SPACE SUSTAINABILITY

A PRACTICAL GUIDE

SECURE WORLD FOUNDATION

updated 2018

Secure World Foundation

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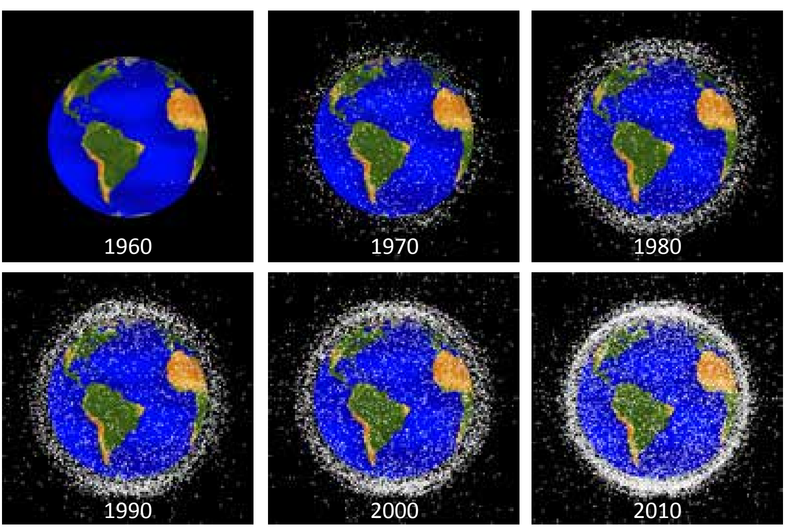
Space sustainability is...

Ensuring that all humanity can continue to use outer space for peaceful purposes and socioeconomic benefit now and in the long term. This will require international cooperation, discussion, and agreements designed to ensure that outer space is safe, secure, and peaceful.

More than 1,800 satellites orbit the Earth, providing tangible social, scientific, strategic, and economic benefits to billions of individuals throughout the globe. Yet the ability to provide important benefits from outer space is now threatened by a number of challenges. One is the increasing density of debris in orbit. Some experts predict the debris population will reach a level at which it becomes self-sustaining: debris–on–debris collisions would continue to increase the amount of debris in orbit, even without new launches. This could quickly lead to a sharp decrease in our ability to sustain the benefits that space systems provide to the entire world.

Spacecraft face an especially high risk in Sun-synchronous orbits (SSO). SSOs are special orbits between 700 and 900 kilometers (km) in altitude primarily used by Earth observation satellites that collect valuable information about the world we live on.



Satellites and debris in low Earth orbit, 1960-2010. Courtesy of NASA.

Increasing crowding in key orbits also presents a challenge to space operations. For example, communication satellites in geosynchronous Earth orbit (GEO), the equatorial orbit where satellites appear to remain nearly stationary above Earth, face increased competition for orbital slots as a result of the strong demand for satellite TV and global communications. This crowding has led to the potential for radio frequency interference and a shrinking margin of error for maintaining separation between satellites.

> **You have a responsibility to behave responsibly, not create debris, and to be transparent with the way you operate.**
>
> *Gen. John Hyten, AFSPC Commander, 2015 SmallSat Conference.*

The expansion of private sector space activities poses new challenges to maintaining a safe operational environment in space, while offering opportunities to expand access to the benefits of space applications on Earth.

The increasing use of space also presents security challenges. As more countries integrate space into their national military capabilities and rely on space-based information for national security, there is an increased chance that any interference with satellites could spark or escalate tensions and conflict in space or on Earth.

Secure World Foundation and its partners worldwide are dedicated to the establishment of effective and efficient systems of governance for outer space and for improving the safety of operations in Earth orbit. This effort includes developing the tools of governance that lead to reducing the threat of orbital debris, promoting international civil space situational awareness to improve knowledge and transparency, and preventing the creation of additional debris through hostile acts.

In order to further the continued utility of space activities for the benefit of Earth and its people, Secure World Foundation strongly supports efforts to work toward sustainability of activities in outer space.

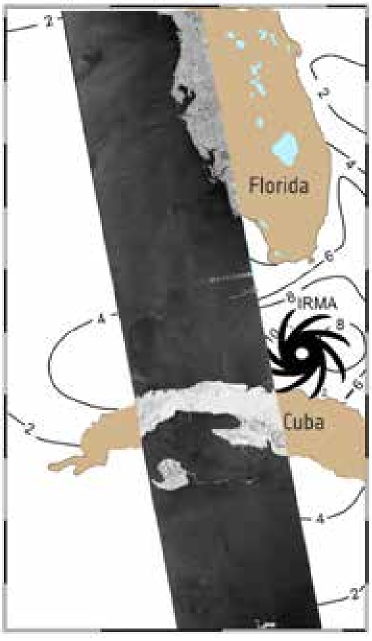
Why Care About Space Sustainability?

In a world inundated with many complex and urgent problems, why does space sustainability matter? If outer space is not safe, secure, and peaceful, the ability to use it could be denied to all. We would be unable to use the space environment for national security purposes, Earth observation, telecommunications (including financial transactions, internet, telephone, data transfer, and television), navigation, scientific exploration, or economic development. Indeed, human spaceflight in Earth orbit could come to an end. In light of many global socio-economic challenges, such as those detailed in the Sustainable Development Goals that were unanimously adopted at the United Nations in 2015, it's more imperative than ever that the vast benefits that can be derived from space-based technology remain accessible to all.

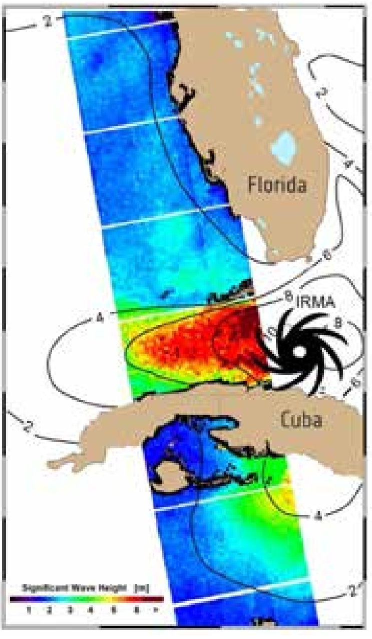
Lack of sustainability would mean that emerging space countries, especially, could face insurmountable problems in using outer space effectively. Addressing the need for space sustainability now means we can prevent negative trends from becoming norms, and ensure that outer space can be used by all countries, not just technologically sophisticated ones.

> **Space tools are highly relevant for the attainment of all 17 Sustainable Development Goals and their respective targets, either directly, as enablers and drivers for sustainable development, or indirectly, as an integral part of the indicators for monitoring the progress towards the implementation of the 2030 Agenda for Sustainable Development.**
>
> *Simonetta Di Pippo, Director of the UN Office for Outer Space Affairs,*
> *June 20, 2018, UNISPACE+50*
> *High-Level Segment.*

Sentinel-1 carries an advanced synthetic aperture radar that works in several specialized modes to capture detailed information about the Earth. Scientists at the German Aerospace Center are using new processing techniques on the radar images to gain better information about wind and waves at the sea surface under hurricanes. Here they reveal waves of up to 10 meters high under Hurricane Irma as it struck Cuba and the Florida Keys in September 2017.



Sentinel-1 Radar image during Hurricane Irma.



Processed image showing wave height.

September 9, 2017, Courtesy of: ESA/DLR.

The Persistent Problem of Orbital Debris

Both accidents and intentional destructive events can produce large quantities of orbital debris that remain as threats for years or centuries. Smaller amounts of debris are also produced through routine operations. Orbital debris is a global problem and shows the need for all nations to work together to ensure space sustainability.

The U.S. military maintains one of the world's most extensive orbital tracking network, recording (in 2018) some 23,000 objects in space measuring roughly 10 cm in diameter or larger. What cannot be reliably tracked yet are the objects smaller than 10 cm because these are too small to follow consistently. Scientists estimate that about 500,000 bits of junk measuring 1 to 10 cm orbit Earth and believe that many millions of pieces smaller than 1 cm exist. Because all objects in Earth orbit travel at extremely high speeds, even very small ones can cripple or destroy working spacecraft or endanger astronauts.

Knowing more about the nature of the problem is critical to space sustainability. Sharing information about orbital debris, mitigating its production, and even developing capabilities to remove existing debris represent key objectives toward ensuring that conditions in outer space are favorable for continued use.

The following pages provide more details of two important events that contributed greatly to the increase in orbital debris.

Satellites & Debris by Orbit

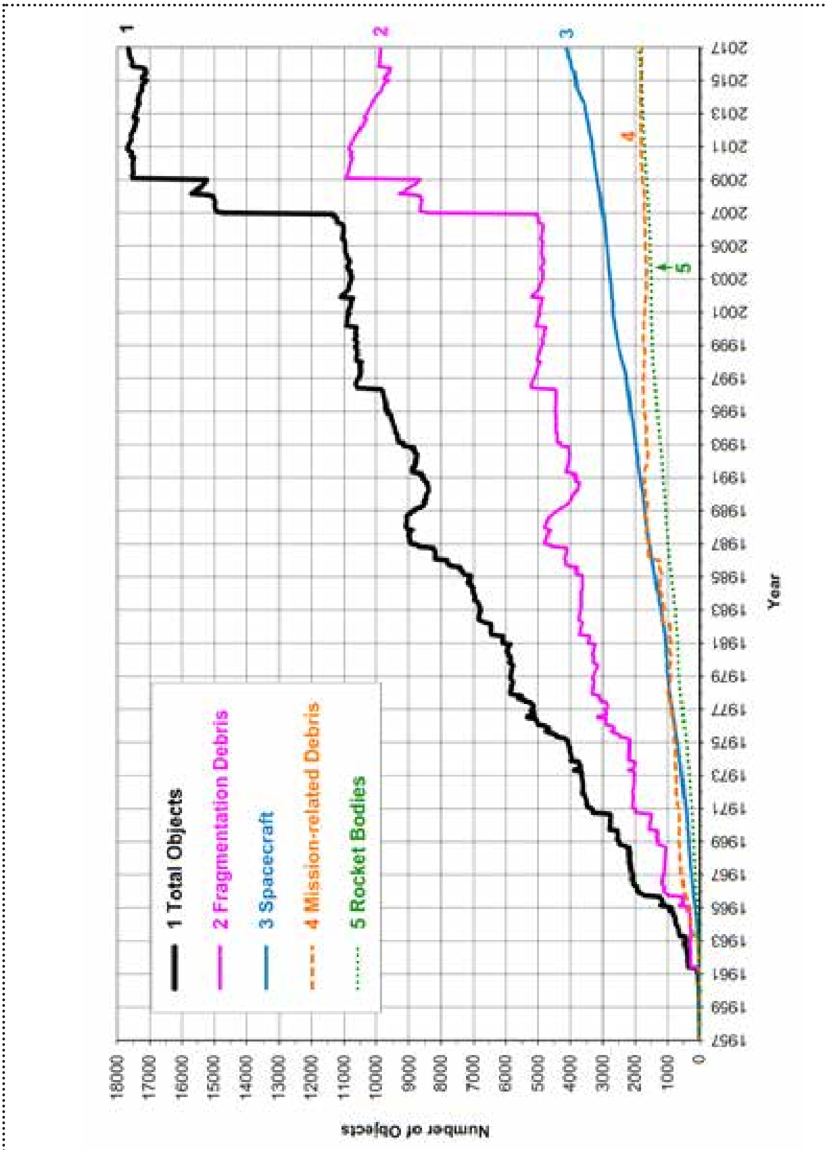
1,200 operational satellites in low Earth orbit (LEO), with approximately 18,000 pieces of trackable debris bigger than 10 cm

150 operational satellites in medium Earth orbit (MEO), with approximately 1,000 pieces of trackable debris

550 operating satellites in GEO, with approximately 1,000 pieces of trackable debris

Source: Union of Concerned Scientists, 2018, and European Space Agency, 2018.

Monthly Number of Objects in Earth Orbit by Object Type



This chart displays a summary of all objects equal to or larger than 10 cm in Earth orbit officially catalogued by the U.S. Space Surveillance Network. “Fragmentation debris” includes satellite breakup debris and anomalous event debris, while “mission-related debris” includes objects dispensed, separated or released as a part of a planned mission. Many more objects are tracked but only those that can be attributed to a specific launch and launching State(s) are catalogued. Courtesy of NASA.

On January 11, 2007, as China's inoperable polar orbiting Fengyun-1C weather satellite passed overhead, a modified Chinese ballistic missile was launched from China's Xichang Satellite Launch Center and streaked toward the satellite, deliberately colliding with tremendous force and creating thousands of small pieces. This cloud of debris quickly spread out across a large region of Earth orbit, covering between 300 and 2,000 km in altitude. Many of these pieces remain in the original polar orbit, the prime location for most Earth observation satellites, including weather and climate satellites operated by the world's space agencies. The deliberate destruction of the satellite created more than 3,000 trackable pieces of orbital debris (larger than about 10 cm). NASA's debris experts estimate that the test created perhaps as many as 150,000 pieces of debris too small to track. Most of these will remain in orbit, posing a serious threat to working satellites in low Earth orbit (LEO) for decades.

Debris-generating kinetic-kill anti-satellite (ASAT) weapons like this Chinese example have become a major international concern, primarily because of the large amounts of debris they create. During the 1970s and 1980s, the former Soviet Union and the United States tested their own forms of these ASATs, but decided that they were of limited tactical or strategic use, in part because of the potential collateral damage to their own satellites from the large amounts of orbital debris generated.

2007 Chinese ASAT Test
Fengyun 1C
Defunct Chinese weather satellite
SC-19
Modified Chinese ballistic missile with kinetic kill vehicle
Debris produced by collision
3,000 trackable pieces (10 cm or larger) 150,000 untrackable
Impact velocity
About 10 km per second

Source: NASA Orbital Debris Program Office.

On February 10, 2009, two satellites collided accidentally, creating a large amount of debris circling 800 km above Earth.

Nearly 2,000 pieces of the two satellites—chunks of metal, foil and plastic—now circle Earth in spreading orbits, posing a collision threat to other satellites and the International Space Station. One satellite was already out of service, but the other helped provide worldwide telephone services. Although the collision might have been predicted, it is unclear whether or not it could have been avoided. At the time neither Russia nor the United States was actively screening these two satellites for potential collisions. Also, with today's technology, satellite operators cannot predict with high certainty whether or not two objects will collide in orbit.

Since this collision, the U.S. military and the satellite communications industry have developed additional procedures to try and reduce the risk of future collisions. Nevertheless, more needs to be done to ensure that all satellite operators are aware of potential threats in orbit and have the information to act responsibly.

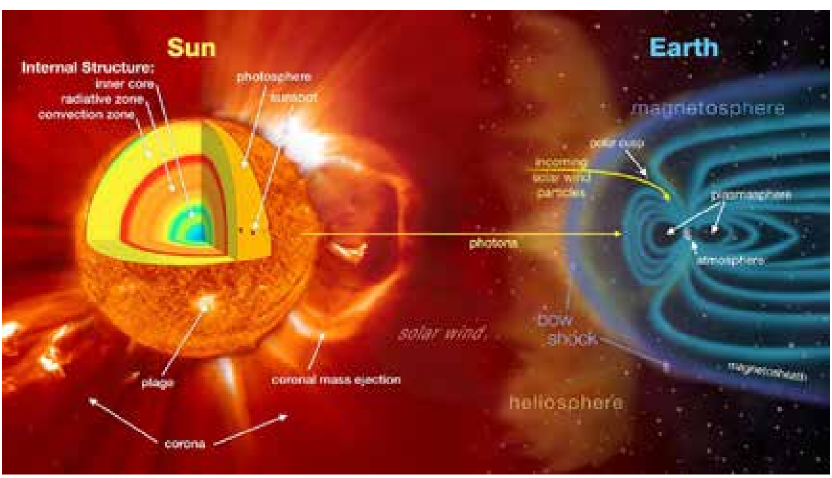
2009 Iridium-Cosmos Collision
Iridium 33
Active commercial communications satellite operated by U.S.-based Iridium Satellite LLC
Cosmos 2251
Inactive communications satellite once operated by the Russian Ministry of Defense
Debris produced by collision
2,000 trackable pieces of debris (10 centimeters [cm] or larger)
Impact velocity
About 10 kilometers per second

Source: NASA Orbital Debris Program Office.

Space Weather

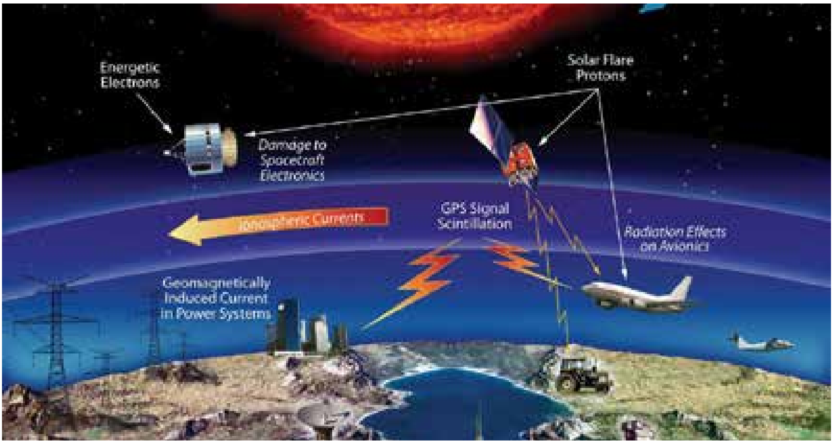
Space weather refers to a group of physical processes that begin as the Sun emits energy and ultimately end by affecting human activities on Earth and in space. Extreme space weather events could have a global impact that requires government preparation and coordination across borders. Increased research and understanding of heliophysics, the Earth's magnetosphere, and mitigation strategies are necessary to maintain the sustainable use of space assets and even basic electric infrastructure considering space weather uncertainties.

The Sun releases a regular flow of energy in the form of the solar wind. Photons and other solar wind particles travel across the 300 million kilometers between the Sun and Earth to interact with the Earth's magnetosphere to generate common space weather such as the aurora. Severe short-term modulations in the Sun's magnetic field can release large amounts of energy in a coronal mass ejection (CME). When the highly charged particles of a CME meet the Earth's magnetosphere it can be disrupted and allow much higher amounts of solar energy to reach the Earth's surface. The interactions between Earth-orbiting satellites, terrestrial electric infrastructure, and these higher amounts of solar energy can disable and damage electronic components.



The Sun-Earth system. Courtesy of NOAA

Although space weather is a natural phenomenon that is not caused by human activity, it still plays an important role in space sustainability. Space weather can impact satellites by damaging onboard electronics and disrupting communications or navigation signals, leading to temporary service disruptions and a long-term degradation of spacecraft reliability and lifetime. Further, if a satellite operator does not know whether a satellite was damaged by space weather or by hostile action there is an increased chance for terrestrial conflict, particularly if there is already a tense geopolitical situation occurring. New research on now-unclassified materials details how this exact scenario played out in 1967 during a major solar storm. Space weather can also affect the orbital debris population as years with a lot of solar activity can see an increase in the rate of orbital decay.



Space weather impacts on technology. Courtesy of NASA.

The most famous space-weather event is the 1859 Carrington Event. A series of CMEs appear to have struck the Earth over the course of a week in August-September 1859. Auroras were reported as far from the poles as Colombia and Sub-Saharan Africa, telegraph lines across Europe and North America failed, and astounded residents of the northeastern United States could read their newspapers by the light of the aurora. In the proto-electric time of 1859, the damage from a direct-hit CME was minimal compared to the significant damage that could be caused by a similar event in the 21st century. As modern economies, societies, and militaries have become more reliant on space, as well ground-based infrastructure, the effects of a Carrington-style CME have been estimated in the trillions of dollars.

It is necessary to continue efforts to bring together U.S. and international experts from government, industry, and academia to consider existing and future efforts to improve collaboration on space weather-related policies, research, and forecasting programs, as well as risk management activities.

Radio Frequency Interference

Radio frequency (RF) communications are essential to satellites. As part of the electromagnetic spectrum, radio waves are used by satellites to receive commands from ground controllers (uplink) and relay information about their health and status in return (downlink). Most active satellites also use radio waves as an important element in their functioning, including retransmitting television broadcasts or transmitting imagery or scientific data that they have collected. Unintentional RF interference can arise from a number of sources. Natural interference can be caused by solar storms and other forms of space weather, interaction with the Earth's atmosphere, and sometimes even clouds and rain. Unintentional human-generated interference can result from a satellite transmitting too close to another satellite on the same frequency or from terrestrial communications systems operating on the same or similar frequency to space systems.

Intentional RF interference, often referred to as jamming, is a way of temporarily or reversibly disrupting the normal functioning of a satellite without resorting to actual destruction of the satellite and the attendant risk of creating long-lived space debris. Intentional interference is also relatively easy to accomplish, often requiring nothing more than an antenna and a transmitter. Applications for jamming range from blocking undesirable radio and television broadcasts from being transmitted into a country, to blocking satellite navigation signals to prevent an employer from tracking movements, to degrading the ability of an adversary to use precision munitions, among others.

International and national mechanisms currently exist to regulate RF communications. However, these mechanisms focus more on the allocation of spectrum and assignment of frequencies than on the prevention of interference. They also lack enforcement powers. As the instances of unintentional and intentional RF interference increase partially due to crowding and congestion on orbit, these regulatory shortcomings present a significant challenge to the long-term sustainable use of space.

Galaxy 15 "Zombiesat"

In April 2010, a malfunction caused Intelsat S.A. to lose contact with Galaxy 15, a geosynchronous communications satellite. The malfunction prevented Intelsat from maneuvering Galaxy 15 and the spacecraft started to drift slowly past other operational satellites in the region.

Galaxy 15's receiver and transmitter equipment were still functioning, meaning it could pick up and re-broadcast signals aimed at other satellites as it drifted past, potentially causing serious radio frequency interference.

In December 2010, Intelsat was able to regain control of Galaxy 15, but only the close communication and cooperation between satellite operators prevented any significant harmful effects.

Artist's rendering of the Galaxy 15 satellite.
Courtesy of Intelsat.

Improving Space Situational Awareness

Orbital debris and orbital crowding mean that owners and operators of satellites and crewed spacecraft need information on the objects whose orbits intersect their own in order to avoid collisions like that experienced between Iridium 33 and Cosmos 2251. Several States and satellite owner-operators monitor the location of objects in space, but only in limited ways—the "big picture" is not fully known by all.

The most robust understanding of the near-Earth space environment is obtained by the United States military's Space Surveillance Network, which tracks about 23,000 human-generated objects in Earth orbit (as of 2018). Because of national security sensitivities, the United States has been reticent to allow owner-operators around the world to access the information, although it does provide some services to share SSA information with trusted partners and, more generally, to provide warnings of potential collisions to satellite operators throughout the world. In order to enable many space safety and sustainability initiatives to be effective, a certain amount of orbital data will need to be available to all users of Earth orbit.

Concerned about satellite operational safety and reliability, satellite communication companies Inmarsat, Intelsat, and SES in 2010 formed a non-profit entity called the Space Data Association (SDA) to provide services to participating operators for collision warning and mitigating radiofrequency interference. Today, both private and governmental satellite operators, responsible for more than 300 operational satellites, are members. Each member satellite operator contributes information on the positions and other aspects of its satellites to the SDA, which in turn provides operators with operational data critical to safe and efficient satellite operations.

Over the last few years, SSA capabilities have continued to increase. Countries with significant existing military SSA capabilities, such as the United States and Russia, have begun to modernize and enhance their facilities. In 2014, the European Union approved funding for a Space Surveillance and Tracking Programme that would fuse together data from existing European national sensors into a central database. Many other countries around the world operate individual sensors for a variety of scientific, academic, or operational reasons, and are investigating how they could be used for cooperative SSA. The definition of SSA has also been expanded by some States to include tracking of Near Earth Objects (NEOs) and space weather.

In anticipation of an emerging commercial market for SSA, companies such as ExoAnalytics and LeoLabs are developing their own private network of sensors to track satellites and space debris. Other companies, such as Analytical Graphics Inc. (AGI), have announced the creation of commercial SSA data centers that purchase data from optical, radar, and RF sensors around the world and offer customers services such as warnings of potential conjunctions and assistance in resolving anomalies.

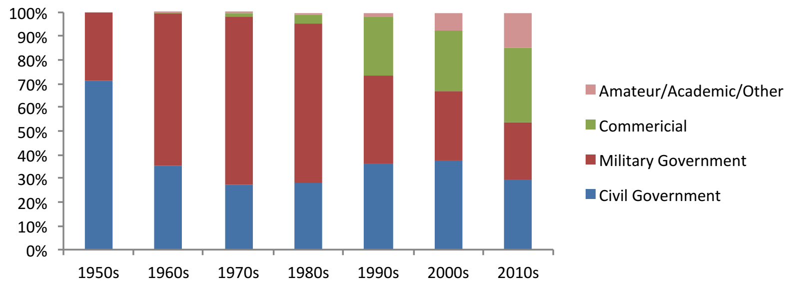
LeoLabs new radar facility in Midlands, TX, which became operational in February 2017. Courtesy of LeoLabs.

> **For Europe, space is a crucial region. Space-based systems have become indispensable to many services critical to Europe's economies and governmental functions, including those related to security, and this dependency will only increase in the future ...The SSA programme will help ensure that the reliability, availability and security of Europe's space-based services are strengthened.**
>
> European Space Agency, "What is SSA?" www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/About_SSA

Private Sector Space Activities

Private sector – or commercial – space activity is in the midst of a worldwide expansion of actors, application areas, and business models. Driven by the rapid commoditization of the underlying technology, easier access to capital, and the spread of a disruptive innovation spirit, private sector space actors are introducing a range of new applications, services, and approaches to space activities. A sector that historically has been dominated by government activities is becoming increasingly commercial in character.

Share of Satellites Launched per Decade, by Operator Type



Source: McDowell, Johnathan C., 2017 — Satellite Statistics.

This growing level of activity offers the potential to expand global access to space technology, applications, and services, as well as the societal and economic benefits derived from that access. It also introduces new complexity in the operating environment, and in how operators interact with each other and with the policy and regulatory system. Continued economic development of, and return from, the space industry requires a space environment that remains accessible to all actors. Funders, developers, operators, and regulators of space activities must realize both the challenges and opportunities that commercial space presents to

Space has become much more globalized. There are many more players in it. Some people call it the democratization of space. But there are certainly many more spacefaring countries around then ever before. There are many more private sector actors that are more capable then ever before. And so it's a much more complex world than when we were responding to a space race, or dealing with the immediate aftermath of the Cold War.

Scott Pace, Executive Secretary of the U.S. National Space Council, in Scientific American, November 6, 2017.

maintaining a safe and sustainable operational environment in space, and to sustaining the benefits of space applications here on Earth.

Commercial space applications and approaches are broadening beyond the traditional communications, visible Earth observation, and space launch services. New commercial actors are also embracing novel technical approaches to the design, manufacturing, and operation of space systems.

New Commercial Activities	Novel Technical Approaches
• Active space debris removal • Space situational awareness services • In-space manufacturing • Non-optical remote sensing (e.g. hyperspectral, weather data) • On-orbit servicing • Space resources development • Space stations & in-space transportation • Suborbital tourism	• Additive manufacturing • Advanced data analytics & machine intelligence • Large constellations of satellites – potentially numbering in the thousands of individual satellites • Partially reusable launch vehicle development • Small & cube satellites and small launch vehicles

The impacts of these private sector developments on space sustainability are nuanced. Some – like active debris removal and on-orbit servicing – offer the potential to address existing challenges, while at the same time raise legal and policy questions. Others – like large constellations and the increasing use of small satellites – raise questions related to space situational awareness and space debris effects, while offering the potential to increase societal access to space applications and their benefits. The fielding of commercial capabilities that have traditionally been provided as a function of government raises policy questions. The increasing diversity of actors and applications requires enhanced dialogue between the private sector and government as well as updating of existing space governance mechanisms. Addressing these challenges – and opportunities – requires collaborative attention and action from all those involved in the space sector, including companies, regulators, and investors.

Rendezvous and Proximity Operations

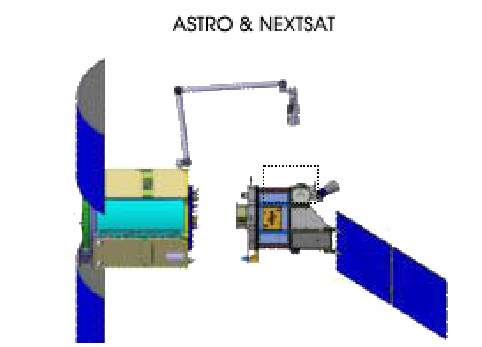
Rendezvous and proximity operations (RPO) involve altering the trajectory of one or more space objects to bring them into close proximity to each other. RPO capabilities are not new and played an important role in many human spaceflight programs over the last sixty years of space activities, such as the lunar orbit rendezvous that enabled the Moon landings and the assembly of the International Space Station.

Over the last decade, there has been a global proliferation of RPO capabilities. Several countries have demonstrated the ability to conduct not only classical RPO activities for human spaceflight, but also RPO involving robotic spacecraft. These RPO capabilities enable satellite formation flying, satellite inspections and surveillance, and on-orbit satellite servicing and refueling. As with many other space capabilities, these RPO capabilities are intrinsically dual-use in character and have potential national security and defense applications, such as disabling or destroying satellites. For this reason, lack of transparency when developing RPO capabilities, such as active removal or space objects from orbit, could give rise to misperceptions and mistrust among States concerning the real intent behind the development and such capabilities.

The proliferation of RPO capabilities presents significant space sustainability challenges. Widespread and sophisticated RPO capabilities could lead to new innovations and capabilities that improve space sustainability and benefits on Earth. But the same capabilities could also result in accidents that generate new space debris or misperceptions that fuel increased tensions and possibly lead to conflict. Thus, there is a strong need to develop standards and norms of behavior for conducting RPO in a transparent, safe, and responsible manner.

Orbital Express

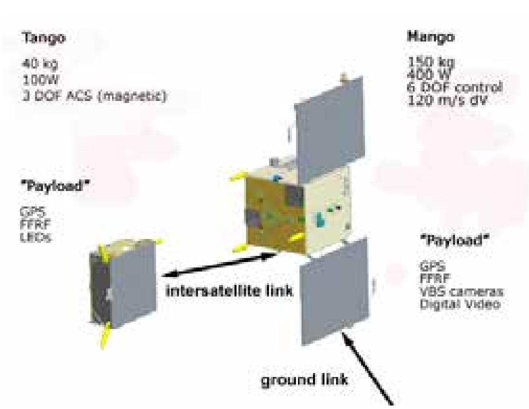
Orbital Express was a satellite servicing technology demonstration mission managed by the U.S. Defense Advanced Research Projects agency (DARPA) that flew in 2007. It utilized U.S. and Canadian robotic technology. Orbital Express consisted of two spacecraft, ASTRO and NEXTSat, that launched into orbit on March 8, 2007. After checkout, they separated and conducted a series of close approach and separation operations. A robotic arm on ASTRO was used to demonstrate the ability to dock with NEXTSat, transfer fuel, and swap components. Rendezvous operations ended on June 29, 2007, and the two spacecraft were decommissioned in July 2007.



Astro and Nextsat. Courtesy of Orbital Express.

Prisma

Prisma was a project run by the Swedish Space Corporation to demonstrate autonomous satellite formation flying. Prisma consisted of two small satellites, named Mango and Tango, that were launched into space on June 15, 2010. The two satellites separated on August 15, 2010, and over the course of several months demonstrated new guidance, navigation, and control (GNC) techniques for performing highly automated rendezvous and proximity operations using onboard sensors, high-accuracy GPS receivers, and radio signals.



Prisma. Courtesy of Swedish Space Corporation.

Strategic Stability and Outer Space

Space technologies are generally agreed to have many peaceful applications and also play an increasingly important role in both national and international security. The military use of space includes the use of spacecraft designed to support terrestrial military and intelligence operations, such as global positioning, navigation, timing (PNT) systems, communications, intelligence, reconnaissance, and surveillance satellites.

However, as more countries integrate space into their national military capabilities and rely on space-based information for national security, there is an increased chance that any interference (either actual or perceived) with satellites could spark or escalate tensions and conflict in space or on Earth. This is made all the more difficult by the challenge of determining the exact cause of a satellite malfunction: whether it was due to a space weather event, impact by space debris, unintentional interference, or deliberate act of aggression.

Some States are developing or have developed a range of counterspace capabilities, including ground and space-based weapons, that could be used to deceive, disrupt, deny, degrade, or destroy elements of space systems. Developing and testing anti-satellite (ASAT) capabilities, especially without clarity of intent, would likely undermine political and strategic stability. Further, testing or using debris-generating weapons could contaminate the orbital environment for decades to centuries, significantly affecting all space actors and severely undermining the long-term sustainability of space activities.

It is very difficult to ban the technologies that could potentially be used to conduct hostile activities since many of them are also used for peaceful purposes, a characteristic called “dual-use.” Verifying the existence of ASAT capabilities or attributing their use to particular space actors is also very challenging. Thus, an important step forward in addressing these challenges is the development of norms of behavior that delineate responsible and irresponsible activities in space. Improved SSA for all actors to enable the detection and attribution of irresponsible behavior is also essential. Transparency and confidence building measures (TCBMs), such as clarification of existing international law applicable to satellites and outer space, can also increase strategic stability and security.

In February 2008, the United States decided to destroy USA 193, an ailing national security satellite that carried substantial amounts of highly toxic hydrazine fuel and was destined to re-enter the Earth's atmosphere within a few months. Officials opted to shoot it down using a modified Aegis SM-3 missile, launched by the USS Lake Erie (pictured) to ensure that the hydrazine would disperse harmlessly on re-entry. In this case, the United States announced the event ahead of time and deliberately struck the ailing satellite when it reached a very low orbit to assure that most debris re-entered quickly.

The United States specifically designed the intercept to generate as little debris as possible and gave international briefings on the operation, in accordance with international agreements. Within eighteen months, the few hundreds of pieces of resultant debris re-entered the atmosphere. Despite assurances by U.S. officials that the intercept was specifically designed to reduce the risk to public safety, many people nevertheless saw this event as an example of how a U.S. anti-ballistic missile defense system can be modified into an ASAT weapon. This concern increases with planned upgrades to the Aegis interceptor that will make it even more powerful and thus capable of reaching higher orbits in the future.

Aegis SM-3 missile launch. Courtesy of U.S. Navy.

The Global Nature of Space Activities

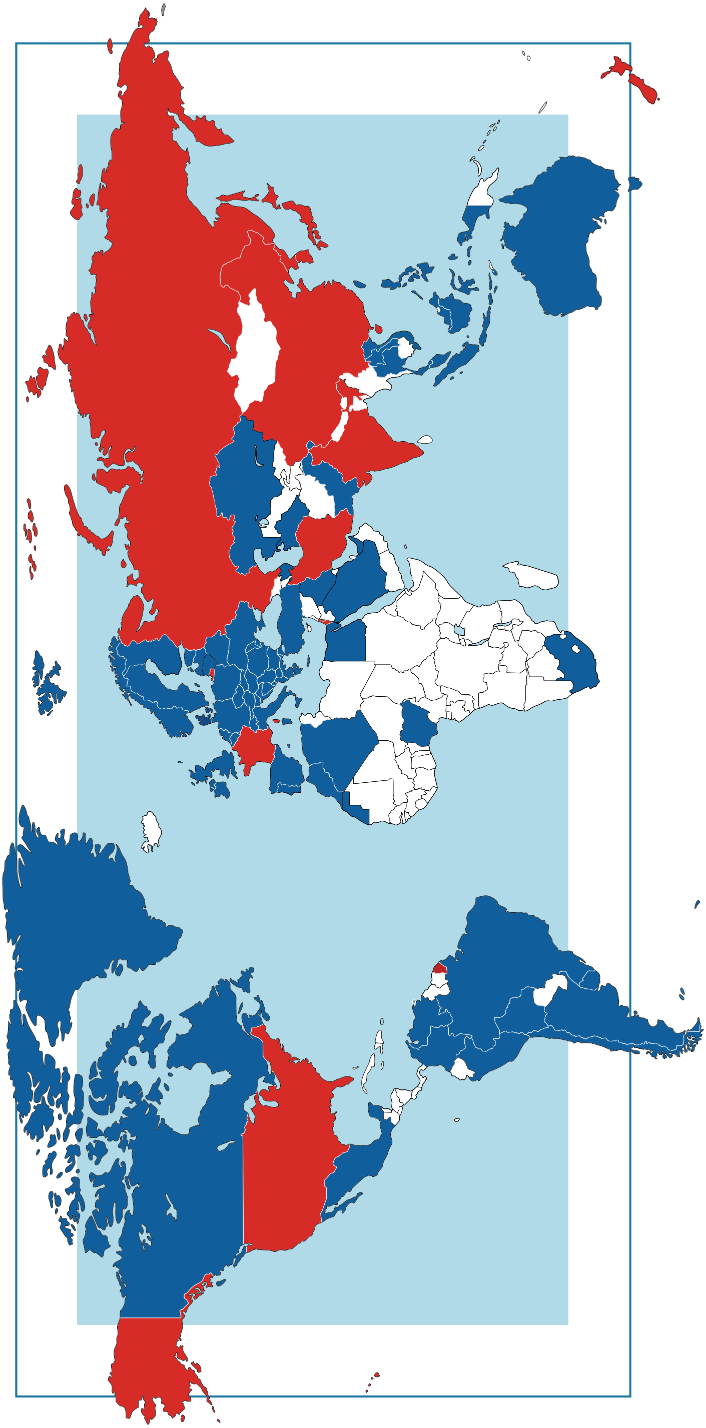
The United States, Russia, China, Europe, India, Japan, and Israel represent the most established space powers, each with indigenous orbital launch capability and a long track record of operating satellites. Iran, North Korea, South Korea, and New Zealand are the newest countries from which satellites have been launched. To date, more than 300 States, commercial companies, universities, and international organizations operate spacecraft in orbit and many companies around the world contribute directly to the global space industry.

Emerging space States recognize the importance of space systems for telecommunications, environmental monitoring, resource management, infrastructure development and national security, not to mention national prestige. With increasing interest in space and the proliferation of technologies enabling the utilization of space by a growing number of actors, it is clear that greater cooperation on space governance is necessary.

The United States and Russia, responsible for ushering in the Space Age during the Cold War, remain the preeminent space powers in terms of budget and number of assets employed in outer space.

This map shows current countries from which satellites have been launched into orbit and those countries that have operated or are operating satellites of their own. Countries with the capability to launch payloads into orbit include the United States, Russia, France (as majority shareholder in Arianespace, which also launches payloads for the European Space Agency), China, Japan, India, Israel, Iran, Ukraine, North Korea, and South Korea.

Countries Launching and Operating Satellites



The United Nations and Space

The United Nations plays a significant role in the cooperative global governance of space activities and the negotiation and adoption of international treaties and other agreements on space, but there are other bodies that play a role as well.

The United Nations (UN) is composed of 193 Member States (as of 2018). The UN General Assembly (UNGA) is the principal policy making and representative organ of the UN. Six permanent committees help the UNGA manage its work on global issues; for space matters, two committees are especially important. The First Committee deals with disarmament and security matters, and the Fourth Committee focuses on special political matters, including outer space. The Committee on the Peaceful Uses of Outer Space (COPUOS) is the UN body responsible for promoting international cooperation in the peaceful uses of outer space and for the progressive development and codification of the international legal regime governing outer space. COPUOS does not deal with military space issues. COPUOS reports each year to the UNGA via the Fourth Committee. The UN Office for Outer Space Affairs (UNOOSA) is the secretariat for COPUOS and is part of the larger UN secretariat. The Office implements the UN Programme on Space Applications and a number of other activities in the legal, scientific, technical, and political aspects of space activities. The Conference on Disarmament (CD), which is not a UN organization but works under the UN auspices, is the international forum for work on disarmament, and for matters related to weapons in space and other space security issues. The CD reports its annual findings to the UNGA via the First Committee.

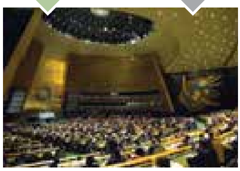
> Composed of 87 Member States and 37 permanent observers (including SWF), COPUOS is the premier international forum for discussing issues of space governance. Its work is divided between two subcommittees: the Scientific and Technical Subcommittee and the Legal Subcommittee. Matters that come before COPUOS are deliberated first in working groups within one of the subcommittees and when agreement is reached, the matter is presented to the full committee as a report of the Subcommittee. After additional deliberation, COPUOS will prepare a report and possibly a resolution for presentation to the General Assembly for its approval as a UN resolution.

Committee on the Peaceful Uses of Outer Space (COPUOS)

Fourth Committee

Conference on Disarmament (CD)

First Committee



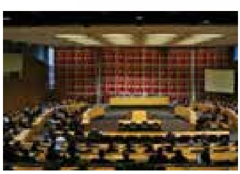
GENERAL ASSEMBLY

SECURITY COUNCIL

Office for Outer Space Affairs (UNOOSA)

SECRETARIAT

TRUSTEESHIP COUNCIL



ECONOMIC AND SOCIAL COUNCIL

INTERNATIONAL COURT OF JUSTICE

The CD is the international forum for negotiating arms control and disarmament matters. One of its core focus areas is the prevention of an arms race in outer space (PAROS). As such, the subject of space and security weapons falls under its purview. The UN Institute for Disarmament Research (UNIDIR) helps provide decision-level information to the CD and identifies potential flashpoints that may lead to an arms race in outer space.

The UNOOSA is responsible for carrying out space-related resolutions passed by the UNGA and maintains the Register of Objects Launched into Outer Space.

The Space Treaties

COPUOS was responsible for the crafting of the five treaties that address activities in outer space. The 1967 Outer Space Treaty (OST) sets out the foundations of outer space law elaborated upon in the other four treaties. Additional non-binding agreements for outer space have been developed by COPUOS to address orbital debris mitigation, cooperative arrangements for sharing remote sensing data, and other related matters.

The Outer Space Treaty was opened for signature in 1967 and entered into force the same year. Over one hundred states have ratified the treaty, which provides the basic framework for international space law. Key principles include: the exploration and use of outer space for peaceful purposes by all States for the benefit of all humankind regardless of their level of development; the barring of national appropriation or claims of sovereignty of outer space or celestial objects; the banning of placing weapons of mass destruction in orbit or on celestial bodies; assigning States the responsibility for and requirement of supervising their national space activities, whether carried out by governmental or nongovernmental entities; establishing that States are liable for damage caused by their space objects; and pronouncing that States shall avoid harmful contamination of space and other celestial bodies.

Rescue Agreement (1968) Requires States to take steps to rescue and assist astronauts in distress and return them to the launching state and to assist launching states in recovering space objects that return to Earth outside the territory of the launching state.

Liability Convention (1972) Outlines the liability of launching states for damage caused by their space objects on the Earth or in space, and procedures for the settlement of claims for damages.

Registration Convention (1976) Requires launching states to maintain a registry of their space objects and to provide the UN with information on the objects they launch into outer space.

Moon Agreement (1984) Reaffirms and elaborates OST provisions applied to the exploration of the Moon and exploitation of resources found on the Moon. Though technically in force, this treaty has been ratified by relatively few countries and is ignored by most.

Elements of Space Governance also include COPUOS endorsement of voluntary guidelines for orbital debris mitigation, negotiations to deal with space weapons and space security at the UN Conference on Disarmament, UN efforts to establish a plan to address the threat of potentially hazardous asteroids, negotiations between public and private entities on international civil space situational awareness, and other efforts.

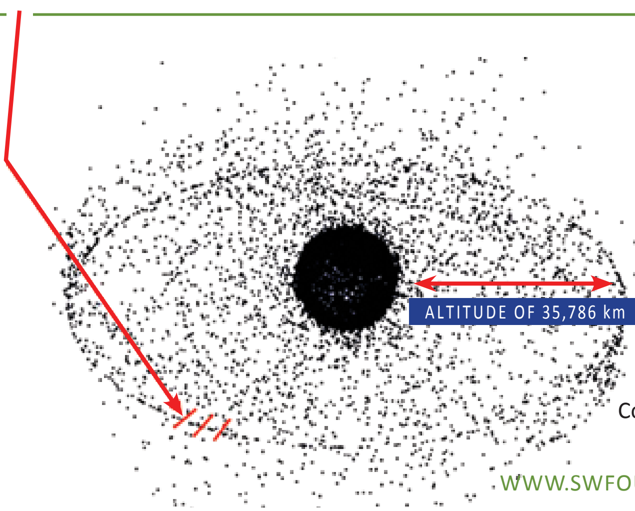
Establishing the elements of systems of governance for outer space translates the basic framework of international space policy into practical, coordinated, and integrated legal infrastructures.

Dealing with Orbital Crowding and Debris

During the 1960s, it became clear that private and public use of geosynchronous orbit for telecommunication and other services would need to be regulated using an international system agreed upon by stakeholder nations. **The International Telecommunication Union (ITU)**, established in 1865 to develop international radio communication standards, was tasked in 1963 by the UN to manage the Geosynchronous Earth Orbit (GEO) belt at an altitude of 35,786 km for purposes of preventing physical and electromagnetic interference. The ITU's Radio-communication Sector is responsible for assignment of GEO slots to States.

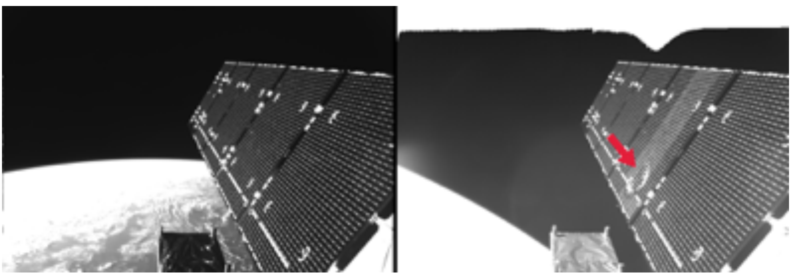
The ITU assigns GEO slots to the Member States by considering three factors:

1. Orbital parameters (west or east degrees longitude).
2. Type of frequencies used.
3. Regions covered on Earth (or footprint).



Courtesy of NASA.

The Inter-Agency Space Debris Coordination Committee (IADC) is an international forum of governmental space agencies for the coordination of activities related to the issues of natural and human-generated debris in space. The primary purposes of the IADC are to exchange information on space debris, to research activities between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities, and to identify debris mitigation options.



Before and after images of an impact by a millimeter-sized particle on the solar panel of the Copernicus Sentinel-1A satellite on August 23, 2016. Courtesy of ESA.

The IADC has published a set of voluntary guidelines designed to reduce the creation of orbital debris. In 2008 most of these guidelines were included in a resolution proposed by COPUOS and passed by the UNGA. Guidelines include:

1. Limit production of debris during routine operations.
2. Minimize the potential for accidental on-orbit breakups.
3. Dispose of spacecraft post-mission.
4. Prevent on-orbit collisions.
5. Prohibit intentional destruction of satellites.

International Initiatives to Ensure Space Sustainability

Growing awareness of the threats to the long-term sustainability of space has prompted governments to take action at both the national and international level.

Over the last few years, three new international initiatives have been created to deal with some of the challenges posed by space sustainability. These initiatives differ from historical efforts in that they are "bottom-up" initiatives that seek to develop voluntary guidelines or norms of behavior, and in some cases involve input from non-State actors. While all of these initiatives are voluntary and non-legally binding, there is broad recognition that they represent an important first step to building consensus on important issues among many countries and space actors.

Group of Governmental Experts on TCBMs

In 2010, the UNGA adopted a Russian proposal to create a Group of Governmental Experts (GGE) to explore possible transparency and confidence-building measures (TCBMs) for space. The GGE was formed in 2011, and included experts from 15 states. The final, consensus report of the GGE was delivered to the Secretary General in July 2013, and included recommendations on how governments can share information with an aim of creating mutual understanding and trust, reducing misperceptions and miscalculations and thereby helping both to prevent military confrontation and to foster regional and global stability. Currently, there are discussions on how to implement the GGE's recommendations through national, bilateral, and multilateral mechanisms.

We must take action now and pursue TCBMs in space. These TCBMs will enhance the long-term sustainability, stability, safety, and security of the space environment. Protecting the space environment for future generations is in the vital interests of the United States and the entire global community.

Frank Rose, former Deputy Assistant Secretary, Bureau of Arms Control, Verification and Compliance, U.S. Department of State. July 24, 2013.

Space Code of Conduct on Outer Space Activities

In 2010, the European Union introduced a "Draft International Code of Conduct on Outer Space Activities" for consideration by the world community. The draft code was an attempt to spell out a broad set of best practices for operating in outer space. While the international community did in general agree on the importance of non-legally binding norms of behavior in order to promote responsible behavior in outer space, the negotiations were bogged down over procedural issues, concerns by some States that a voluntary Code should not be seen as an alternative to legally binding space and arms control arrangements, and related concerns about the inclusion of the right to self-defense in space. The last major international meeting on the issue was held in July 2015 and it has been in stasis ever since.

UN COPUOS Long-Term Sustainability Guidelines

In 2010, the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) established the Working Group on the Long-Term Sustainability (LTS) of Outer Space Activities. The Working Group was tasked with producing a set of voluntary guidelines for all space actors to help ensure the long-term sustainable use of outer space. The Working Group's mandate ended in June 2018. During its mandate, the UN COPUOS member States agreed on 21 guidelines and a context-setting preambular text. The States also agreed to continue their discussions of space sustainability under a dedicated agenda item of the Scientific and Technical Subcommittee of COPUOS.

> **These [LTS] guidelines are really, I believe, going to change the way we work in space, collectively and globally.**
>
> David Kendall,
> former chair of UN COPUOS.
> October 21, 2016

The 21 agreed guidelines comprise a collection of internationally recognized measures for ensuring the long-term sustainability of outer space activities and for enhancing the safety of space operations. They address the policy, regulatory, operational, safety, scientific, technical, international cooperation, and capacity-building aspects of space activities and are relevant to both governmental and non-governmental entities. They are also relevant to all space activities, whether planned or ongoing, as practicable, and to all phases of a space mission, including launch, operation, and end-of-life disposal.

The guidelines are intended to support the development of national and international practices and safety frameworks for conducting outer space activities while allowing for flexibility in adapting such practices and frameworks to specific national circumstances. They are also intended to support States and international intergovernmental organizations in developing their space capabilities in a manner that avoids causing harm to the outer space environment and the safety of space operations.

The guidelines are voluntary and not legally binding under international law. However, despite this, the guidelines can have a legal character in the sense that States may choose to incorporate elements of the guidelines in their national legislation, as has been the case with the COPUOS space debris mitigation guidelines.

States and international intergovernmental organizations are encouraged to implement these guidelines to the greatest extent feasible and practicable, in accordance with their respective needs, conditions and capabilities, and with their existing obligations under applicable international law.

The long-term sustainability of outer space activities is defined as the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations.

Definition developed by the UN COPUOS Sustainability Working Group.

UN COPUOS LTS Guidelines

A. Policy and Regulatory Framework for Space Activities

Guideline A.1	Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities
Guideline A.2	Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities
Guideline A.3	Supervise national space activities
Guideline A.4	Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites
Guideline A.5	Enhance the practice of registering space objects

B. Safety of Space Operations

Guideline B.1	Provide updated contact information and share information on space objects and orbital events
Guideline B.2	Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects
Guideline B.3	Promote the collection, sharing and dissemination of space debris monitoring information
Guideline B.4	Perform conjunction assessment during all orbital phases of controlled flight
Guideline B.5	Develop practical approaches for pre-launch conjunction assessment
Guideline B.6	Share operational space weather data and forecasts
Guideline B.7	Develop space weather models and tools and collect established practices on the mitigation of space weather effects
Guideline B.8	Design and operation of space objects regardless of their physical and operational characteristics
Guideline B.9	Take measures to address risks associated with the uncontrolled re-entry of space objects
Guideline B.10	Observe measures of precaution when using sources of laser beams passing through outer space

C. International Cooperation, Capacity-Building and Awareness

Guideline C.1	Promote and facilitate international cooperation in support of the long-term sustainability of outer space activities
Guideline C.2	Share experience related to the long-term sustainability of outer space activities and develop new procedures, as appropriate, for information exchange
Guideline C.3	Promote and support capacity-building
Guideline C.4	Raise awareness of space activities

D. Scientific And Technical Research And Development

Guideline D.1	Promote and support research into and the development of ways to support sustainable exploration and use of outer space
Guideline D.2	Investigate and consider new measures to manage the space debris population in the long term

Source: UNOOSA, A/AC.105.2018.CRP.22/Rev 1, June 28, 2018.

About SWF

Secure World Foundation is a private operating foundation working with governments, industry, international organizations, and civil society to develop and promote ideas and actions to achieve the secure, sustainable, and peaceful uses of outer space benefiting Earth and all its peoples.

At this point, just half a century into the Space Age, SWF believes it has a unique opportunity to play a role in establishing the secure and sustainable use of the space domain. Central to this opportunity are: increasing knowledge about the space environment and the need to preserve it as a stable and safe operating environment for all space actors; promoting international cooperation and dialogue; and helping all space actors realize the benefits that space can provide.

The Foundation engages with the space and other relevant communities to support steps that encourage the long-term sustainability of outer space activities and the effective use of space to benefit humanity through three primary methods:

1. **Informing**: SWF generates research and analysis for decision-makers to promote creation of sound policy and raise awareness of key issues that may threaten the security, sustainability, and utility of outer space.
2. **Facilitating:** SWF convenes timely public and private meetings with stakeholders on key issues in support of its mission to encourage discussion and constructive dialogue for next steps.
3. **Promoting:** When viable solutions or next steps become apparent, SWF formulates and disseminates policy positions that are aligned with its vision and mission in order to move them from idea to implementation.

With such an important and timely mission, SWF has high expectations of its employees, contractors, and partners. We strive to be a trusted and objective source of leadership and information on space security, sustainability, and other matters within the Foundation's interest. We use a global and long-term lens to examine proposed solutions to the governance of outer space. While recognizing the complexities of the international political and legal environment, SWF seeks to encourage and build relationships with all willing stakeholders in outer space - government, commercial, military, civil society and academia - seeking mutual respect and trust.

SECURE WORLD
FOUNDATION

Promoting Cooperative Solutions
For Space Sustainability

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