SMALL SAT MARKET INTELLIGENCE

Q2 2018

SMALL SATELLITE MARKET INTELLIGENCE REPORT

This issue of the Satellite Applications Catapult's quarterly Small Satellite Market Intelligence report provides an update of the small satellites launched in Q2 2018 (1st April to 30th June 2018). This edition also includes a closer look at space debris with a focus on small satellites and future technologies.

CATAPULT
Satellite Applications

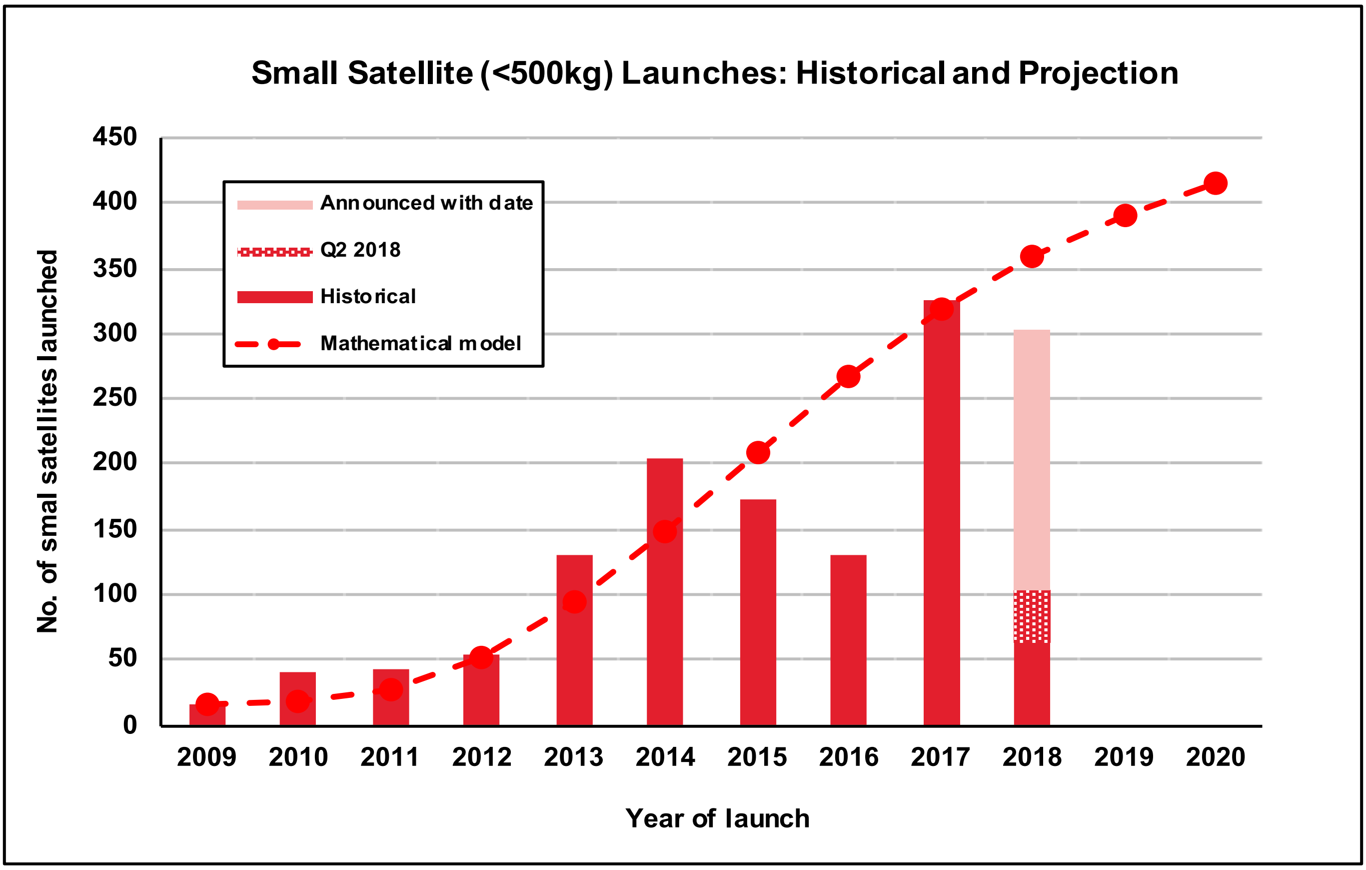
SMALL SATELLITES FACTS AND FORECASTS

Overview

41 small satellites were launched in Q2 2018, a decrease from the Q1 total of 63 and the lowest amount since Q3 2016. These satellites were spread over 10 launches with the greatest number of satellites on one launch being 15 on the Antares launch to the ISS in May; many of the satellites on this mission were part of NASA's

41 small satellites were launched in Q2 2018

ELaNa program. Unlike last year, 2018 is set to have few high-quantity launches with only three further launches scheduled to carry over 20 small satellites. It is possible that this will be increased as further details are given on launches later in the year.

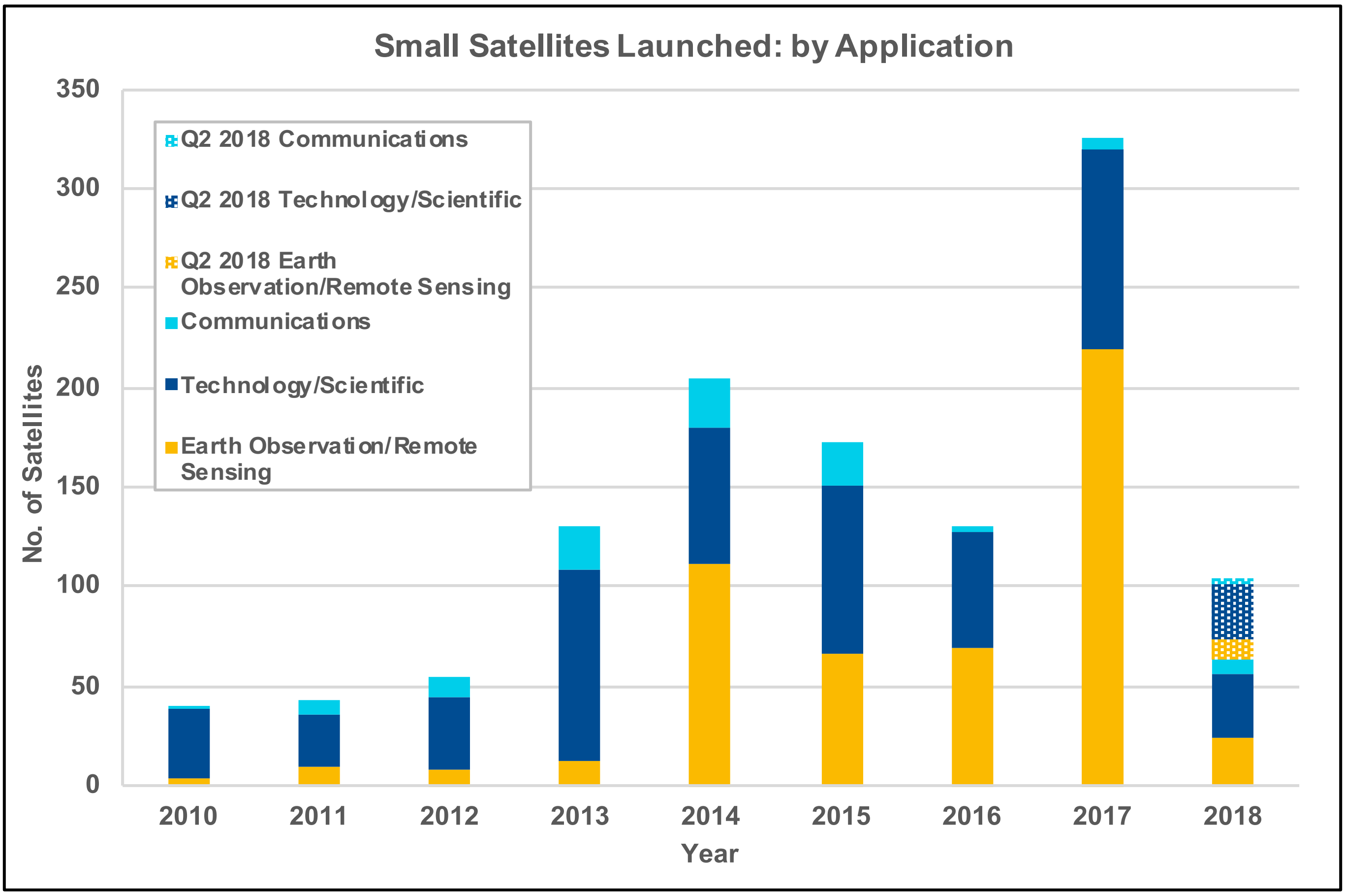


The mathematical model line in the graph above (simulating an accelerating market uptake from low levels in 2009 followed by a levelling off) provides a general trend over 5 years and not a prediction per year. Launch failures in 2015, with knock-on effects in 2016 and 2017, can explain the offset between actual launches and the model. Last year's high quantity PLSV launch of 103 small satellites is unlikely to be matched, partly due to Planet's reduced launch manifest this year.

Progress in the nascent small launcher industry remains gradual, with the first commercial launch of Rocket Lab's Electron rocket further delayed from its late June launch window due to a problem with a motor controller. The new launch window for Electron is to be confirmed, while Vector and Virgin Orbit have not provided firm dates for their respective first launches.

The second half of 2018 is expected to see the first commercial launches of several vehicles, including SpaceX's Falcon Heavy (carrying 29 small satellites), Virgin Orbit's Launcher One and Rocket Lab's Electron. Furthermore, despite delays, the first of the OneWeb satellites are due to launch in Q4.

Application



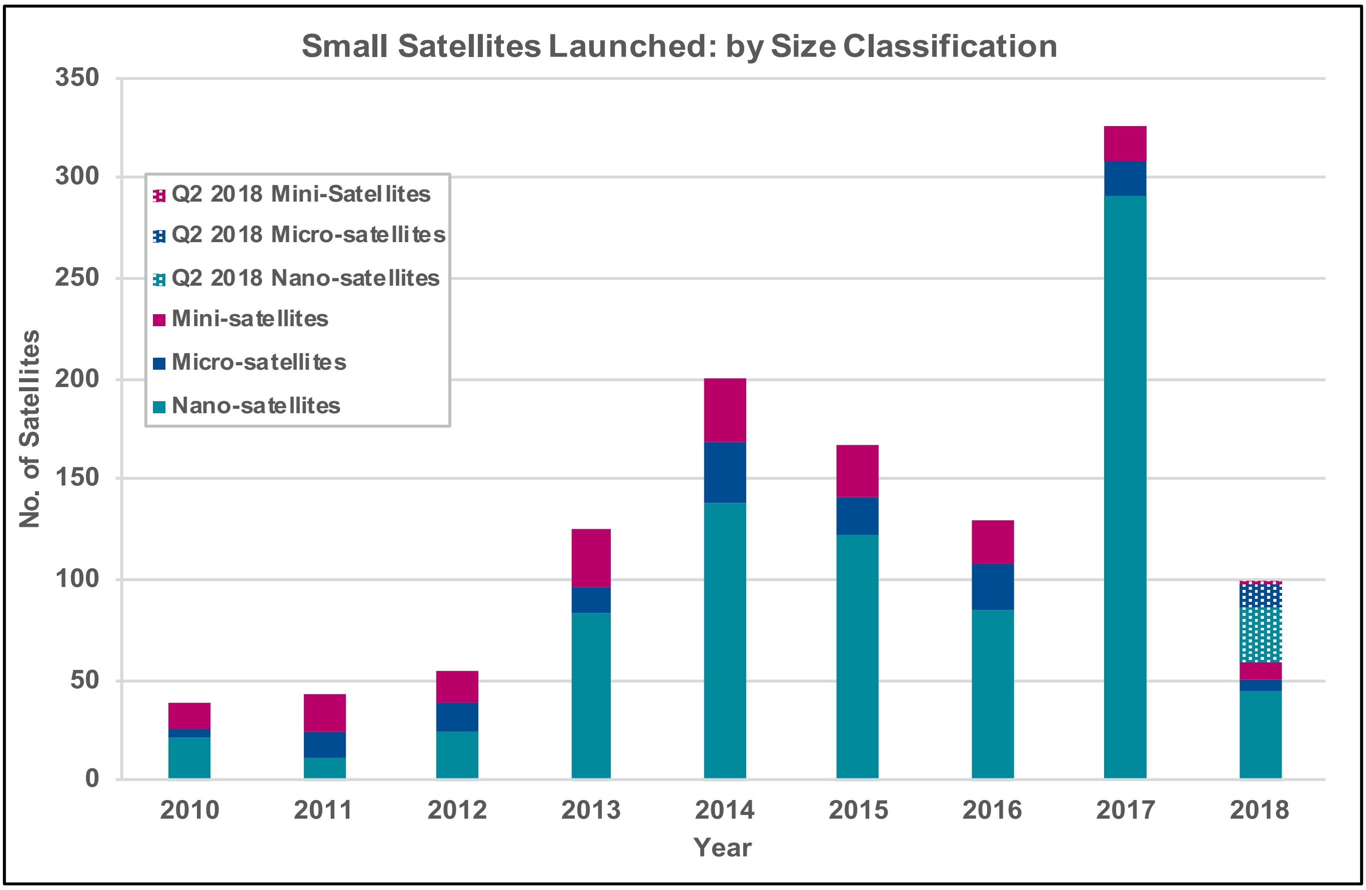
Applications are defined by the primary objective of the mission with the following groupings:

- Communications: the objective of the mission is to transmit or receive signals to/from a user terminal or gateway;
- Technology/Scientific: the objective of the mission is to gather knowledge to better understand physical phenomena or to test the functionality of a payload or equipment;
- Earth observation/Remote sensing: the objective of the mission is to provide imagery or data relating to the Earth or its atmosphere.

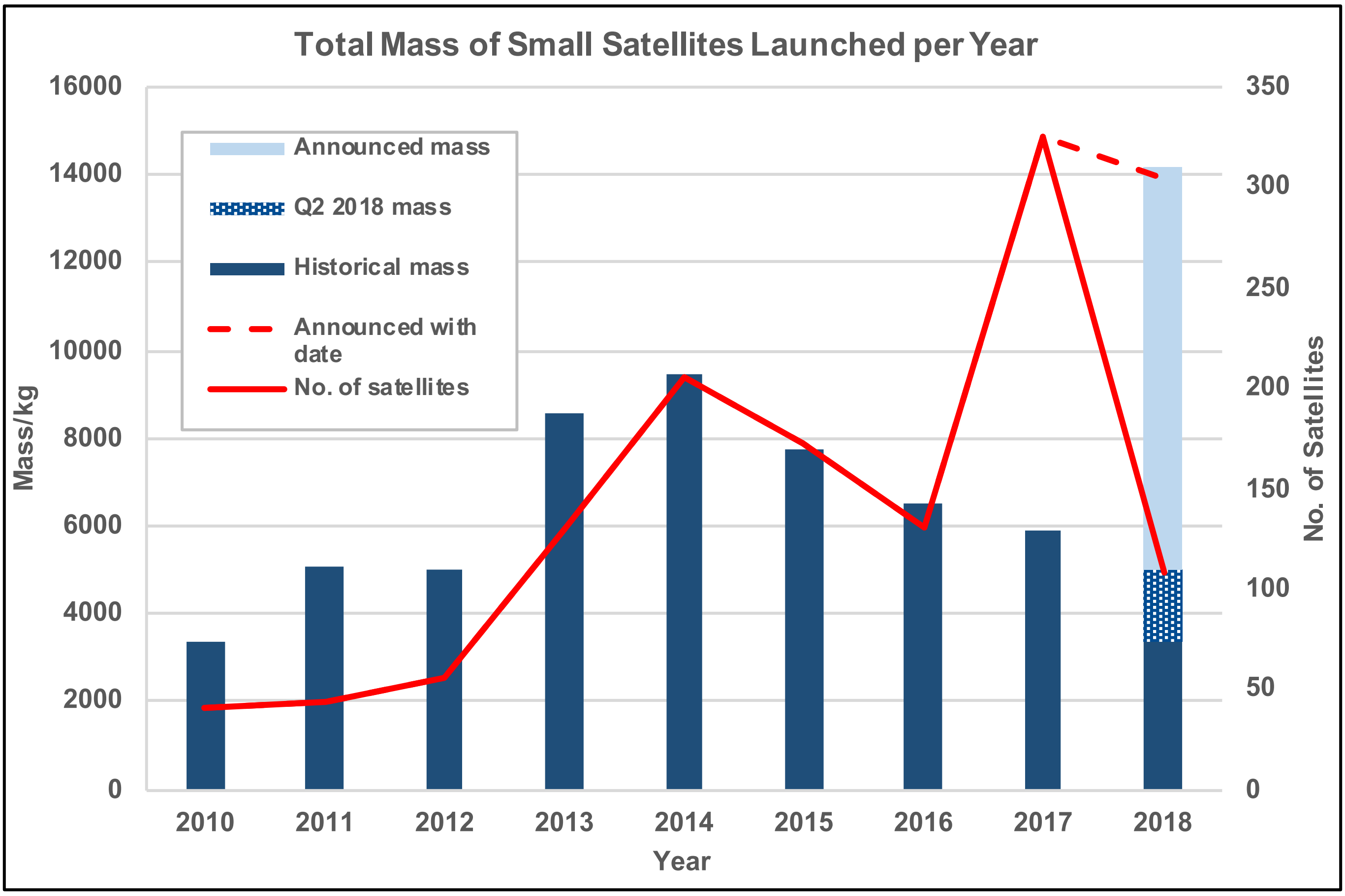
In Q2 2018 Technology/Scientific remained the dominant application, making up 58% of small satellites launched. This comprises CubeSats launched by universities and schools with a small number of technology demonstration satellites. Programmes to assist educational institutions and small nations to launch satellites have contributed strongly to this trend, including seven this quarter supported by NASA's ELaNa programme and the three from the Joint Global Multi-Nation Birds Satellite Project.

Size

SATELLITE CLASSIFICATION	SATELLITE SUBCLASSIFICATION	ASSOCIATED WET MASS RANGE
Small Satellite < 500 kg	Mini-satellite	100 kg - 500 kg
	Micro-satellite	10 kg – 100 kg
	Nano-satellite	1 kg – 10 kg
	Pico-satellite	0.1 kg – 1 kg



Nano-satellites remain the most popular, comprising 68% of small satellites launched - similar to Q1. The 6U configuration continues to increase in popularity, with 15 launched so far this year compared to 14 in all of 2017. Later in 2018 a launch of ten OneWeb satellites and two Falcon launches carrying many micro and mini-satellites will increase the proportion of more massive small satellites. The proportion of pico-satellites, of which 4 were launched in 2018 so far, is due to increase with the launch of three PocketQubes and at least 12 Twiggs Space Lab ThinSats later this year.



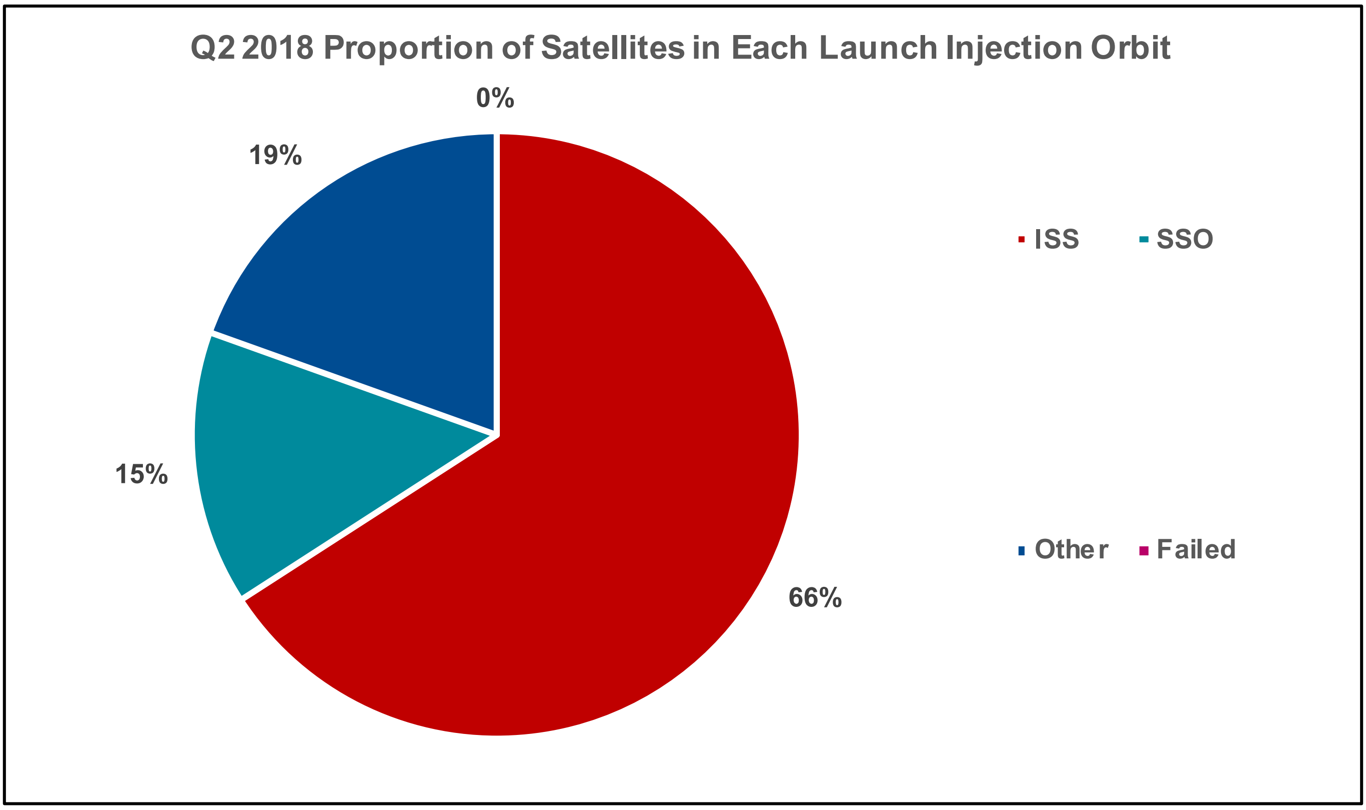
2017 stands out as an anomaly with a high number of satellites and low total mass due to the large number of Spire and Planet satellites launched. This shows the sensitivity of the data to a small number of companies.

The total mass of small satellites launched in Q2 was about half of that launched in Q1, despite the number of launches leaning towards two thirds of that in Q1, implying the average mass of small satellites decreased in Q2. This follows the general trend of the last decade. By the end of the second quarter, the mass of small satellites launched in 2018 had almost reached that of those launched in all of 2017; announced launches are set to more than double this total by the end of the year. The two micro-satellites launched in Q2 (China's Queqiao and NASA's TESS) comprised almost half of the total mass in this period.

By the end of **the second quarter,** the mass of **small satellites launched in 2018** had almost reached that of those launched in all of 2017; **announced launches are set to more than double** this total by the end of the year.

[1] For CubeSats of unpublished mass, it was assumed that they massed 1.3kg per unit, leading to an uncertainty of ±1% in the total mass featured in the graph

Orbit



Q2 2018 saw 66% of small satellites launched to the International Space Station (ISS), comprising Falcon 9, Atlas and Antares launches. Just 6 small satellites were injected into Sun Synchronous Orbits (SSOs) this quarter - an unusually low number. In May, the launch of Mars Cube One, two 6U CubeSats accompanying the InSight Mars lander, marked the first flight of a CubeSat beyond Earth orbit.

No small satellite carrying launch vehicles failed this quarter

Launch Failures

No small satellite carrying launch vehicles failed this quarter, however on the 30th June the Interstellar Technologies MOMO-2 failed seconds after launch, crashing back onto the landing pad. Interstellar Technologies was the first Japanese company to launch a private rocket with its MOMO-1 back in 2017, however it has yet to reach orbit.

Following the unauthorized January launch of four of Swarm's satellites, the FCC have referred the case to its enforcement bureau and released an enforcement advisory to ensure other companies do not attempt to do the same. The 'SpaceBee' satellites were launched on a PSLV despite denial of their FCC operating license request due to concerns over tracking the pico-satellites.

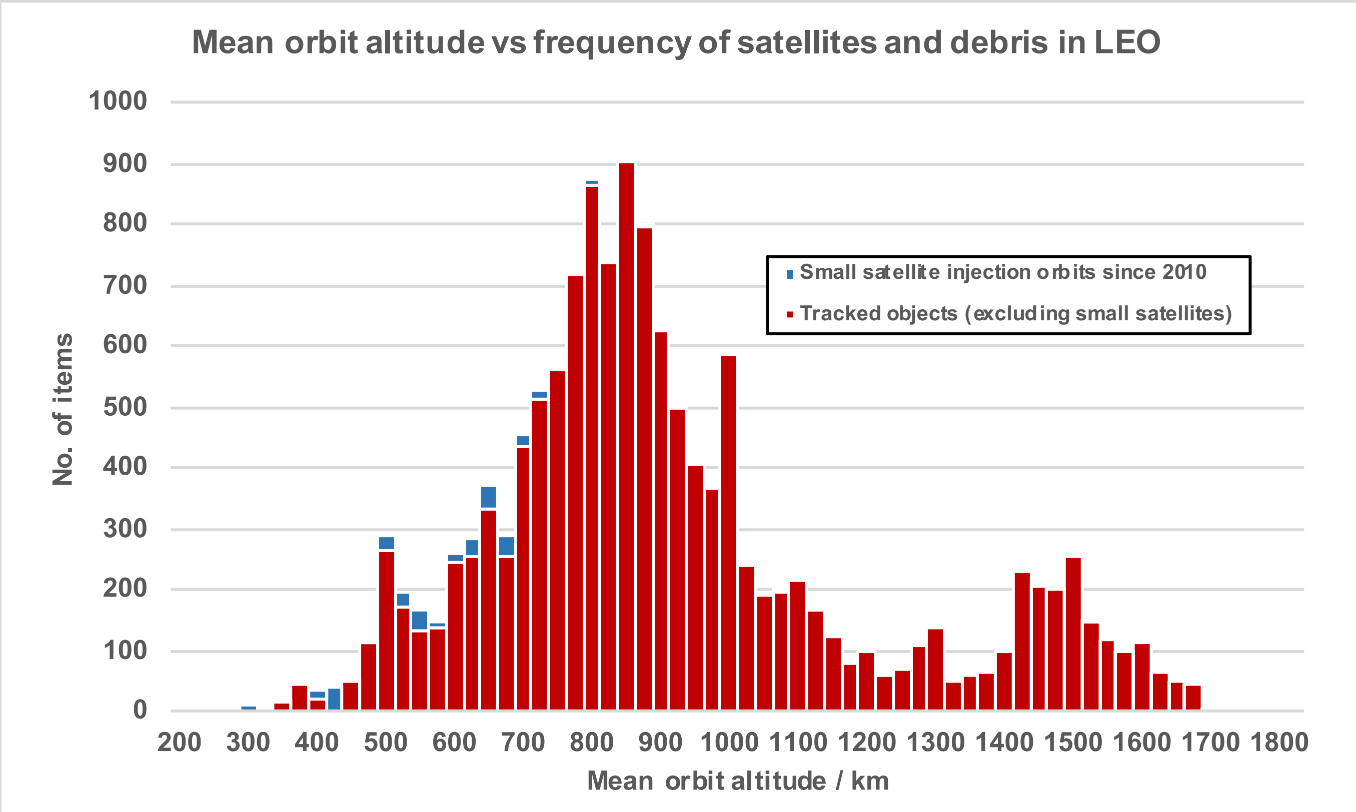
SMALL SATELLITES AND SPACE DEBRIS MITIGATION

The Challenge of Space Debris

Outer space, similarly to the frequency spectrum, is a physical resource the space sector exploits using satellites. As with any resource, it is limited and requires coordination for sustainable sharing. Space has accumulated more than half a million artificial objects larger than 1cm since the first rocket reached the frontier of space in the 1940s. The accumulation of objects over time makes space a riskier environment as any object is a projectile for the others with relative speeds that can reach 14km/s. Despite this, the risk is still considered secondary in most space missions as it is mitigated by the very low likelihood of impact due to the vastness of space.
With more than 80 constellations announced, totalling close to 17,000 satellites, to be launched over the next 4 years (see Q4 2017 Market Intelligence Report about small satellites constellations), this section of the report will look at the current status of space debris and possible ways for small satellites to reduce their impact on the space debris situation.

Status and Generic Considerations

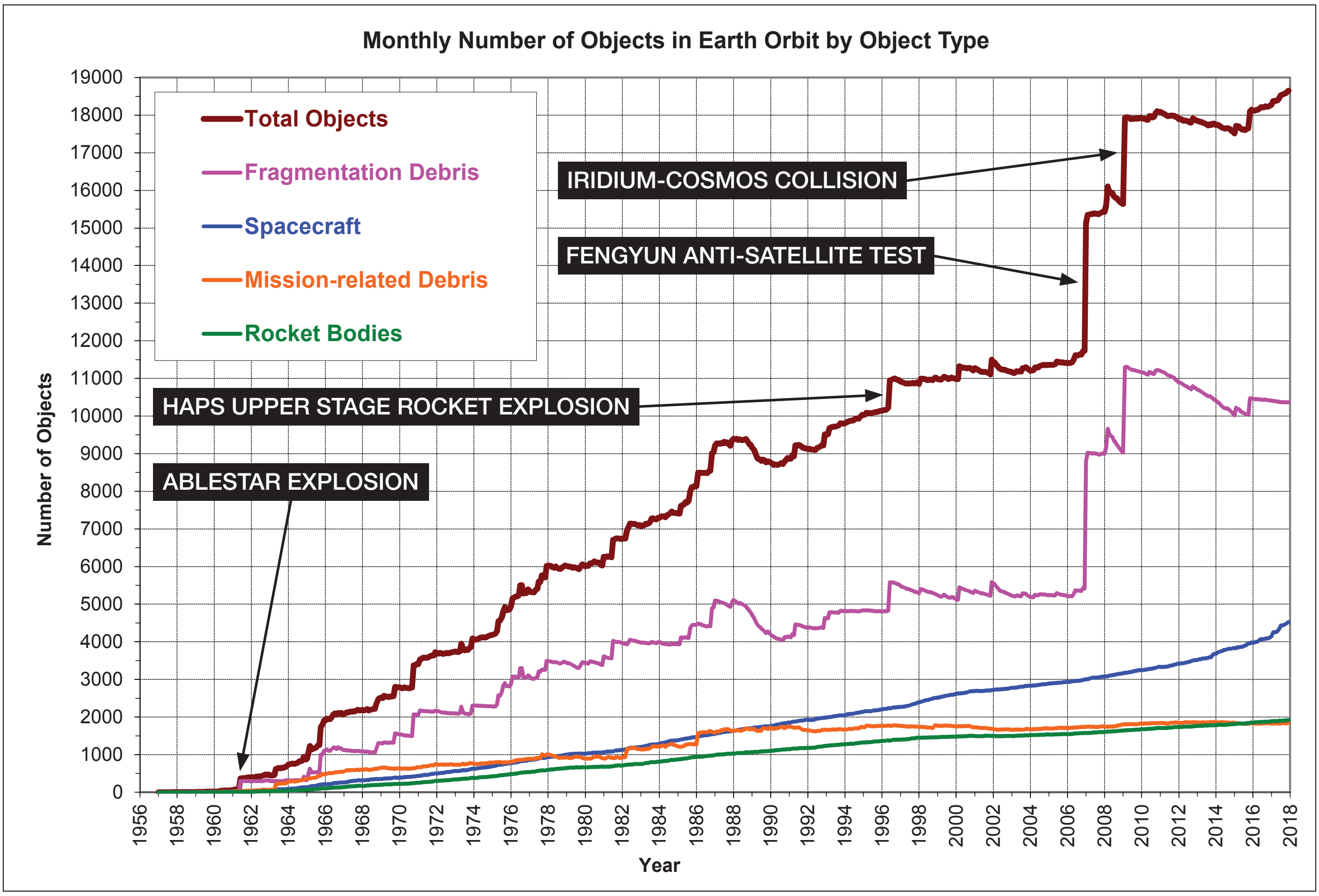
The US Space Surveillance Network currently tracks over 23,000 pieces of debris larger than 10cm in orbit over earth. This includes satellites, discarded rocket bodies and debris from collisions; all man made. This figure appears large, and many news reports warn of an imminent increase of collisions and an impassable LEO, but for now the risk is relatively low and the issue requires much inter-organizational cooperation to deal with.



Source data provided by Jonathan McDowell, based on orbital data provided by Space-Track.org and other sources. The small satellite injection orbits include all launches since 2010 and is therefore a conservative estimate as many will have returned to earth.

There are several regions in LEO where there are greater densities of satellites and the risk of collision is higher. Orbits between 700-800km have the greatest density of satellites, with SSOs presenting the greatest risk of collision due to the satellites concentrating over the polar regions. These orbits are commonly used by Earth Observation (EO) but also host telecommunication constellations such as Iridium.

Several historical events have created large amounts of space debris and roused concern across the industry. To date, excluding micro debris (<10cm), there have been four known collisions between satellites and debris, including the infamous Iridium-Cosmos collision in 2009 that created around 2000 pieces of trackable space debris. In addition to this, both the US and China have shot down large LEO satellites: the latter caused the largest creation of space debris in history; over 3000 trackable pieces of space debris. Each of these events are clearly visible on the graph below.



Source: NASA Orbital Debris Quarterly News (February 2018) using data from the US Space Surveillance Network

With just a small handful of collisions between satellites and catalogued debris, it is difficult to measure the trend over time. In 1978, D. J. Kessler proposed his eponymous effect, whereby following a collision, the increased likelihood of further collisions increased geometrically, due to and resulting in an exponential increase in space debris. Much has been written about Kessler's effect and about the increasing risk of space debris, but it is not possible to say whether the effect has initiated, or at what point in the future it will. Subsequently, until recently, very little has been done to address this potential issue.

A Complex Issue

The issue of space debris requires knowledge of several areas and coordination with multiple stakeholders. From science and engineering - to better understand the risks and find solutions - to insurance - for legal purposes and international treaties for regulation. The real economic aspect of space debris is still emerging and provides a commercial incentive for self-regulation.

At international level, space debris is addressed through the Space Liability Convention Treaty from 1972. It establishes a framework of fault-based liability regime between launching states for damages occurring in space. This means that the resolution for damages occurring in space needs to be happen between states. It is then down to each state to legally implement a national regulation to protect the state from the possible damages caused by the activities under their jurisdiction. A typical example is the state asking any satellite licence applicant to provide a third-party liability insurance from an insurance company. In the UK, the Space Industry Act 2018 specifies that the licensee, often the spacecraft operator, must be insured against any collisions caused by their spacecraft to indemnify the government against claims brought to them.

The **Inter-Agency Space Debris Coordination Committee** was founded to coordinate space agencies in working together to **reduce space debris**

While providing the basis for a legal framework, the practicalities remain challenging: the lack of detailed definition of ‘fault’ in space, the ability to track objects, the involvement at state level for resolutions and the economic impact of third party liability insurance. To date, no official resolution has occurred for damages occurring in space.

A complimentary approach has been the definition of international standards. The Inter-Agency Space Debris Coordination Committee (IADC) was founded in 1993 to coordinate space agencies in working together to reduce space debris. Their guidelines specify that post-mission LEO orbital lifetime should not exceed 25 years. In addition, the guidelines address specific ways of reducing the creation of space debris, for example by ensuring satellites don't break up in space, propellants are 'passivated', and consideration is given to post mission disposal. However, in 2013 they concluded that "current implementation level [is] considered insufficient and no apparent trend towards a better implementation is observed". For example, according to some experts and studies, even with a 95% compliance to the rule, the debris population will still increase.

Part of the issue is the spread of responsibilities. Whilst member states have an obligation to keep space clean under the UN Committee on the Peaceful Uses of Outer Space (COPUOS), who have published similar guidelines to the IADC, it is down to companies to ensure their spacecraft are compliant. Companies often include debris mitigation processes in their designs, but it is difficult to hold companies accountable for non-compliance with IACD guidelines, particularly in the case of unavoidable satellite failures and collisions. When the burden of responsibility is spread across governments, agencies, and companies, progress is often slow.

Recently, there has been an increase in commercial pressure to include deorbiting in mission and hardware design. With the increase in LEO constellations, companies have an incentive to find a way of removing dead satellites to avoid damaging their active ones or clogging up their orbit. A simple way of doing this, adopted by Spire and Planet, is to keep constellations in orbits under 600km, so that drag naturally limits satellite lifespan. However, this may not be possible for all missions.

Mitigation And Future Technologies

The possible mitigations to the space debris risks are:

- Prevention through regulation or adoption of standards as mentioned above;
- Collision avoidance: tracking and manoeuvring of space objects during mission lifetime;
- Disposal: disposing of the satellite post mission-lifetime, including removing space objects through dedicated missions to remove defunct satellites.

Collision Avoidance

Collision avoidance requires a tracking and a manoeuvring capability. Observations can be done using telescopes or radars (such as the 25m Chilbolton Advanced Satellite Tracking Radar) with orbital motion propagators generating the expected trajectories. Currently, most of the tracking and cataloguing is carried out by governmental organisations such as US Space Surveillance Network and the Russian Space Surveillance System. Smaller objects (typically under a few cm in LEO), which cannot be tracked, are statistically modelled. Last year, OSG-1, a collaboration between Kyoshu University and Astroscale, sponsored by OSG, began monitoring much smaller pieces of debris in LEO to gather data about small space debris and model the LEO environment more accurately. Alongside this, Silicon Valley start-up LeoLabs is hoping to increase the data available to commercial operators by offering real time tracking of space debris using ground based phased array antennas. This will be increasingly important as the larger planned constellations begin to take shape.

Satellites bigger than 50kg often have propulsion systems available to avoid conjunctions and are able to make corrective manoeuvres to reduce collision risk

Manoeuvring can be done through several techniques. Satellites bigger than 50kg often have propulsion systems available to avoid conjunctions and are able to make corrective manoeuvres to reduce collision risk. For example, the ISS often conducts small manoeuvres to avoid tracked debris, or the crew are placed in Soyuz 'life rafts' when there is a last-minute risk of collision. In contrast, micro and smaller satellites are limited in their manoeuvrability, often simply spiralling down into the Earth's atmosphere at the end of the mission lifetime, and less emphasis is placed on tracking and loss prevention. Propulsion systems for small satellites are currently being developed that will allow small satellites to avoid conjunctions – see the Q1 2018 Market Intelligence Report about small satellite propulsion systems for more information.

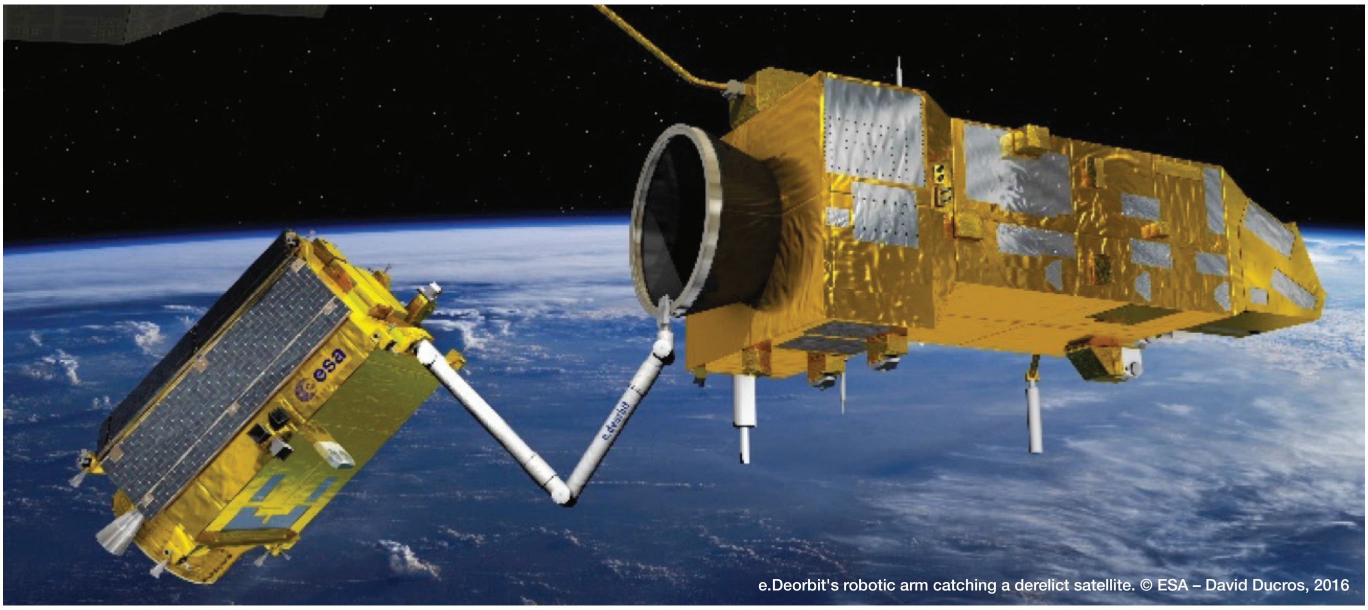
Disposal

The most common method of decommissioning for LEO satellites is to allow them to descend under atmospheric drag and eventually burn up in the atmosphere. This is only really effective for orbits under 650 km; above this, less drag means spacecraft descend at a slower rate than the 25-year guideline. These satellites require active deorbiting, often to bring them to a lower altitude where drag can take over or, in the case of Globalstar, to raise them above LEO. Small satellite propulsion systems, mentioned above, will allow satellites at higher altitudes to descend to lower altitudes.

On a smaller scale, platform level deorbit technologies are increasingly being tested. These include drag sails and extra propulsion units such as the D3 created by D-Orbit, an Italian company. This off-the-shelf solid fuel propulsion system is controlled separately from the satellite platform, allowing it to be activated even if the satellite is dead; it delivers a kick that pushes the satellite into a lower orbit. In addition to this, small scale thruster technology is improving for use in CubeSats. Combined with better tracking technology, even small satellite conjunctions could be avoided.

In April 2018, RemoveDEBRIS, a project lead by the Surrey Space Centre, was launched. Comprising a 100kg platform manufactured by SSTL and two CubeSats, the mission will test various new technologies for actively removing space debris. In a series of tests over the next few months, the main satellite will release the two CubeSats, before capturing one with a net and imaging another with LiDAR and a 2D-imaging camera to test new tracking technology. Furthermore, the platform will also test a harpoon, firing at a target attached to the satellite. Once these tests are complete, the satellite will deploy a sail, increasing the drag on the vehicle and causing it to descend into the atmosphere faster, where it will burn up.

e.Deorbit, an ESA mission, will likely be the first active deorbit program: launching specifically to collect space debris from space before returning to the atmosphere. It will also test further space tug capabilities: if you can collect a satellite with a claw, you could potentially drag it to GEO or move it to a more desirable orbit. Parallel to this, CleanSpace, an initiative of EPFL in Switzerland, are planning to launch CleanSpace One, a technology demonstrator that will recover the SwissCube cubesat from LEO using a net.



e.Deorbit's robotic arm catching a derelict satellite. © ESA – David Ducros, 2016

Whilst the idea of space harpoons and nets sounds exciting, questions remain over the viability of such a method. Satellites would have to be launched and rendezvous safely in an already congested orbit with potentially tumbling defunct satellites, before being deorbited themselves; a costly process. A further obstacle to this technology is that even dead satellites remain under the jurisdiction of the entity that owns it, so clearance satellites would need permission from satellite operators before junk could be collected. Whilst this technology will be needed, and further development is encouraged, it will be decades before it is an effective method of clearing space junk.

Further methods of reducing space debris include recycling, either in orbit or on earth, or extending the life of existing satellites, though the economic case still needs development. In 2011, DARPA began work on in orbit recycling but the project has now reduced to servicing of GEO satellites.

A promising idea is the need for commercial end-of-life services. For example, a constellation of 500 satellites with 95% reliability will still experience a 99.98% chance of having at least 10 defunct satellites potentially colliding with other satellites of the constellation. The company Astroscale plans to launch the ELSA-d mission in 2019, testing the technologies required to propose this end-of-life service, including tracking and capture technologies.

Conclusion

Space debris presents a small short-term risk to an individual satellite but a major medium-term collective issue, becoming more apparent with the advent of small satellite constellations. The two major Cubesat operators Planet and Spire (57% of the small satellites launched in 2017), are demonstrating responsible approaches to space debris and compliance to the standards. While providing a strong baseline, current standards and regulations were set-up before the growth of small satellites and constellations and would need to be revisited. Concurrently an increasing number of technologies, engineering processes and missions are being developed towards better disposal techniques. OneWeb, for example, has presented plans for post mission disposal within 5 years and are considering design accommodations to facilitate active debris removal. Removal of defunct satellites would start carrying an economic incentive as large constellations could see their integrity jeopardized by their own satellites. The re-emergence of constellations will also see the birth of end-of-life services, a first step towards solving the space debris challenge and creating a sustainable and economically viable space ecosystem.

Regular information on space debris can be accessed through the following websites:

ESA: https://www.esa.int/Our_Activities/Operations/Latest_report_on_space_junk

NASA: https://www.orbitaldebris.jsc.nasa.gov/quarterly-news/newsletter.html

Contact

The Small Satellite Market Intelligence report is designed as a free data source to share information that is easy to access and use. We welcome feedback on other data points that would be of value to include. You can contact us at:

E: marketintelligence@sa.catapult.org.uk

T: +44 (0) 1235 567999

W: sa.catapult.org.uk/small-sats-market-intel

Disclaimer: whilst every effort has been made to provide accurate and up to date information, we recognise that this might not always be the case. If any reader would like to contribute edits or suggestions to our reports, kindly email the team and we will make the amends.

The Catapult thanks Jonathan McDowell for allowing the use of his data on historical satellite orbital parameters, which can be found on his webpage at: http//planet4589.org/

Electron Building
Fermi Avenue
Harwell Campus
Didcot
Oxfordshire
OX11 0QR
United Kingdom

For more information:

T: +44 (0) 1235 567999
W: sa.catapult.org.uk
E: info@sa.catapult.org.uk
@SatAppsCatapult

August 2018

SMALL SAT MARKET INTELLIGENCE

CATAPULT Satellite Applications