Observations on the safety risks of nearby space congestion

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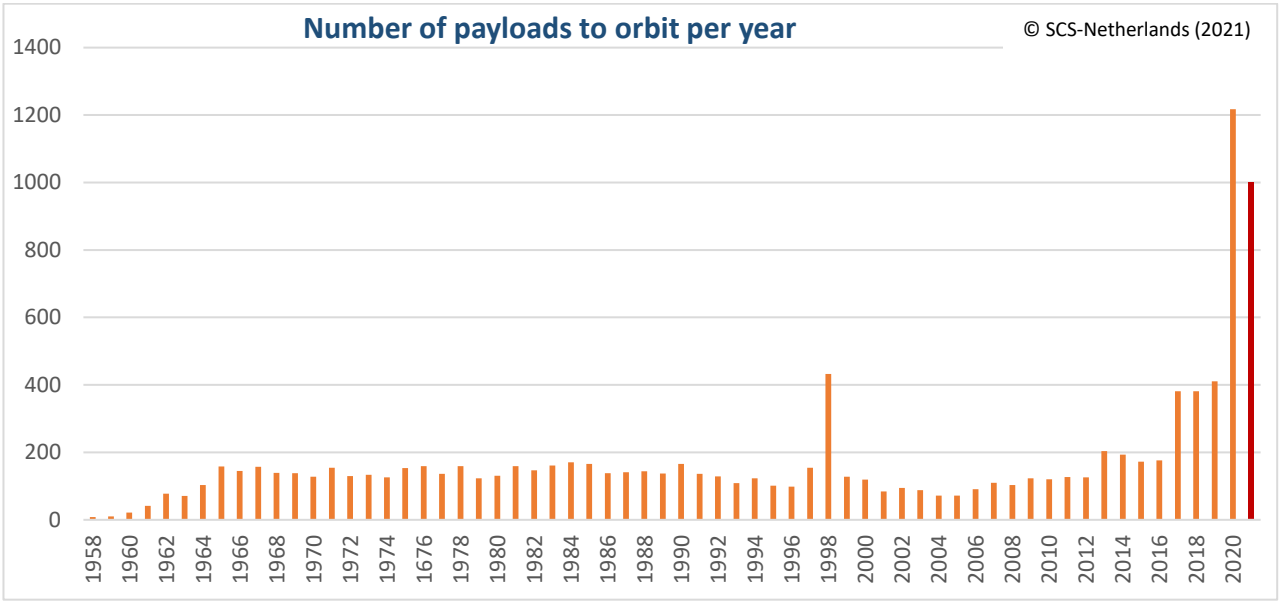
Satellite density in near-Earth space

According to the satellite database of the Union of Concerned Scientists (UCS), on January 1, 2021, 3,372 active satellites were in orbit, a 46.6% increase from the 2,298 active satellites of 2019. On that date, the US Space Force / Space Surveillance Network has more than 20,000 dead satellites and observable space debris[1] registered and monitored. [*Depending on the sources consulted, numbers in this report may vary slightly*].

According to the Index of Objects Launched into Outer Space, which is maintained by the United Nations Office for Outer Space Affairs (UNOOSA), as of March 31, 2020, 5,774 individual satellites (active or dead) were in space; an increase of 15.78% compared to the beginning of 2019.

Space-Track.org recorded that in 2019, 411 payloads (satellites) were launched into space and 381 in both 2018 and 2017. Together with the exception year of 1998, these were the largest annual numbers ever recorded. However, these records were completely smashed in 2020 by the release of 1,217 payloads. [*1998 is an exceptional year with the launch of IRIDIUM (telecom) (40 satellites), ORBCOMM (internet) (18 satellites) and FLOCK (earth observation) and other CubeSats) (110 satellites)*]

Since October 4, 1957, 10,334 payloads have been launched into space, according to Space-Track.org (reference date January 1, 2021). However, almost a quarter (23.1%) of these objects (2,390) have been released into space in the past four years alone. This is a phenomenal growth and that is nothing compared to what is yet to come. In the first two months of 2021, with 10 months to go, the counter was already at 306. SCS expects for 2021, depending on the almost unpredictable supply of CubeSats and rideshare satellites, at least 1,000+ payloads launched.



[1] Space debris here is understood to mean all things that pass through space and cannot be influenced / controlled from Earth. This e.g. includes dead satellites and used rocket stages

The growth in the number of satellites launched over the past decade was started with the development / launch of many CubeSats and the large number of new satellite constellations for Earth observation (including Planet Labs). However, the latest growth spurt is driven by satellite internet entrepreneurs such as Starlink (SpaceX) and OneWeb / Airbus, while other companies have plans to launch tens of thousands of satellites in the near future.
NB. The above numbers represent payloads / satellites in all sizes and types. For the purpose of this report, it concerns numbers of objects in space, not weight and / or volume.

Differentiation

Using the UCS database, it can be determined that 1,918 satellites (more than half of the 3,372 active satellites) are in orbit around the earth below 2,000 km. This means the greatest satellite density (number of satellites per unit of space) ever achieved.

Classification by function (reference date January 1, 2021)
- Communications: 1,211 satellites; increase of 55% compared to January 1, 2019;
- Earth observation: 884 satellites; increase of 24% compared to January 1, 2019;
- Technology: 312 satellites; increase of 40% compared to January 1, 2019;
- Navigation: 148 satellites; increase of 8% compared to January 1, 2019;
- Space observation: 93 satellites; increase of 9% compared to January 1, 2019.

Commercial companies that have launched the most satellites as of March 1, 2021
- SpaceX : 1,143 Starlink satellites (internet);
- Planet Labs: 21 SkySat, 5 RapidEye and 299 CubeSat satellites (Earth observation);
- Iridium: 170 Iridium satellites (communication);
- OneWeb: 110 satellites (communication);
- Spire Global: 90+ CubeSat satellites (Earth observation).

Overview of companies / plans for large constellations *)
Amazon | Amazon announced a large broadband internet satellite constellation in April 2019, planning to launch 3,236 satellites in the next decade (Project Kuiper), a satellite constellation that will work in concert with Amazon's previously announced large network of twelve satellite ground station facilities announced in November 2018.
Chang Guang Satellite Technology (CGSTL) | CGSTL is the first commercial remote sensing satellite company in China which operates Jilin-1 satellites. 16 satellites (March 1, 2021) have been launched. Complete constellation will have 138 satellites launched by 2030.
Hongyan | The Hongyan / Hongyun project (CASIC) plans a constellation of around 320 LEO satellites. They have launched some test satellites, expect to have 60 satellites in orbit and operating around 2023 and will be able to provide global coverage with the full constellation by 2025.
ICEYE | ICEYE is a Finnish microsatellite manufacturer attempting to develop a satellite constellation of 18 microsatellites equipped with synthetic-aperture radars in collaboration with the European Space Agency (ESA).

Iridium | The Iridium satellite constellation provides, since 1998, L-band voice and data information coverage to satellite phones, pagers and integrated transceivers over the entire Earth surface. The constellation consists of 66 active satellites in orbit, required for global coverage, and additional spare satellites to serve in case of failure.

OneWeb | OneWeb is a planned 650 satellite constellation (Phase One) to provide global satellite Internet broadband services to be completed in 2022. In March 2020, OneWeb filed for Chapter 11 bankruptcy protection but maintained the satellite operations center for the 68 satellites already in orbit. In January 2021, OneWeb announced that it would reduce the number of satellites in Phase Two from 47,844 to 6,372.

Planet (Labs) | Planet designs, builds, and launches earth observation satellites. Doves CubeSat satellites make up the world's largest constellation of Earth-imaging satellites. 299 CubeSat satellites launched per March 1, 2021. New Doves satellites are launched into orbit every three or four month.

Samsung | A 2015 proposal from Samsung outlined a 4,600-satellite constellation orbiting at 1,400 km that could provide a zettabyte per month capacity worldwide, but by 2020, no more public information had been released about this constellation.

Spire Global | Spire Global is a space-to-cloud data and analytics company that specializes in the tracking of global data sets powered by a large constellation of nanosatellites, such as the tracking of maritime, aviation and weather patterns. The company has launched some 125 Lemur CubeSats of which more than 90 are operational, being the largest by number of sensors.

Starlink | Starlink is a satellite internet constellation being constructed by SpaceX providing satellite Internet access. The constellation eventually will consist of thousands of mass-produced small satellites in LEO.

Telesat | Telesat announced a small 117 (up to 512) satellite constellation in 2015 with plans to deliver initial service in 2021.

*) A number of companies / plans have already been defunct (Celestri, 63 satellites; LeoSat, 108 satellites; Teledesic, 1000+ satellites) or partnerships are being sought (Boeing and OneWeb).

Conclusion 1

Over the next decade, the number of satellites being launched into space will continue to explode. Despite the fact that satellites are actively being brought back to Earth at their end of life and the natural decay of satellites, the satellite density will increase accordingly. Market research firms predict that production and launch of small satellites will rise to 10,000 over the next decade and could potentially generate $ 50 billion in cumulative revenue (which is the main drive of this increase in satellites). Many of these satellites are expected to be part of global constellations for communication in all forms. A close second is earth observation. The development and miniaturization of passive sensors in a wide frequency range and active sensors such as radars will only increase the application of small satellites.

Space Traffic Management (STM) and Space Situational Awareness (SSA)

The launching of satellites into space and / or the provision of specific satellite service, for example in the field of earth observation and communication, or commercial, military or scientific application, is not only technical in nature. National interests play a major role in operating in the international space and therefore international agreements and partnerships are important to regulate this.

On January 29, 2020, two dead satellites nearly collided with each other. One was the Gravity Gradient Stabilization Experiment (GGSE-4) (USAF) and the other was the Infrared Astronomical Satellite (IRAS), a space telescope jointly designed by NASA, the Netherlands (NIVR) and the United Kingdom (SERC). Both dead satellites were in themselves a space hazard and there developed an unusually high chance of colliding with each other. GGSE -4 and IRAS passed each other at about 18 meters. This was a threat from the launch of satellites in the past.

On March 11, 2021, NASA ground controllers sent commands to the International Space Station (ISS) to release a 2.9 ton cargo pallet loaded with old nickel-hydrogen batteries. This is the most massive object ever having been released from the ISS. This uncontrollable garbage truck is expected to be two to four years in orbit before it plunges into the earth atmosphere. NASA said in a statement that it expects that the cargo pallet will harmlessly burn-up in the atmosphere. NASA did not mention the risk that this unguided piece of junk could collide with a satellite or another piece of space debris in the meantime. This is a threat emerging in the present and will continue for the next two to four years.

On September 2, 2019, the European Space Agency (ESA) tweeted that it has diverted one of its satellites, the earth observation satellite Aeolus, to avoid a potential collision with a SpaceX Starlink satellite. *For the first time ever, ESA has performed a 'collision avoidance maneuver' to protect one of its satellites from colliding with a 'mega constellation'*. In general, collision avoidance maneuvers are quite common - ESA conducted in 2018, 28 such maneuvers - but usually these events are caused when satellites crosses paths with dead satellites or space debris. However, in this case the Aeolus satellite was on a potential collision course with an active satellite owned by SpaceX. In a later statement, SpaceX explained that early estimates indicated that the risk of a collision was very low and, at the time, it believed no evasive action was needed. They said they would have better coordinated with ESA had the situation worsened, but a bug in the paging system of the Starlink Satellite prevented SpaceX to receive an update on the crash risk.

The last clash in earth orbit of two satellites took place on February 10, 2009, when an inactive Russian military communications satellite (Cosmos 2251) collided with an active commercial communications satellite from the American company Iridium. The clash between the American Iridium and Russian Cosmos produced nearly 2,000 pieces of space debris larger than a tennis ball, most of which will stay in orbit for decades to come. How many smaller pieces (than a tennis ball) of space debris this collision produced, is unknown.

Prior to the collision between the Iridium and Cosmos satellites, there had been clashes between space debris or between a satellite and space debris, but not between two satellites. There are other suspected incidents of active satellites that have been affected by space debris, but none have resulted in the destruction of those satellites.

At the time of the collision between the American Iridium and the Russian Cosmos satellites (2009), fewer than 1,000 active satellites were in orbit and about 15,000 pieces of space debris had been cataloged. The only public source of information on approaches and collisions between space objects was the US Air Force's First Space Control Squadron that monitored only approaches of 'national security satellites' and manned space objects. Probably as a result of the collision between the Iridium and Cosmos satellites, the US policy changed in 2010. The US Air Force 's Space Situational Awareness (SSA) mission has been broadened to provide approach alerts to all satellite operators in the world.

The US Air Force's First Space Control Squadron is currently monitoring all space traffic and informs stakeholders to avoid collisions. When they detect a potential collision, they notify both parties so the operators can find the best course of action. Regulations require sending notifications when there is more than 1 in 10,000 chance of a collision. Today, this information exchange is done by exchanging emails - an archaic process that no longer seems viable as more and more satellites in space mean more space traffic. Many of these types of messages at the same time can / will cause a blockage in some computer system or end up as junk e-mail in another. This example shows that in the absence of rules and communication protocols, the avoidance of collisions depends entirely on the pragmatism of the operators involved.

Space Traffic Management (STM) is the provision for operating safely in space. This includes, in any case, being able to safely (without being bothered by satellites / space debris) launch satellites to space, operate those satellites and manage them in a safe manner or continue to manage them at the end of their life or bring them back to earth. Preventing the creation of space debris is mandatory in this respect. STM can only be effective if one is aware of what is present in space and how it moves (Space Situational Awareness (SSA)). Without appropriate and accurate information about the space environment and activities in space (SSA), it is impossible to effectively manage or monitor the space environment (STM) in accordance with international obligations. One cannot exist without the other.

SSA Organizations (not complete)

US S pace Force Space Surveillance Network
Detects, tracks, catalogs and identifies artificial objects orbiting Earth. The system is the responsibility of United States Space Command and is operated by the United States Space Force.

US SSA Sharing Program
Promotes data exchange with other organizations tracking space debris.

ESA SSA Program
Develops capabilities to track objects in orbit that could disrupt other satellites or impact ground-based infrastructure.

Russian Military Space Surveillance Network (SKKP)
Russia's equivalent of the US Space Force Space Surveillance Network. The SKKP catalogs space objects and tracks and predicts their location in orbit.

International Scientific Optical Network (ISON)
Partnership of scientific and academic institutions around the world organized by the Russian Academy of Sciences in Moscow.

Space Data Association (SDA)
An international not for profit organization or satellite operators working to, in part, enhance the "accuracy and timeliness of collision warning notifications."

Conclusion 2

SSA plays a role in political initiatives to address sustainability and safety in space. Information exchange on space activities was brought up by the United Nations Group of Government Experts (2013) as an important transparency and confidence-building measure for space activities. The United Nations Committee for the Peaceful Uses of Space (UNCOPUOS) discusses SSA data exchange as part of its agenda item on the long-term sustainability of activities in space.
There is a growing discussion on a national and international level about Space Traffic Management (STM). Although there is no consensus definition, STM usually refers to operational, policy and regulatory measures taken or to be taken, to minimize the impact of space debris and congestion in space.

Incidents of (near) collisions - of which there are many - require better systems to prevent (near) collisions in the future. Maybe space travel should check out its colleagues from air traffic control. Improved worldwide SSA capabilities are a precondition for a future STM system and verification of contracts, whatever form they take.

Consulted sources (February / March 2021)

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The technical challenges of better Space Situational Awareness and Space Traffic Management - ScienceDirect
US Government Looks to Mitigate Space Congestion (nationaldefensemagazine.org)
US military keeps sharp eyes on orbit as congestion grows - SpaceNews

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