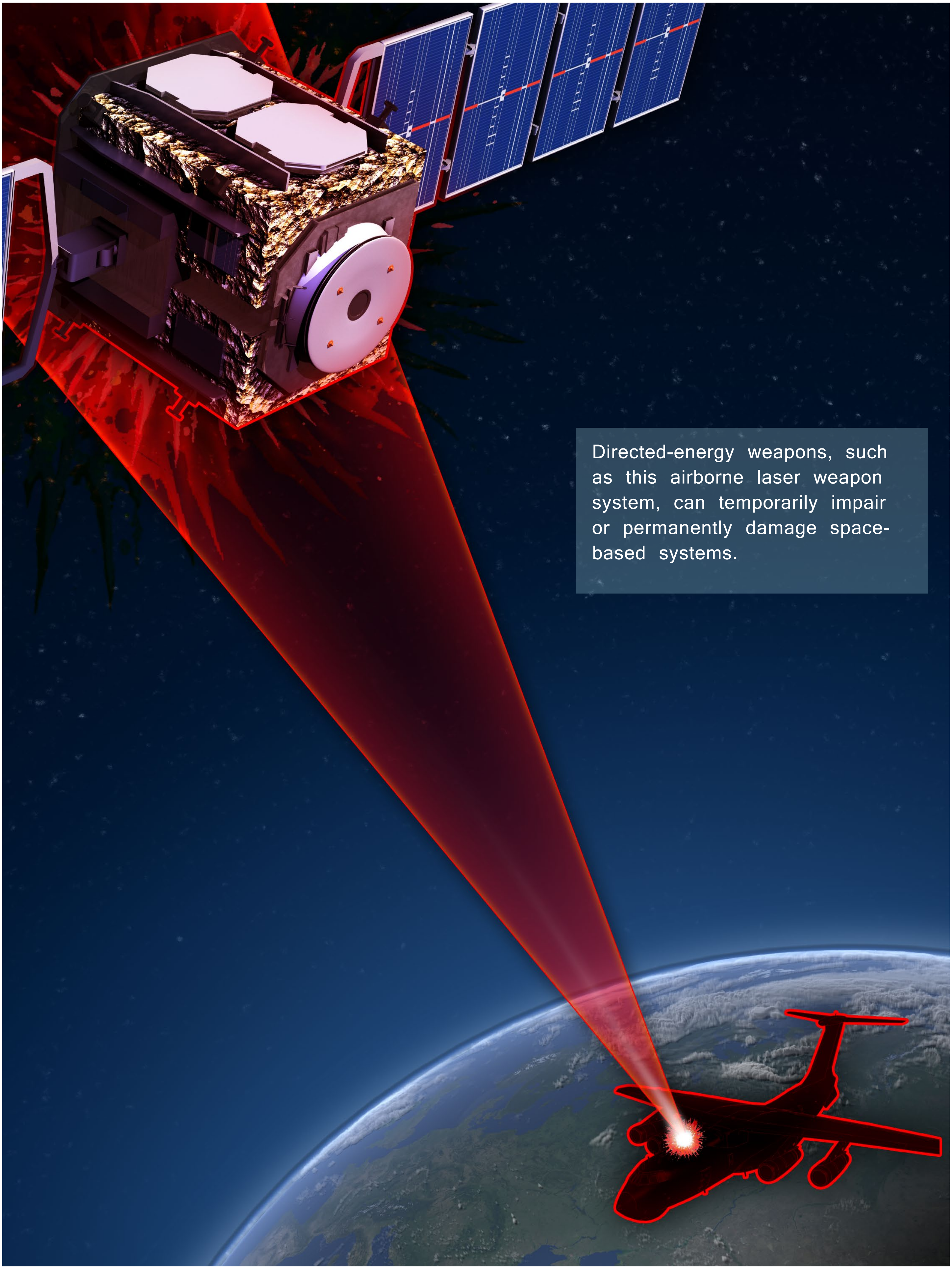
Satellite command and data distribution networks expose space systems, ground infrastructure, users, and the links connecting these segments to cyber threats. The graphic below indicates possible cyber threats to each of a space system's segments.

Foreign competitors are capable of conducting electronic attacks to disrupt, deny, deceive, or degrade space services. Jamming prevents users from receiving intended signals and can be accomplished by two primary methods: uplink jamming or downlink jamming.

Uplink jamming is directed toward the satellite, and must operate at the same frequency and approximate power level as the target signals. Effects can be widespread. Conversely, downlink jamming is directed at users on the ground, and its effects are more localized.

China and Russia consider both offensive cyber capabilities and electronic warfare as key assets for maintaining military advantage. As a result, both countries are researching and developing cyber capabilities and modernizing electronic warfare assets.





Directed-energy weapons, such as this airborne laser weapon system, can temporarily impair or permanently damage space-based systems.

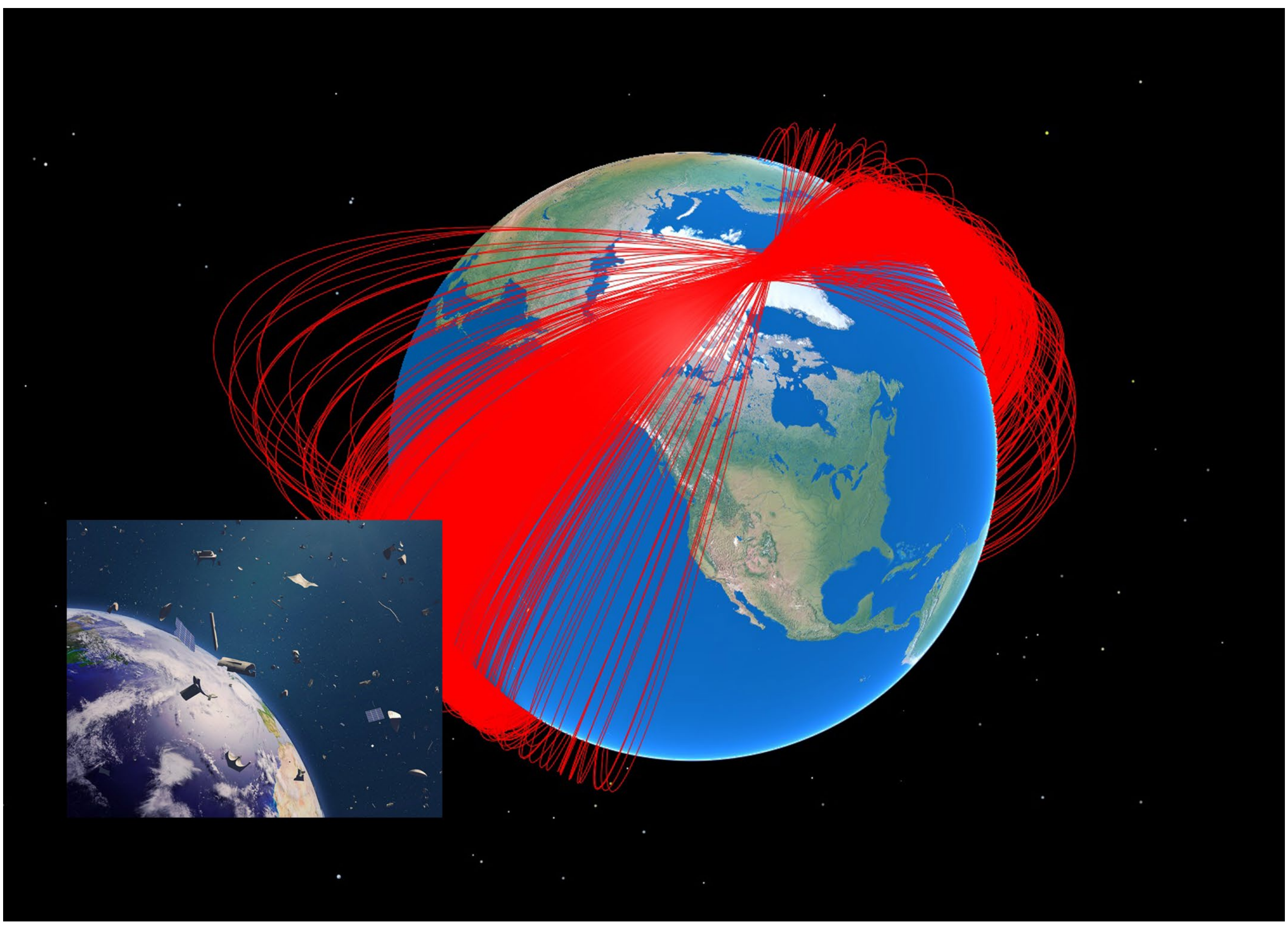
Anti-Satellite Missiles and Directed-Energy Weapons

Anti-satellite missiles destroy targeted satellites. Using a ground-launched anti-satellite missile in 2007, China destroyed one of its defunct weather satellites more than 500 miles above the Earth. As seen below, the impact of this collision generated over 3,000 pieces of space debris that will continue orbiting the Earth for decades.

China has military units that have begun training with anti-satellite missiles. Russia is probably also developing an anti-satellite missile. These missiles can destroy U.S. and allied space systems in low Earth orbit, making intelligence, surveillance, reconnaissance, and communications satellites vulnerable.

Counterspace directed-energy weapons are designed to produce reversible or non-reversible effects against space systems by emitting highly focused radiofrequency or laser energy. Reversible effects include temporarily blinding optical sensors. Non-reversible effects include permanently damaging or destroying sensors or other satellite components.

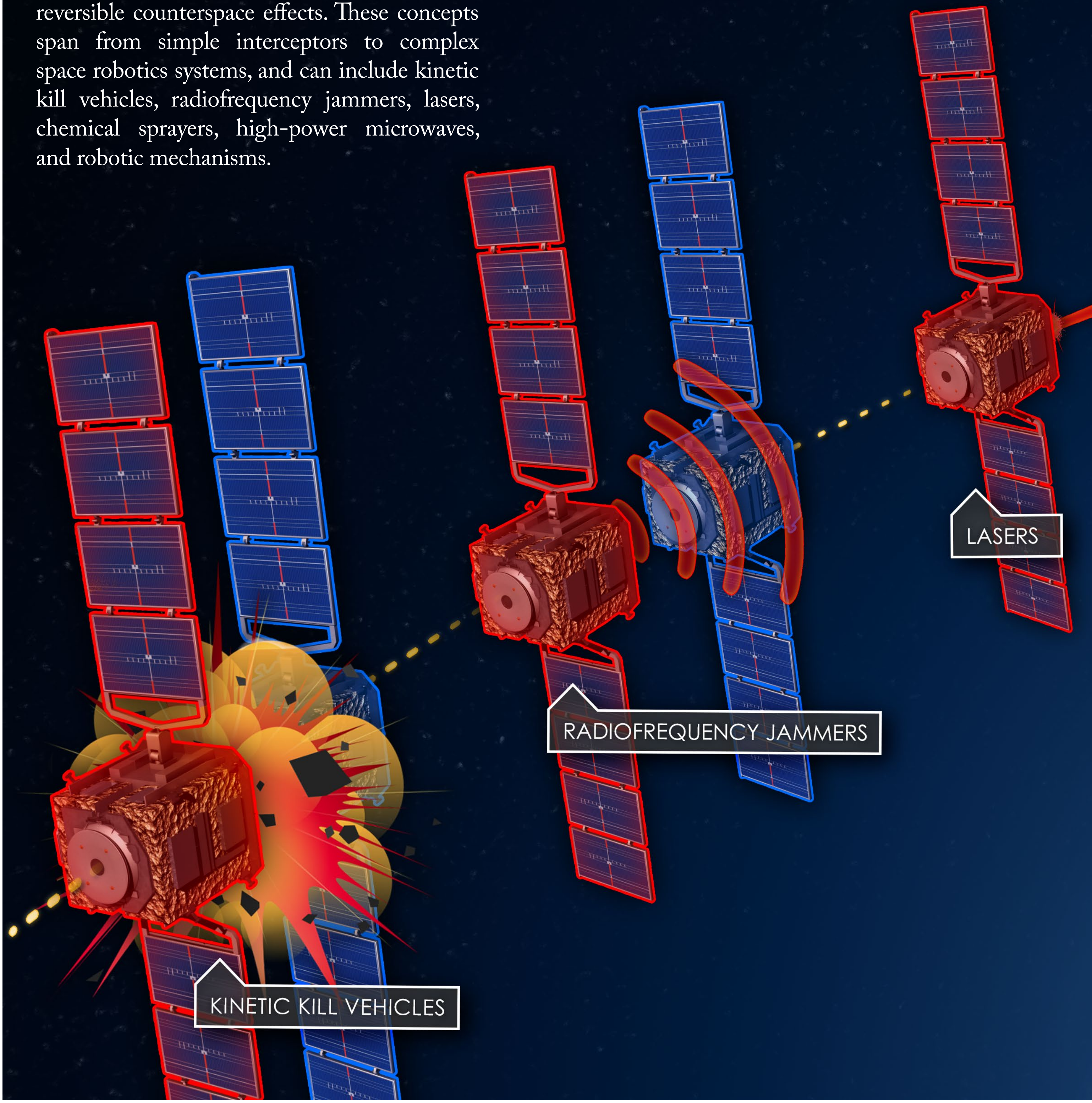
Both China and Russia intend to field counterspace directed-energy weapons. Over the past two decades, Chinese defense research has proposed the development of several reversible and non-reversible counterspace directed-energy weapons. Russia is reportedly developing an airborne laser weapon system intended for use against space-based missile defense sensors.

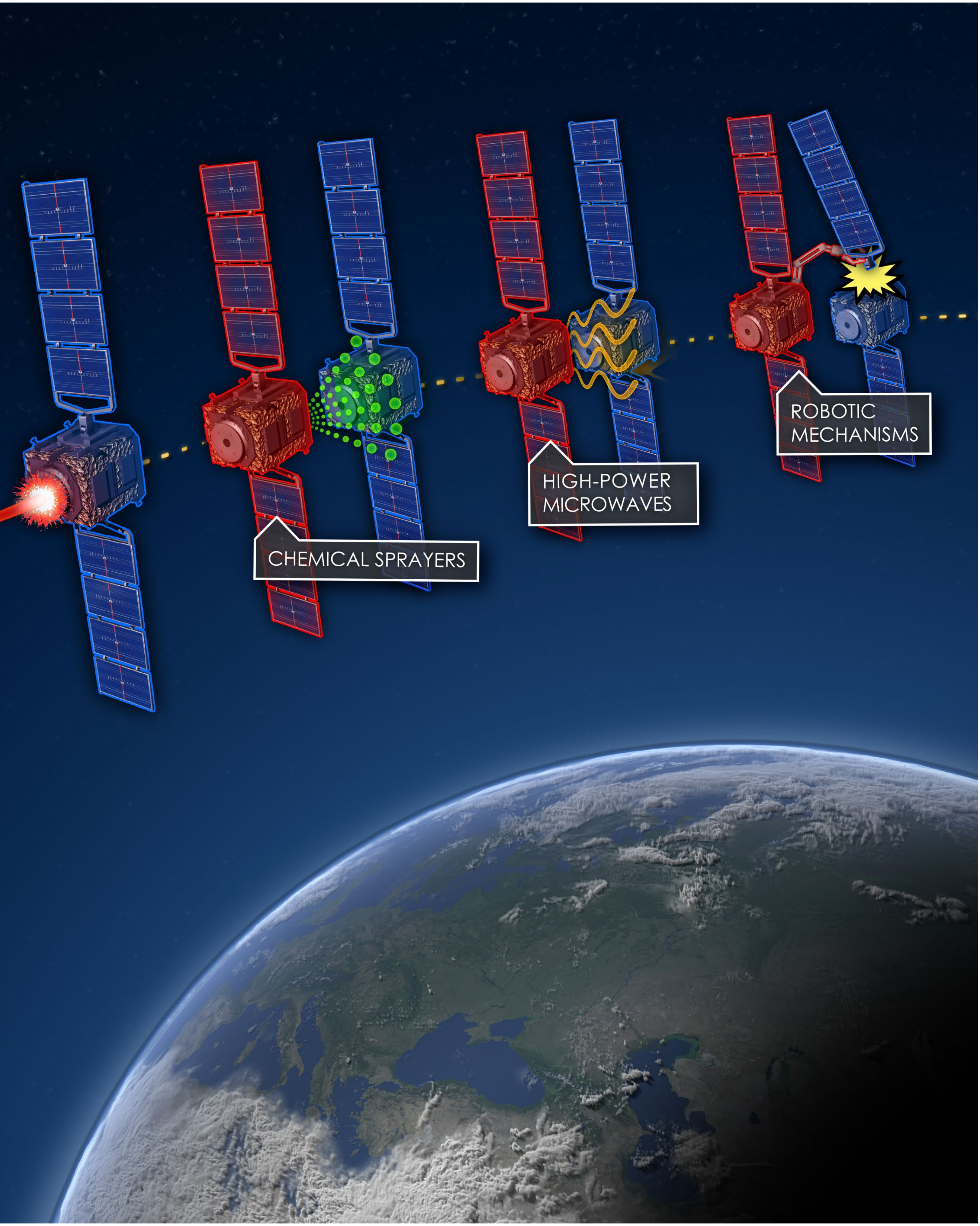


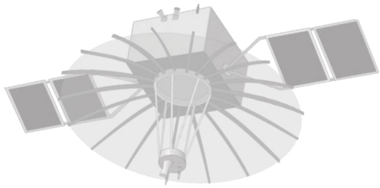
Space-Based Weapons

Space-based anti-satellite systems are satellites that target other space systems. Concepts for space-based anti-satellite systems vary widely and include designs to deliver a spectrum of reversible and non-reversible counterspace effects. These concepts span from simple interceptors to complex space robotics systems, and can include kinetic kill vehicles, radiofrequency jammers, lasers, chemical sprayers, high-power microwaves, and robotic mechanisms.

Some spacefaring countries are testing or researching sophisticated on-orbit technologies for satellite servicing and debris removal. These technologies could also damage satellites.




CHEMICAL SPRAYERS
HIGH-POWER MICROWAVES
ROBOTIC MECHANISMS

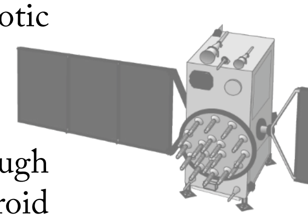


SPACE OUTLOOK

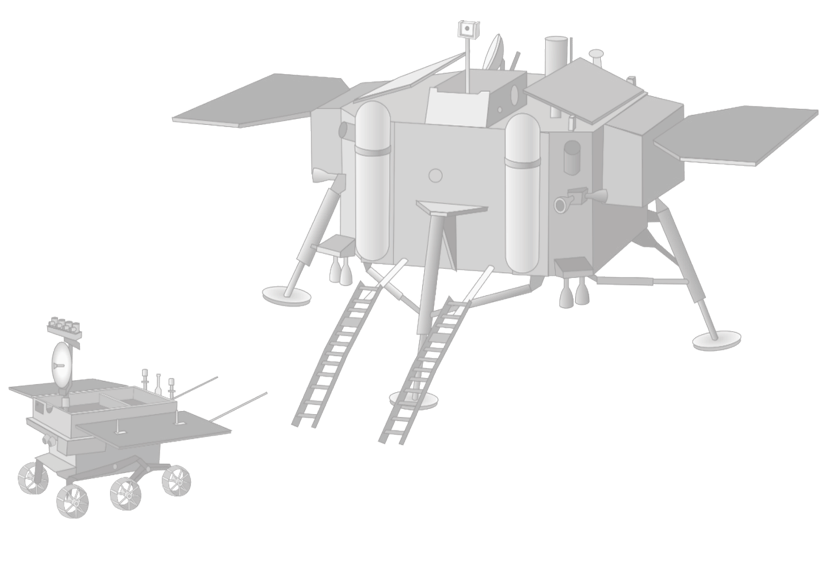
Foreign space competitors will pursue new capabilities to access, operate in, and conduct war using the space domain, while working to deny the same to others. In the near future, competitors will enhance their warfighting capacity by improving space capabilities. Increasingly affordable space systems will heighten space congestion and raise the risk of collision. Development of some space technologies could lead to a misperception of intent, driving countries to adopt a more hostile posture. Understanding the risks created by emerging technologies is critical to maintaining a peaceful space domain.

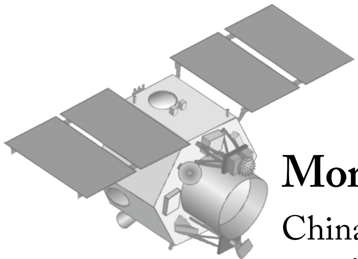
New Competition for Space Beyond Earth's Orbit

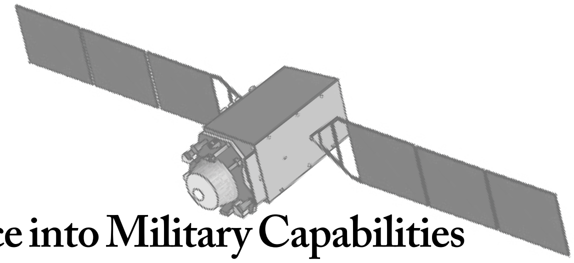
In the past two decades, foreign competitors have looked to lunar missions as key demonstrations of technological sophistication and economic prosperity. In 2013, China became the first country to land a mission on the Moon's surface since the Soviet Union in 1976. China plans to become an international leader in lunar research and exploration with goals to assemble a lunar research station beginning in 2025, perform a crewed Moon landing mission in 2036, and establish a Lunar Research and Development Base around 2050. Russia plans to launch a robotic Moon mission in 2021.



China and Russia have active Mars and deep space exploration programs. Through the mid-2020s, China intends to launch its first Mars rover mission and an asteroid sample return mission. Russia's Mars program can be traced back to Soviet ambitions in the 1960s. Since then, it has launched several Mars exploration missions, with the only two successful missions occurring in 1971. Recently, Russia has partnered with the European Space Agency in the European-led ExoMars program, which launched a Mars orbiter in 2016 and plans to launch a rover in 2020.







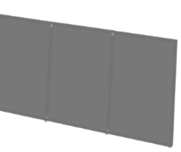
More Competitors will Integrate Space into Military Capabilities

China and Russia are the most capable competitors in space today. However, reduced cost, increased access, and proliferation of space systems will drive more countries to integrate these systems into military capabilities. Furthermore, commercial or openly available space-based intelligence, surveillance, and reconnaissance, communications, and navigation services may enable non-state actors (e.g., terrorist groups) to improve operational capabilities.

Growing Number of Space Objects will Increase Risk of Collisions

As the number of objects in space increases, particularly in low Earth orbit, the risk of collisions will grow. Amidst the growing popularity of smaller satellites, U.S. and allied space monitoring capabilities, which help prevent collisions in space, may struggle to track and identify objects and discriminate between threats and non-threats.

Increasing Use of Dual-Use Technologies Obscures Intent, Deterrence in Space



Dual-use capabilities will challenge U.S. ability to provide advanced warning of nefarious intentions or discern between peaceful and potential hostile activity. For example, future satellite servicing and recycling capabilities incorporate a variety of technologies, such as robotic arms, to inspect, repair, or dispose of damaged satellites. However, the same technologies have inherent counterspace capabilities that could be used to inspect non-consenting satellites or to cause physical damage, steal parts, or grapple with a satellite.

Future Concepts will Advance Space System Capabilities

Several concepts for future technologies promise to provide new enhancements to competitors' space capabilities. For instance, advanced artificial intelligence and improved sensors will provide satellites the situational awareness for autonomous self-protection. Additionally, 3D printing in space could allow competitors to nearly eliminate the cost of space launch by servicing, repairing, or manufacturing new systems entirely on orbit.