SMALL SATELLITE MARKET INTELLIGENCE

Q4 2017

This issue of the Satellite Applications Catapult's quarterly Small Satellite Market Intelligence report provides an update of the small satellites launched in Q4 2017 up to 31st December 2017. This edition also includes a closer look at small satellite constellations, and applications for which small satellites are well suited in terms of costs and capabilities.

2017 Summary

328 small satellites were launched:

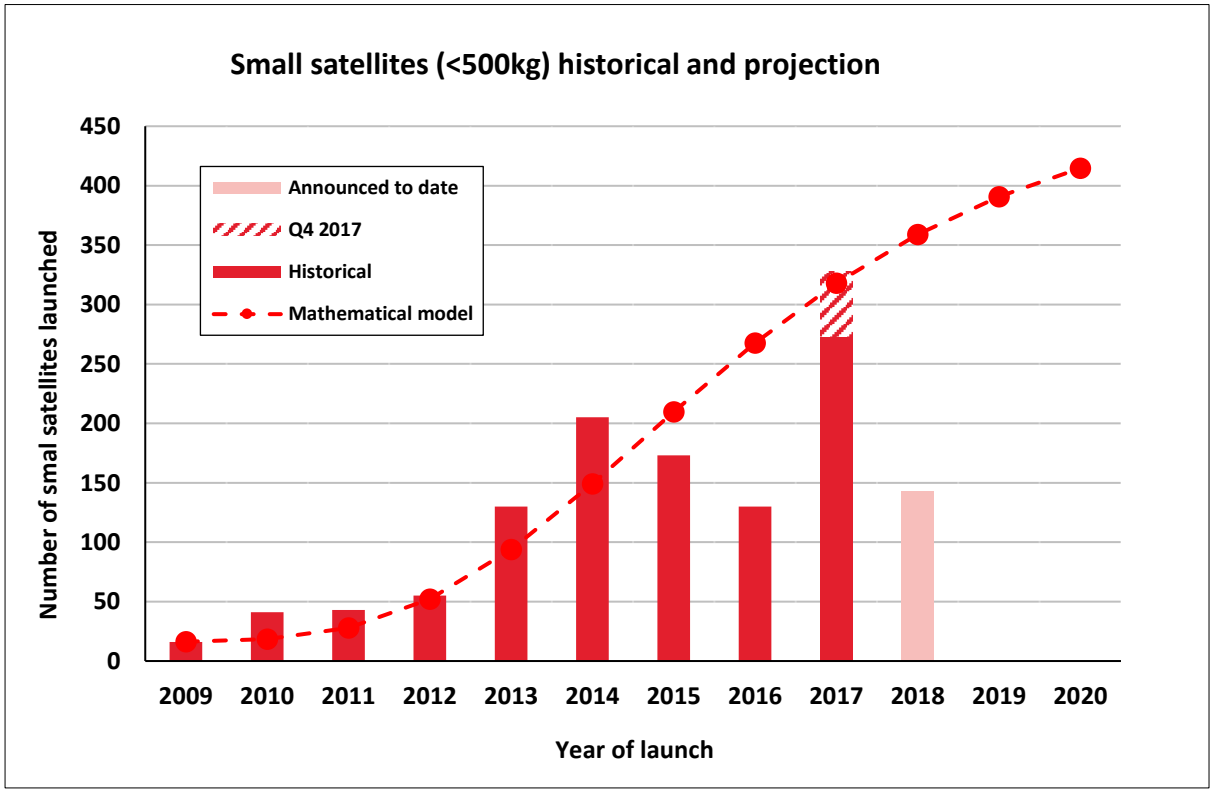
- 103 were on a single PSLV launch
- 19 were lost due to launch failure
- Total mass was 5567kg - 89% less than 10kg, 7% between 10-100kg, 4% between 100-500kg
- 2% were for communications
- 67% were for Earth Observation
- 31% were for technological and scientific applications

As mentioned in the previous release, 2017 has seen the largest number of satellites launched for any previous year.

SMALL SATELLITES FACTS AND FORECASTS

OVERVIEW:

55 small satellites were launched in Q4 2017, bringing the 2017 total to 328.



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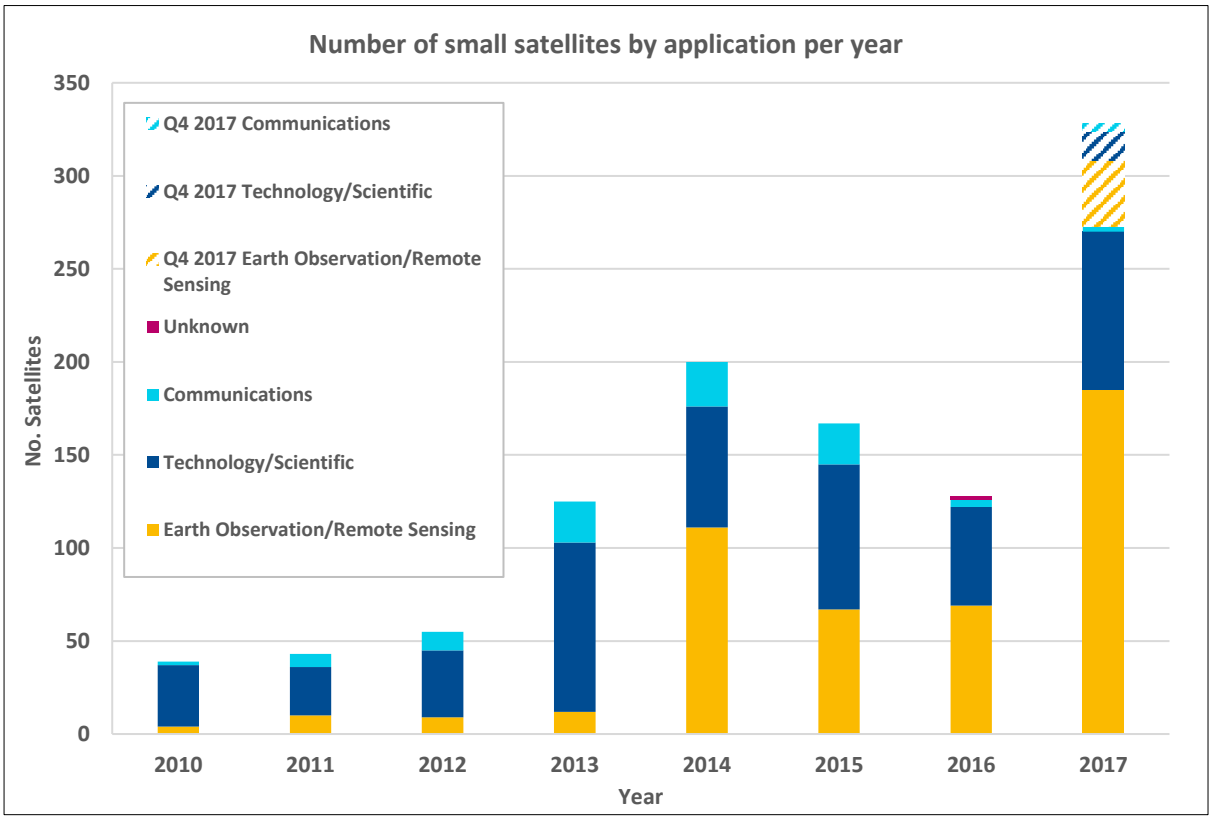
The mathematical model line simulates a market uptake from the past 8 years followed by a levelling off. While this can be considered a good approximation, the launch failures of 2015 and subsequent 2016 delays have impacted that growth and explain the large offset in actual launches from the mathematical model.

The number of satellites launched in Q4 was less than estimated in the previous release of this report as an Indian PSLV launched slipped from December to January. The 103 satellites launched by a single launcher demonstrate the impact one failure could have on the uptake of the market, as discussed later in this report.

Based on the mathematical model, around 1,200 satellites will be launched over the 2018-2020 period. The proposed constellations identified by the Catapult suggest that the actual number could well be higher, and the number shown as 'announced' on the graph is expected to increase as launch slots are confirmed

APPLICATION:



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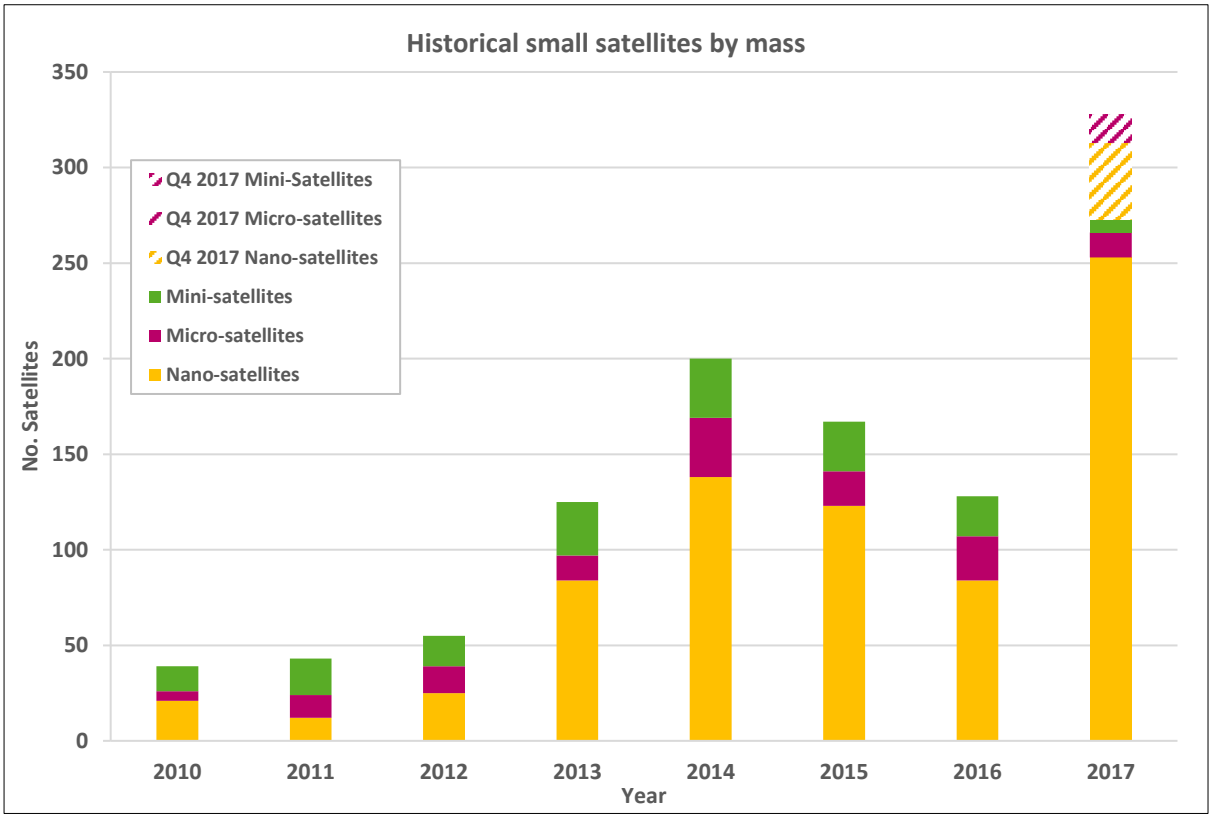
Applications are defined by the primary objective of the mission with the following groupings:

- 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.

Earth Observation and remote sensing continue to be the main drivers for small satellite launches with 64% of the satellites launched in Q4 being primarily for this purpose; 60% of this application subcategory is comprised by satellites from Spire and Planet (17 Lemurs and 4 Doves respectively). Catapult expects satellites launched for communications to grow significantly in 2018 and start to dominate in 2019 with the maturation of players such as SAS, Kepler and other Internet of Things (IoT) companies, and for this trend to continue in the near future as communications mega-constellations begin launching (eg. OneWeb).

SIZE OF SATELLITES:



Nano-satellites still represent the majority of small satellites launched; approx. 89% of the total in 2017 (216 of these in the 3U CubeSat format, and 14 in the 6U format).

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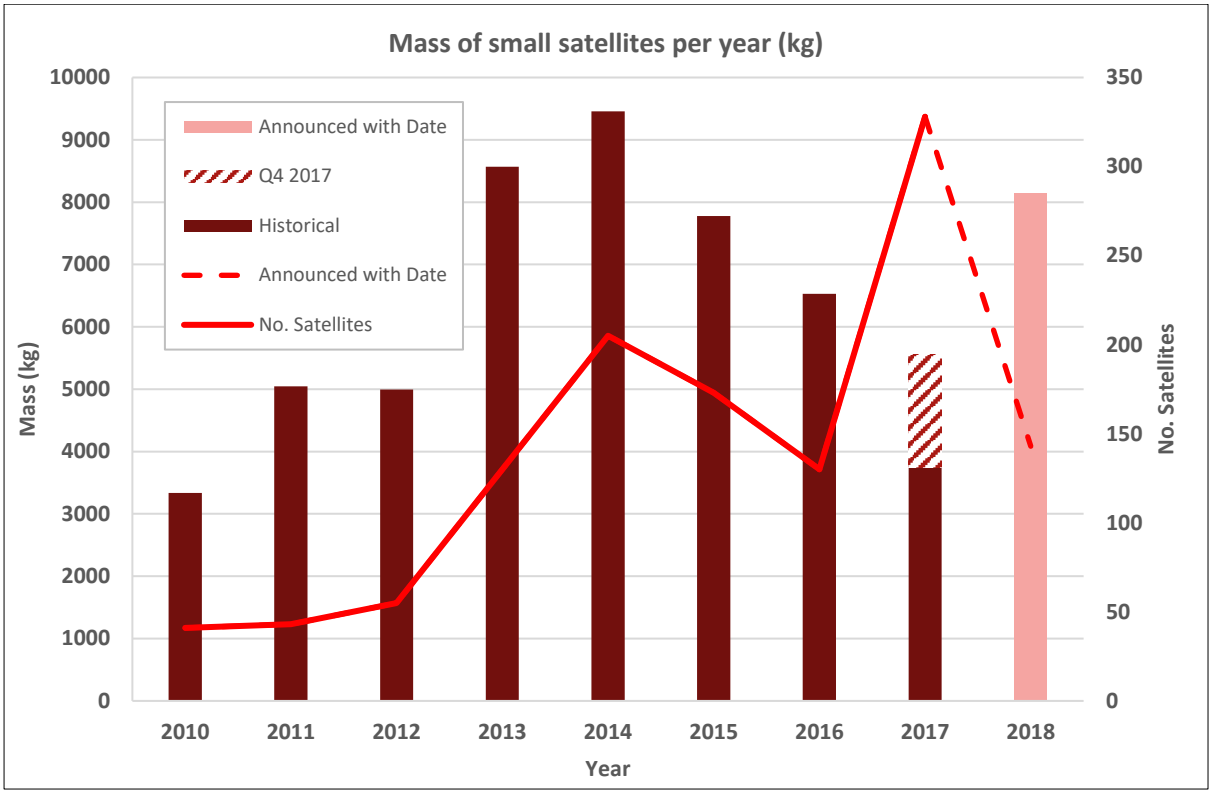
Satellite classification	Satellite sub - classification	Associated wet mass range
Small Satellite < 500 kg	Mini-satellite	100 kg - 500 kg
	Micro-satellite	10 kg – 100 kg
	Nano-satellite	1 kg – 10 kg



The total mass[1] of small satellites launched in Q4 varied from what was expected before , as around 20 satellites previously announced to launch at the end of 2017 slipped into 2018. The very high proportion of nano-satellites for 2017 means that even though a record number of small satellites was launched, the total mass of small satellites launched decreased from 2016.

This total mass is expected to increase in 2018 as the number of mini-satellites grows, in part due to the initial ten OneWeb satellites (150kg) as well as six Taiwanese 'FORMOSAT-7' satellites (200kg). As the year progresses, it is expected that more satellites will be announced, particularly nanosatellites, which are often announced on launch manifests only weeks before the launch date.

Other likely trends in the near future include the introduction of a number of additional launch options as the small launchers discussed in the previous report begin operations. It is likely that small satellite operators will increasingly make use of the high launch-rate and desirable orbits that will be offered by small launch providers.

[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

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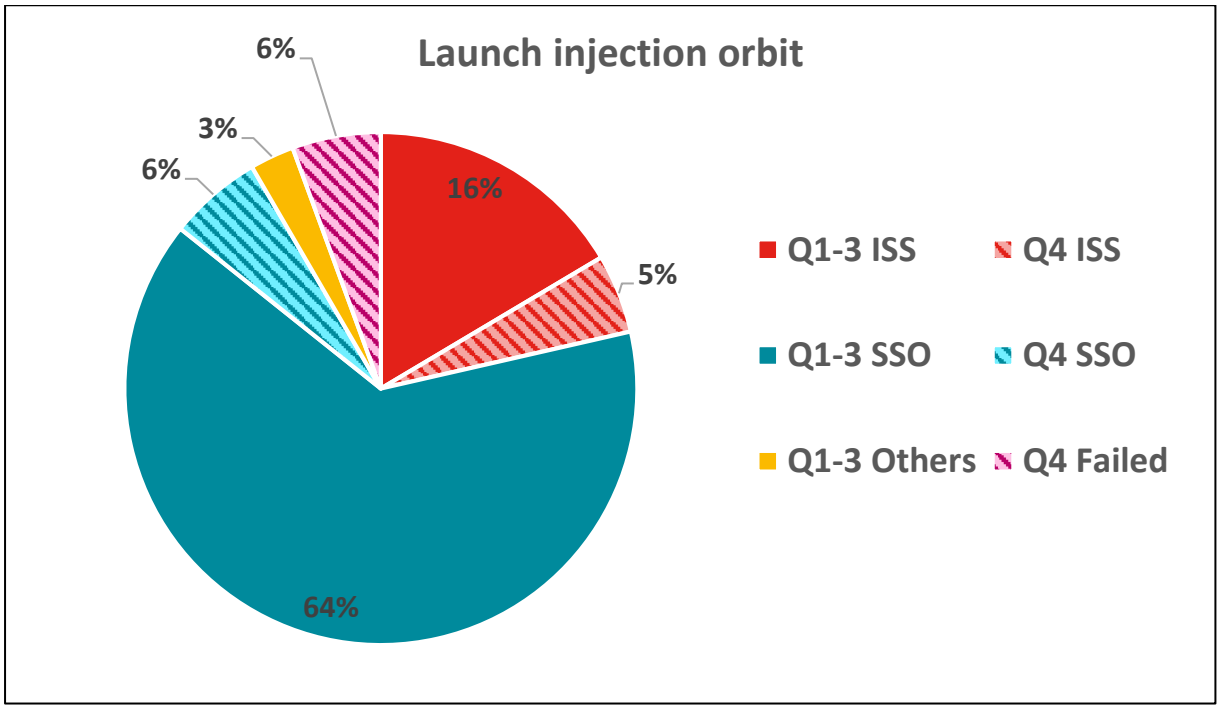
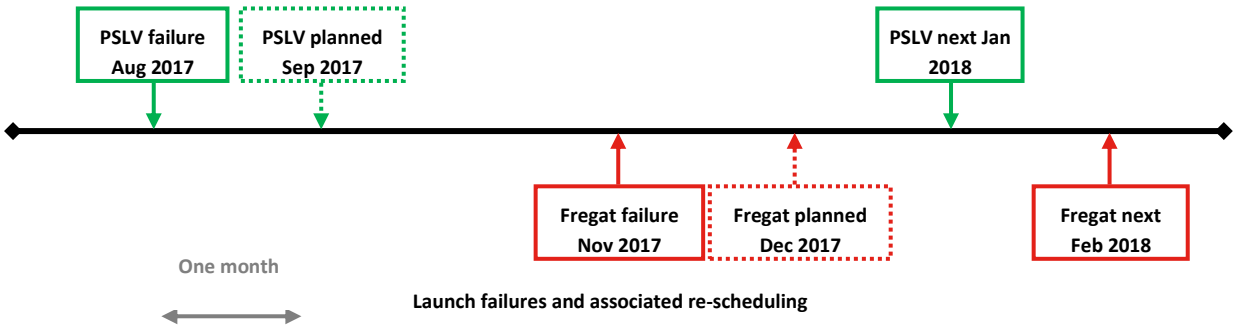
ORBIT:

The Sun Synchronous Orbits and ISS orbits remain the most favoured with 70% and 21% respectively in 2017. SSO dominates due to the high proportion of Earth observation satellites launched.



LAUNCH FAILURES:

Ridesharing with large numbers of small satellites on a single launch is of significant risk for the total number of satellites launched, for example one third of the small satellites were launched by one launch vehicle in 2017. The knock-on effects can also have consequences, as future launches are pushed back, opportunity for flight heritage is lost, and further development stages reliant on successful launches are hindered. The November failure of the Fregat upper stage resulted in the loss of 18 small satellites, including two 'Landmapper' satellites, the first two of which had also failed after deployment from the previous Fregat launch. Losing the initial four satellites of a constellation of 8-10 shows the risk launch failures present.



Launch failures and associated re-scheduling

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Though not carrying small satellites itself, the fairing failure of the Indian PSLV launcher in August pushed a number of small satellites from a September 2017 launch to January 2018, showing that small satellite launches are also susceptible to knock-on effects from incidents across the launch industry.

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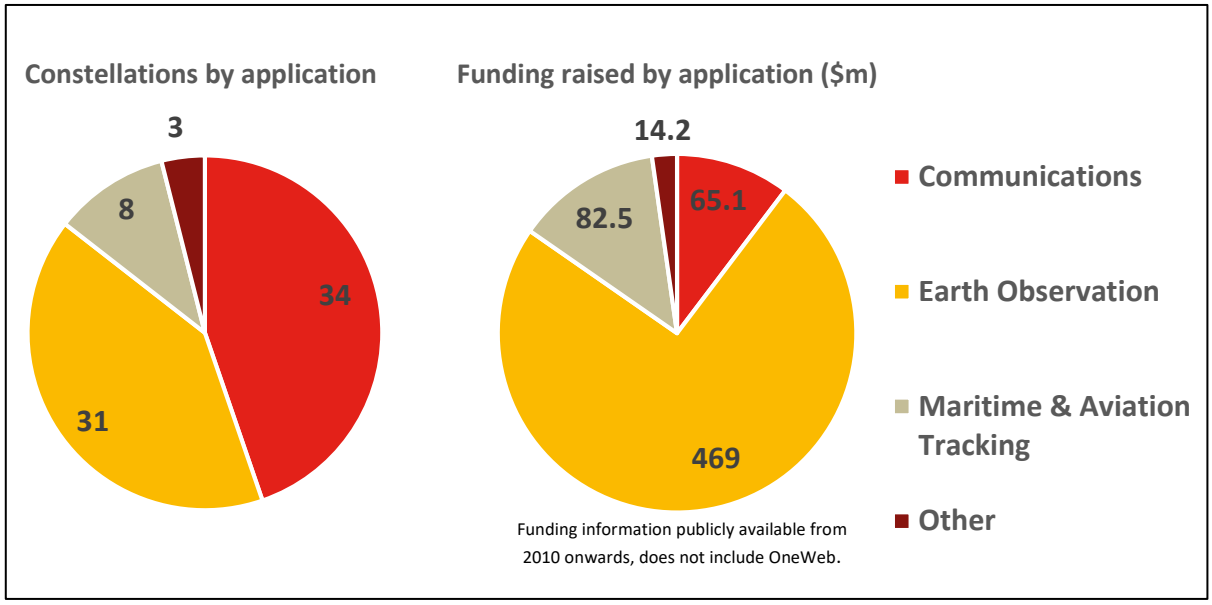
SMALL SATELLITE CONSTELLATIONS

The biggest advantage of small satellites is their scalability to constellations and associated ubiquity of service. For Earth observation this means decreased revisit time, for telecommunications this means being able to take advantage of higher performing link budgets while maintaining coverage initially granted by higher altitudes. The brief report below provides an overview of some smallsat constellations and their applications, as well as a focus on Earth observation and Internet of Things.

SMALL SATELLITE CONSTELLATIONS OVERVIEW AND APPLICATIONS:

The primary applications for small satellite constellations are Earth observation and communications, within communications the largest sub-division is Internet of Things (IoT). Earth observation constellations are broadly split between active and passive sensing, where active sensors emit a beam and use its reflection to image the Earth and passive sensors use sunlight reflected, or other radiation emitted, by the Earth. This report considers 76 small satellite constellations, with these two applications making up much of the market, as highlighted in the chart below. Recent interest in cryptocurrencies has also spurred announcements of communications constellations with a focus on blockchain technology.



Funding for small satellite constellations generally comes from external investment due to the large proportion of companies planning constellations being start-ups. The exceptions to this are the large communications constellations from companies such as Boeing and SpaceX. The total external investment in small satellite constellations is approaching $2.5 billion, with $1.7 billion of that inOneWeb. These constellations continue to seek funding for different stages of their initial processes, such as payload development, technology demonstrator missions, initial launches, and ongoing launches.

The total number of satellites in constellations of sizes currently announced is 16,800 over the next 4 years. An estimate for constellations of unspecified size raises this total to 17,600 in that time period. It is uncertain how many of the currently announced constellations will eventually be launched, but it is to be expected that some may not be. Already there have been constellations announced and

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dropped in favour of other solutions, such as renting capabilities from existing satellites, searching for hosted payload opportunities, or purchasing data from other operators, while other plans have been halted by the inability to find sufficient funding.

BENEFIT TO EARTH OBSERVATION APPLICATIONS

Using small satellites for Earth observation constellations carries two clear benefits but also a necessary trade-off.

With the ability to place many more satellites into a constellation, the revisit time decreases, allowing for more frequent observations to be made, a very important feature for applications involving the tracking of change over shorter time periods. As with other applications, small satellites allow Earth observation constellations to benefit from cost reductions derived through standardisation, miniaturisation, and cheaper launch costs.

However, with the reduction in the size of optics and electronics, small satellites cannot capture the same amount of data as a larger satellite (with often a smaller swath width and lower resolution), meaning a reduced level of detail captured per image.

Using small satellite constellations for imaging purposes is therefore justified on two grounds, firstly through concluding that high revisit is more important for customers than resolution (e.g. Planet[2]), and secondly through combining the benefits of small satellites with the sharp resolution offered by larger satellites (e.g. DigitalGlobe Scout & Legion, UrtheCast UrtheDaily & OptiSAR). This “tip and cue” relationship allows small satellites to utilise their high revisit rate to spot areas of potential interest, before a larger imaging satellite is tasked to observe the location with a much higher resolution.

Small satellites are capable of using a variety of techniques to capture images, with small satellite constellations proposed that utilise techniques including optical, synthetic aperture radar, thermal infra-red, multispectral, hyperspectral, meteorological, as well as video from space. Once operational, these constellations will represent an abundance of data types capable of being developed into diverse applications ranging from commercial intelligence to measuring vegetation change to vessel tracking.

The Earth observation small satellite constellation leader is Planet (formerly PlanetLabs), having raised ~$200m and already launched more than 330 satellites, in comparison to the 30 other small satellite EO companies who between them have raised just ~$275m and launched just 16 satellites.

Finally, one emerging trend is that of prospective EO small satellite constellation operators deciding to forego their original plans of proprietary constellations in favour of focusing on developing analytical capabilities to be applied to imagery data captured from other organisations’ satellites. This has been observed with Ursa Space Systems (originally planned a SAR constellation, now focusing on SAR analytics), EarthCube (originally planned a thermal infra-red constellation, now focusing on building an analytical capability) and Promethean Labs (now delivering “AI-powered remote sensing

[2] Planet’s infamous “Mission 1” was to image the Earth’s entire surface every day, thus prioritising a high-revisit rate over resolution.

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analytics for the agriculture and forestry community"). It is thought likely that this trend will continue, as prospective constellation operators struggle to overcome the high barriers to designing, launching, and operating constellations, and instead see more immediate value in developing applications.

BENEFIT TO INTERNET OF THINGS APPLICATIONS

A number of constellations are targeting the Internet of Things (IoT) market, where small devices are connected to the internet in order to share data on performance or local measurements. The satellite-connected IoT market opportunity is strongest where terrestrial backhaul for connected devices is uneconomical, due either to geographical remoteness or very low bandwidth requirement. Satellite-connected IoT is only a very small part of the overall market of internet connected devices.

Estimates for the current size of the satellite IoT market give revenues of around $1.5 billion per year, while predictions suggest strong growth by another $1 billion in the next 6-7 years. This corresponds to 3 million user ground terminals in use, predicted to be 5.8 million by 2023.

The predicted growth in this market is fuelled by an increasing demand for data and analytics across the economy, although these demands vary across different sectors of the market. The larger sectors within the satellite IoT market are transport and infrastructure, civil government, and military. Market applications for IoT exist where ongoing low frequency monitoring is required, with the most attractive markets being those where achieving this through human labour is difficult or expensive, and terrestrial connections are unavailable at affordable prices. This includes applications in areas such as energy, extractive industries, infrastructure, weather, environmental monitoring, and insurance.

Small satellite LEO constellations are well suited to break into this market. They can easily meet the requirements for revisit time and bandwidth, while their low cost allows for a low ARPU[3] business model, with a larger potential customer base.

[3] Average Revenue Per User

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To date, the Catapult is aware of 13 Machine-To-Machine communications small satellite constellations:

Company	Location	Investment raised	Target Markets and (B2B/B2C focus)	Intended spectrum
Kepler Communications	Canada	$5m	Shipping, Agriculture, Transport *(Primarily B2B)*	Ku Band
Sky and Space Global	UK/Israel	$7m	Comms & M2M *(B2B and Consumer)*	S&L Band*
Else/Astrocast	Switzerland	>$4m	Monitoring, Predictive maintenance *(Primarily B2B)*	L Band
Fleet Space	Australia	-	Extractive, Transport, Agriculture *(Primarily B2B)*	-
NSLComm (SkyFi)	Israel	$3m	-	-
Blink Astro	USA	-	Energy, Extractive, Military, Construction *(Primarily B2B)*	-
Helios Wire	Canada	~$1m	Comms, Tracking *(Primarily Consumer)*	S Band
Hiber (ex Magnitude Space)	Netherlands	~$2M	Rail, Maritime *(B2B)*	VHF/UHF*
Myriota	Australia	~$2m	Agriculture, Monitoring *(Primarily Consumer)*	-
SpaceQuest/Aprize Satellite	USA	-	Extractive, Transport, Comms *(B2B and Consumer)*	S Band
4skies	France	-	Extractive, Maritime, Disaster *(Primarily B2B)*	-
SAT4M2M	Germany	$2m	Transport, Infrastructure	-
Altsen	Indonesia/Singapore	-	Agriculture, infrastructure monitoring (*B2B)*	-
Kaskilo	Germany	-	Transport, Extractive, Agriculture (Primarily B2B)	Ka Band

The specific market sectors targeted varies between companies, with oil & gas, agriculture, and maritime communications being the most common target markets between them. These companies vary in the solutions that they provide across features such as:

- packet size and cost
- terminal lifetime and autonomy
- collection frequency

The variation in these features controls which markets will be most suitable for a given constellation.

Whilst some companies have announced which areas of spectrum they intend to use, so far only Sky and Space Global and Hiber have announced spectrum allocations. Their maturity follows a spread, with those companies that have announced intended dates for the beginning of a commercial service aiming between 2019 and 2021, some having demonstration satellites launched or manifested already (Sky and Space Global, Fleet Space), while Blink Astro is selling terminals with initial services provided by existing satellite operators.

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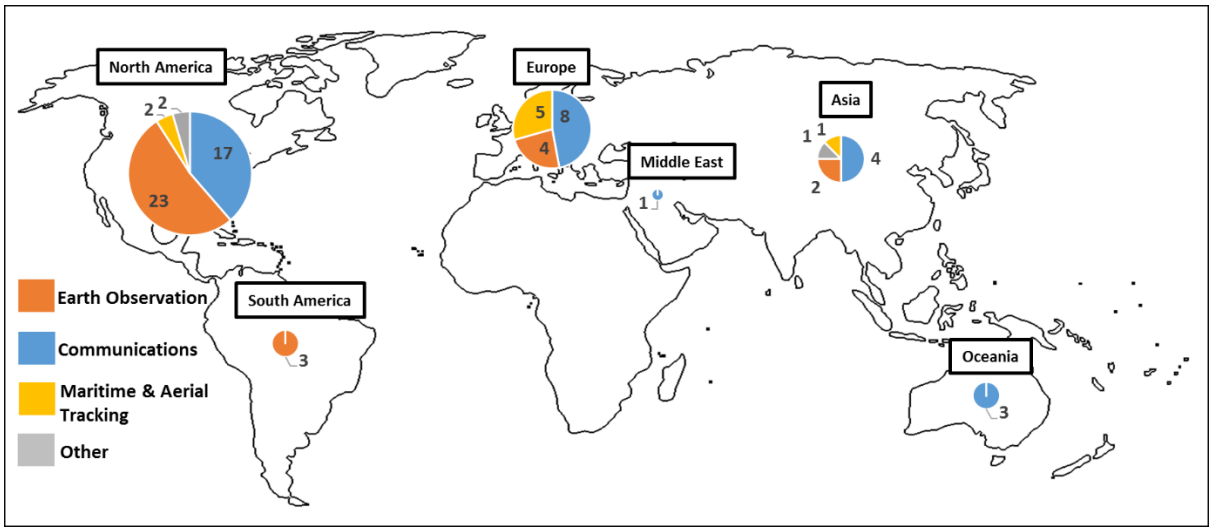
LOCATION



The USA is home to nearly half of the total number of constellations, at 36, with Canada having the second largest number at 8, and the UK following at 4. Location is determined by the headquarters or centre of activity for the company operating the constellation. Alhough the small satellite manufacturing market is attractive in the US, Surrey Satellite Technology Ltd. announced in November that it was selling its US factory to General Atomics, as it was unable to capture as much of the US market as it had hoped.

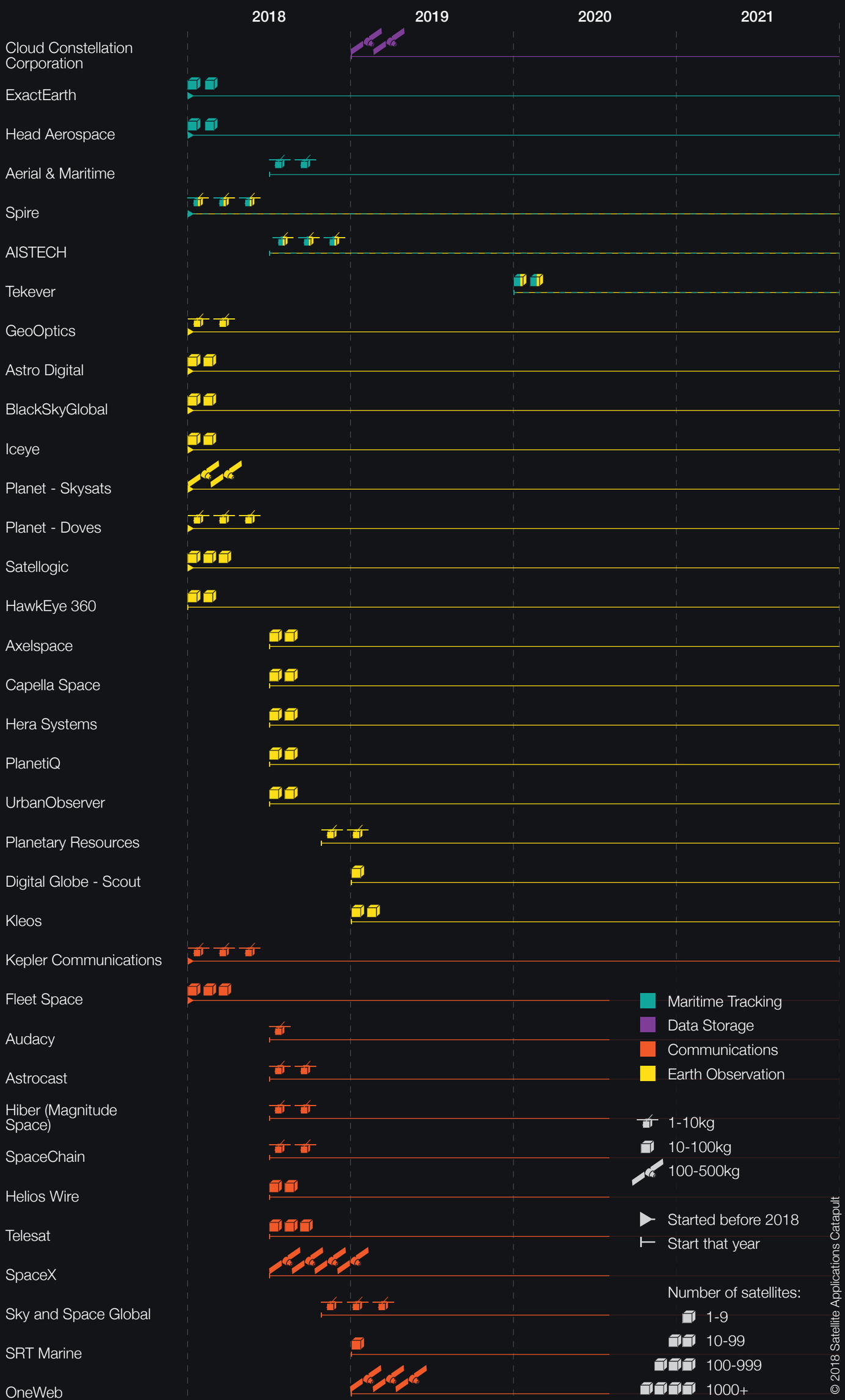
BRITISH SMALL SATELLITE CONSTELLATIONS

Companies located in the UK that have announced small satellite constellations include Lacuna Networks (an IoT constellation of unspecified size), SRT Marine (6 micro-satellite maritime tracking constellation), and Earth-i (15 micro-satellite Earth observation constellation). The OneWeb communications mega-constellation is to be licensed in the UK, meaning an unprecedented number of satellites that the UK will be legally responsible for. In related news, AAC Microtec announced at the end of December that it plans to acquire Clyde Space for a total value of $35.5 million, and that the merged company will be a dominant force in the small satellite manufacturing industry.

SUMMARY DIAGRAM

The companies that feature on the following diagram are the ones where the following information has been found through public sources: funding raised, number of satellites expected, applications, launch announced, satellite mass. Prototype satellites are counted as initial satellites for constellations, and where a specific launch date is unknown outside of the year the initial launch is assumed to be mid-year. Only publicly available information has been used for this report, if you notice any information that we have missed, please feel free to let us know.

A SUMMARY OF ANNOUNCED CONSTELLATIONS FOR THE NEXT FOUR YEARS



FULL LIST OF SMALL SATELLITE CONSTELLATIONS CONSIDERED IN THIS ANALYSIS

Company Name	Mass Category	Application	No. of Satellites	Company country	Manufacturer	First launch date
Aerial & Maritime	1-10kg	Maritime and aviation tracking	80	Denmark	GOMSpace	2018
AISTECH	1-10kg	Maritime Tracking & Earth Observation	100	Spain	GOMSpace	2018
Altsen	1-10kg	Communications				
Analytical Space	1-10kg	Communications		USA		2018
Astranis		Communications		USA		
Astro Digital	10-100kg	Earth Observation	30	USA	Aquila Space	2017
Astrocast	1-10kg	Communications	64	Switzerland	NanoSpace	end-2017
Audacy	1-10kg	Communications	3	USA	Clyde Space	2018
Axelspace	10-100kg	Earth Observation	50	Japan	Axelspace	2018
BlackSkyGlobal	10-100kg	Earth Observation	60	USA	Spaceflight services	2016
Blink Astro	1-10kg	Communications	8	USA		
Blockstream satellite		Communications		USA		
Bluefield Technologies	10-100kg	Earth Observation	22	USA		
Boeing		Communications	1396	USA	Boeing	202X
Canadensys		Communications		Canada	Dauria Aerospace	2020
Capella Space	100-500kg	Earth Observation	36	USA	Capella Space	2018
Cloud Constellation Corporation	100-500kg	Data Storage	12	USA	SSL	2019
Conasat	1-10kg	Earth Observation	6	Brazil		
Digital Globe - Scout	100-500kg	Earth Observation	6	USA	KACST	2019
Dunvegan Space Systems	1-10kg	Communications	24	USA		
Earth-i	10-100kg	Earth Observation	15	UK	SSTL	
ExactEarth	10-100kg	Maritime Tracking	65	Canada	LuxSpace	Ongoing
Fleet Space	10-100kg	Communications	100	Australia	Fleet Space	end-2017
FP Space		Earth Observation		Poland		2022
GeoOptics	1-10kg	Earth Observation	24	USA	Tyvak	mid-2017
German Orbital Systems	1-10kg	Communications		Germany		2018
GHGSat	10-100kg	Earth Observation	20	Canada	UTIAS Space Flight Laboratory (SFL)	
Harris	1-10kg	Earth Observation	12	USA	Space Dynamics Laboratory	
HawkEye 360	10-100kg	Earth Observation	21	USA	GOMSpace/Deep Space Industries/ UTIASFL	end-2017
Head Aerospace	10-100kg	Maritime Tracking	30	China	Shanghai Academy of Spaceflight Technology (SAST)	Ongoing
Helios Wire	10-100kg	Communications	30	Canada	Helios Wire	2018
Hera Systems	10-100kg	Earth Observation	48	USA		2017
Hiber (Magnitude Space)	1-10kg	Communications	24	Netherlands	ISIS	2018
Iceye	10-100kg	Earth Observation	10	Finland	York Space Systems	2018

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Karten Space	1-10kg	Maritime Tracking & Earth Observation	14	Spain		
Kaskilo		Communications	300	Germany		2019
Kepler Communications	1-10kg	Communications	140	Canada	Clyde Space	2018
Kleos	10-100kg	Earth Observation	21	Luxembourg	Blue Canyon Technologies	2019
Koolock	1-10kg	Earth Observation		USA		
Lacuna Networks		Communications		UK		
Laser Light Communications		Communications	12	USA		
Loft Orbital	100-500kg	Payload Hosting		USA		2019
Myriota	1-10kg	Communications		Australia		
NSLComm (SkyFi)	1-10kg	Communications	60	Israel		
OneWeb	100-500kg	Communications	900	USA	OneWeb Satellites	2019
Orbital Micro Systems	1-10kg	Earth Observation	40	USA		
Planet - Doves	100-500kg	Earth Observation	250/year	USA	Planet	ongoing
Planet - Skysats	100-500kg	Earth Observation	21	USA		
Planetary Resources	1-10kg	Earth Observation	10	USA	Planetary Resources	end-2018
PlanetiQ	100-500kg	Earth Observation	18	USA	Blue Canyon Technologies	mid-2017
Promethean Labs	1-10kg	Earth Observation		Canada		late 2018
Ragnarok Industries	1-10kg	Communications		USA		
Rupercorp	1-10kg	Earth Observation		Argentina	NanoAvionics	2019
SAT4M2M	1-10kg	Communications		Germany		
Satellogic	10-100kg	Earth Observation	300	Argentina	Satellogic	mid-2017
Sky and Space Global	1-10kg	Communications	200	Australia	GOMSpace	end-2018
Spacebit	1-10kg	Communications		UK		
SpaceChain	1-10kg	Communications	72	China	ComSat, GOMSpace	2018
SpaceQuest/Aprize Satellite	10-100kg	Communications	64	USA	SpaceQuest	
SpaceX	100-500kg	Communications	4425	USA	SpaceX	2018
SpaceX	100-500kg	Communications	7518	USA	SpaceX	
Spire	100-500kg	Maritime Tracking & Earth Observation	125	USA	Spire/Clyde Space	ongoing
SRT Marine	10-100kg	Communications	6	UK	Clyde Space	2019
Star-ALE	10-100kg	Entertainment		Japan		
Tekever	10-100kg	Maritime Tracking & Earth Observation	12	Portugal		2020
Telesat	10-100kg	Communications	117	Canada	SSL for one prototype, SSTL for another prototype	2018
Terran Orbital	1-10kg	Earth Observation		USA	Tyvak	2019
Transcelestial Technologies	1-10kg	Communications	100	Singapore		
Trident Space	100-500kg	Earth Observation		USA		
UmbraLab	10-100kg	Earth Observation	12	USA		
Unseenlabs	1-10kg	Maritime Tracking		France	GOMSpace	
UrbanObserver	10-100kg	Earth Observation	10	Russia	Dauria Aerospace	2018
UrtheCast	100-500kg	Earth Observation	16	Canada	SSTL	

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Xenesis	100-500kg	Communications		USA		2020
XinWei		Communications	32	China		
XpressSAR		Earth Observation	4	USA		2020

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.

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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:

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