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Plans for satellite constellations of hundreds or thousands of satellites have provided new urgency to the question of space traffic management. (credit: OneWeb)

Space traffic control: technological means and governance implications

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Since the first human-made object was launched into space in October 1957, the number of objects orbiting the Earth has risen into the thousands. The term “space traffic” refers to all spacecraft (both active and inactive) and space debris that are currently orbiting the Earth. The current amount of space traffic in orbit is quite striking. According to NASA, there are more than 500,000 pieces of debris the size of a marble or larger, orbiting the Earth, travelling at speeds of up to 28,000 kilometers per hour, enough to damage a satellite or spacecraft upon contact. In fact, at that speed, even “tiny flecks of paint can damage a spacecraft”. Data provided by the United States Space Surveillance Network (SSN) quotes that there are around 21,000 objects larger than 10 centimeters orbiting the Earth and more than 200,000 smaller objects.

The variety of objects in space is large. Orbital debris comprises expired spacecraft, spent rocket boosters, individual pieces of space assets, and even objects such as gloves. The last few decades have seen a drastic increase in the amount of objects in the low Earth orbit (LEO) domain—between 200 and 2,000 kilometers in attitude—which is by far the most congested orbit and contains important space assets such as the International Space Station (ISS) and other crewed spacecraft, as well as the Hubble Space

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Telescope. The economic importance of the LEO domain is growing rapidly with the emergence of new space systems, comprising hundreds to thousands of small or medium-size satellites, for Earth observation and telecommunications. These new space systems create new space traffic risks and are themselves at risk from others satellites and debris.

The amount of traffic in space complicates the task of launching new satellites. Launch windows already depend on a variety of factors and thus must be very carefully planned. Windows for launch can be limited, and the need to assess space traffic to avoid collisions simply adds another factor for consideration. Today, more than 60 nations spend a portion of their national budgets on space projects and, increasingly, private companies are launching new objects into orbit. Over the course of several years, scientists have noted a stark increase in the number of times two space objects have passed closer to each other than the minimum distance generally understood as safe. Any object larger than one centimeter can cause damage to satellites and other space assets, and most space debris are uncontrolled travel at high speed. The "over-congestion" of key orbits greatly decreases their utility, as collisions become far more likely. Collisions between existing objects can create further debris, subsequently increasing the chance of collision and jeopardizing future space travel.

The feasible destruction of satellites and other space assets has many negative implications for research, military and communications technologies, which we rely on for logistical, commercial and scientific services. For example, the ISS must be frequently maneuvered to avoid collisions, which is costly. In 1996, the French satellite Cerise was damaged by the debris of a French rocket which had been launched 10 years earlier, degrading the satellite significantly. In 2009, a defunct Russian satellite destroyed a functioning Iridium commercial satellite in a collision, adding over 2,000 pieces of debris to the known inventory of space junk. Moreover, there have been instances of collisions involving tracked objects, with space debris twice causing the collisions, and a third incident involving a segment of an operational satellite which had exploded.

In addition, the Chinese anti-satellite (ASAT) weapons test of 2007, in which China destroyed one of its weather satellites in polar orbit to test a ground-based ASAT missile, caused enormous damage, adding up to 2,087 objects to the trackable space objects database and resulting in the production of over 35,000 smaller pieces of debris down to once centimeter in size. This incident sparked severe geopolitical tensions, as generating such a large amount of debris can drastically threaten other space objects following the same orbit. In general, the prospect of large quantities of uncontrolled objects in congested orbits has the potential to increase tensions between nations, particularly in a case where an uncontrolled and unidentifiable object were to collide with a nation's military or commercial space asset.

Managing space traffic

Vital immediate concerns surrounding space traffic management include collision avoidance, improving the utility of less congested orbits (such as geosynchronous orbit), the congestion of Sun-synchronous orbit (SSO) and LEO, and dangers to human-rated craft. To mitigate such hazards, both space agencies and private companies are coming up with innovative responses. However, one should stress the fact than detecting and following small space objects in space, with optical and radar devices, is a very difficult technical endeavor. It has been historically mastered only by the United States, which maintains the major global database on satellite orbits; Russia (but the operational status of the system is unknown); France to a certain extent; and possibly China.

The US Department of Defense manages a very accurate catalogue on objects larger than a softball in Earth orbit. NASA also cooperates with DoD and they share the responsibilities for characterizing the satellite environment, which includes orbital debris. The Space Surveillance Network (under the structure of the DoD) can currently track and catalogue objects with a diameter between five and ten centimeters in LEO and up to one meter in geosynchronous orbit.

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The risks of collision are divided into three categories, depending on the size. For objects with a size of ten centimeters or larger, maneuvers for collision avoidance are normally quite effective. Smaller objects are usually too difficult to track and too large to shield against.

Debris shields are useful especially for debris that is smaller than one centimeter. Ironically, shields could become debris themselves, as it happened in March 2017, when a debris shield about 1.5 meters long and weighing eight kilograms installed by US astronauts on the International Space Station was simply lost as it floated away. This shield joined the more than 21,000 tracked objects in space. This is, however, a rare occurrence as larger objects are not frequently lost (astronauts may occasionally lose smaller objects, but it is not common to lose larger pieces.) The previous known incident happened in 2008, when an astronaut lost half of her tool bag during a spacewalk, as she was working on a solar panel. Incidents such as these may be isolated, but the sheer quantity and speed of debris makes collisions risks very serious.

NASA has long-standing experience in setting guidelines for assessing the seriousness of threats related to the possible approach of orbital debris to a spacecraft. NASA started implementing conjunction assessments and collision avoidance for human spaceflight back in 1988 with the shuttle mission STS-26. In 2005, NASA implemented similar measures to mitigate the risks of collision for high-value robotic missions. The conjunction assessments for all the designated NASA space assets are performed by the DoD’s Joint Space Operations Center, which then informs NASA.

“Debris avoidance maneuvers” are normally based on calculations. If the probability of a collision is calculated to be greater than 1 in 100,000, a maneuver will be conducted, unless it would jeopardize the mission’s objectives. When the probability of a collision is greater than 1 in 10,000, a maneuver is automatically conducted, except for situations when the maneuver could lead to additional risks to the crew. These maneuvers can be planned and executed in a matter of hours and they normally occur from one to several hours before the moment of conjunction. On many occasions, however, the tracking data is not precise enough for maneuvers to be conducted so the solution can be that the crew is moved into the Soyuz spacecraft that transfers crew to and from the station. Indeed, the Soyuz act as “lifeboats” for crew members in the event of an emergency.

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However, national space programs and private companies are developing advanced systems for tracking and classifying thousands of pieces of space debris, which are currently untracked. One effort to monitor space traffic is the Space Fence program, which is being developed by Lockheed Martin for the US government and will, according to the company, “make 1.5 million observations a day to detect, track, measure and catalog items as small as a baseball and will support catalog growth to 200,000 objects." This project aims to increase the amount of space objects we are currently able to survey by a factor of ten. Other technological and engineering-based responses include proposals to create autonomous hazard avoidance systems for space assets. Space assets could also be equipped with maneuvering and controlled end-of-life re-entry capabilities, to avoid the generation of debris through collisions when an object becomes defunct. In the long term, experts have called for the establishment of space debris remediation systems, whereby objects can be removed systematically. In fact, there have been numerous proposals in this regard, including from Gecko technology, the EUSO telescope, Space Sweeper with Sling-Sat, and the Electrodynamic Debris Eliminator, among many others.

Other mitigation strategies are rooted in cooperation. The United Nations Office for Outer Space Affairs (UNOOSA), an intergovernmental body which implements decisions on outer space taken by the United Nations General Assembly and United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), recommends providing the satellite owner with information on avoidance maneuvers and tracking data, from which point they can conduct their own cost-benefit analysis on how to best avoid collisions. In fact, some space agencies (particularly in the US, as stated before) and companies do collect and disseminate data to help satellite owners avoid collisions. Real-time, accurate positioning data for objects are crucial for establishing sustainable orbits. Additionally, geosynchronous data sharing allows space actors to more efficiently plan their maneuvers by creating a clear separation between stationkeeping spacecraft and mobile satellites.

Yet there are problems with collecting the data necessary to avoid collisions, as no state has, in principle, the right to monitor any other actor's activities in outer space and thus cannot obtain sufficient or uniform data, even if, as stated before, the US satellite catalog is a *de facto* reference. Currently, states which have signed the 1974 Convention on the Registration of Objects Launched into Outer Space agree to inform the Secretary General of the United Nations about the details of spacecraft launches for which they are responsible. However, states do not currently share enough data among themselves, with several actors collecting their own incomplete data, such as through the SSN. Sharing this data in the interests of everyone would provide a solution to this issue, but the geopolitical sensitivity of revealing certain space activities (the US catalog is, for instance, silent on some US military satellites) discourages states from sharing such information. Aside from recommendations provided by international organizations, the private sector is increasingly making its own suggestions for space traffic management, as this sector has an obvious interest in maintaining the future usability of space.

Another solution to the issue of space traffic may be the allocation of certain orbits for specific activities. For example, there have been calls for the creation of various zones for robotic Earth observation and monitoring satellites and other zones for the disposal of dead satellites and waste.

An international framework for space traffic management?

Despite the possible technological developments which could mitigate issues stemming from space traffic, many onlookers question the effectiveness of fragmented engineering efforts, arguing instead for the necessity of adopting a comprehensive international regulatory framework for coping with space traffic management. Indeed, international space law remains largely based on the 1967 Outer Space Treaty and a few other treaties. Domestic laws and regulations provide some regulations on conduct for outer space activities, but currently there are no legally-binding international rules on space traffic.

However, discussions on the concept of space traffic management (STM) have begun. STM was a single item at the UN COPUOS Legal Subcommittee in 2016. Before that, detailed studies were conducted on this issue in 2006 by the International Academy of Astronautics (IAA) and in 2007 by the European Space Policy Institute (ESPI), with both papers expressing a deep concern about the lack of regulations and provisions required for a comprehensive space traffic management regime. According to these studies, current deficiencies in international regulations include the lack of compulsory pre-launch notification systems, in-orbit maneuvering systems, right-of-way values for space objects, rules for spacecraft transporting humans, zoning rules, debris mitigation, and regulations for reentry.

In their 2007 report, ESPI argued that an international treaty would be a starting point for creating a framework for STM. However, the sensitivity and state-centric nature of the international legal playing field has rendered this objective difficult. In particular, UN COPUOS has a reputation for extremely slow decision-making, with its member states reluctant to accept changes in regulatory frameworks. These claims are reflected by the organizations inability to pass any binding provisions for over 20 years. Topics such as enforcing regulations, establishing arbitrary measures to resolve disputes, and the possibility of sanctions are extremely geopolitically sensitive and thus contribute to slow progress.

As outer space is the last true global commons, it must remain available for global use, to the benefit of all humanity. The international community must act fast to design a system in which data-sharing on space activities becomes a norm and which incentivizes spacefaring nations to avoid the over-congestion of key orbits.

Nonetheless, the current legal framework is clearly outdated and insufficient to regulate situations which now include non-governmental actors and private companies. Consequently, states and companies tend to focus on developing their own tracking systems, and organizations such as the International Telecommunication Union (ITU) have established regulations which have essentially become soft law. However, it is clear that a binding legal framework for regulating space traffic is absent. This absence is of great significance, as an active traffic management regime could allow tracking systems to move beyond simply establishing the location of space objects and invest them with the capability to understand the intentions and adaptable trajectories of various space assets. Such a system would have clear implications for global security, as it could reduce ambiguity and deception surrounding space objects capable of threatening vital space assets.

Conclusion

The challenges and potential solutions surrounding space traffic highlight the need to view space activity regulation as a comprehensive topic, which requires cooperative mitigation strategies.

As outer space is the last true global commons, it must remain available for global use, to the benefit of all humanity. The international community must act fast to design a system in which data-sharing on space activities becomes a norm and which incentivizes spacefaring nations to avoid the over-congestion of key orbits. In the future, it will be crucial to improve space governance in order to prevent new collisions. Coordination between all space actors in space traffic control must become a priority in order to keep space usable and to sustain our current activities in space for future generations. Another solution could be the creation of a group comprising representatives of all the major space nations, who would provide data from their countries and act as an apolitical body solving international problems.

Additionally, with the increasing economic importance of commercial space programs, the creation of space traffic control authorities for civil activities (on the model existing in civil aviation), could be considered, and a debate is going on in the US on the possible transfer of a part of space situational awareness (SSA) activities from defense organizations to a civil organization like the Federal Aviation Administration. Eventually, such a move could be replicated in other countries and perhaps extended at the international level.

From a geopolitical perspective, the importance of controlling space traffic is paramount. As states increase their reliance on outer space technology for military, communications, and scientific services, the stakes of potential collisions get higher. Without a means of regulating orbital activities in space, we risk heightening geopolitical tensions, but we can control this through greater international cooperation.

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