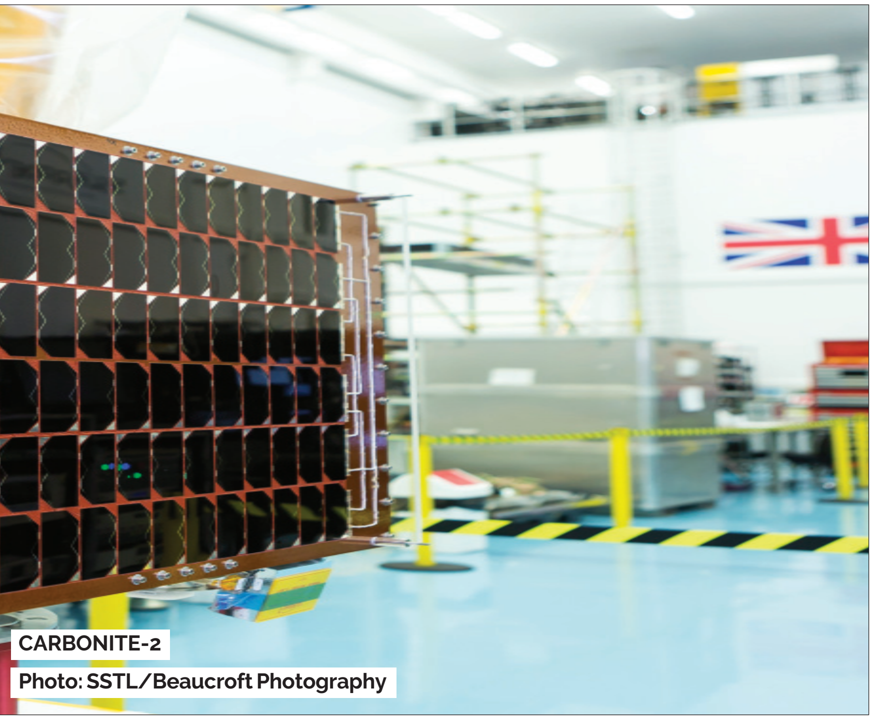
Small satellites:
The NewSpace revolution

Small satellites have truly come into their own in recent years, with unique applications for Earth observation, research and development, and new communications solutions all paving the way for new applications, and in turn, new demand. Martin Jarrold, Chief International Programme Development at the Global VSAT Forum (GVF), opines on the key role small satellites will play in the NewSpace revolution.

Launch of Tintin A & B on a flight-proven Falcon 9

Photo: SpaceX



CARBONITE-2

Photo: SSTL/Beaucroft Photography

Traditional news and social media over this year's long Easter weekend gave an atypically high profile to some space stories – from both the 'old space' and NewSpace environments.

From the old space world, the Chinese Space Agency's Tiangong-1 space station, adrift and out of control since 2016, was reported tumbling to atmospheric re-entry and a fiery end, with surviving debris crashing into the Pacific Ocean according to morning reports on 2nd April.

At the same time, SpaceX, one of the biggest players in the NewSpace revolution – wherein access to space and applications using space is undergoing change from a domain dominated by governments (although, of course, with the private sector always having had a technology and services supplier role/relationship with governments) to a more accessible, affordable, and commercially-oriented domain (that has, in actuality, prompted more governments to establish their own space agencies) – was celebrating yet another success of its reusable Falcon 9 launcher technology, whilst at the same time ruminating on the decision of the US Federal Communications Commission relating to the imposition of, in the SpaceX view at least, a less than ideal orbiting schedule for its Starlink constellation.

Another reported aspect of the NewSpace environment was the 2nd April launch of the proof-of-concept RemoveDebris mission, a spacecraft carrying camera technology and a laser ranging Lidar to track, characterise and target orbital debris, a harpoon plus a net to capture debris, and a 'dragsail' membrane which will unfurl from the spacecraft to hasten its atmospheric re-entry and destruction, along with the captured 'space junk.'

Making the headlines

Aside from the technology, if the financial forecasts for the scale of the emerging NewSpace market prove true, it is destined to continue as front-page news. Bank of America Merrill Lynch has estimated the current value of the space market — manufacture and use of infrastructure, space-enabled applications, etc., a pan-industry figure not limited to just the NewSpace/small satellites arena — at US$339 billion, predicting that by 2045 this figure will grow with expansion across the satellite deployment, ancillary services and launch capability segments by a factor of eight, to US$2.7 trillion.

The NSR's *Small Satellite Markets* (4th edition) report forecasts that the value of the small satellites market will increase year-on-year over the period 2019-2022, and in each of the years 2021, 2022 and 2023, the market value will approximate to US$2.2 billion.

Figures like this serve to illustrate the point that space is trending away from being the sole preserve of government agencies. Now, a myriad of private companies, including new start-ups and spin-offs from academia, and driven by commercial competition for customers, are the very fabric of NewSpace. Thus, NewSpace investment isn't only coming from the pockets of well-known billionaires such as the performance car manufacturing, commercial airline, or Internet environments, nor only from the makers of one of the better-known carbonated drinks.

> If the financial forecasts for the scale of the emerging NewSpace market prove true, it is destined to continue as front-page news

Investors of all flavours and sizes channelled a total of US$2.8bn into NewSpace start-ups in 2016; this evolving and expanding commercialisation of space, facilitated by and reflected in these investments, is originating from companies located in a widening range of countries. These include not only more traditional government space and commercial space nations such as the USA, Russia, China, Japan, India, France, Italy, Canada, Spain, the UK, and many European countries not previously considered space-active nations (except for having crew members on the ISS) through to smaller developing nations including most recently Laos and Nepal. The latter countries are cooperating in the Tricom-1R micro-satellite programme led by Tokyo University which, in Laos, will serve a low-data rate communications application for environmental monitoring, but also using complementary imaging technology.

Small satellites, big expectations

According to Satellite Applications Catapult analysis, 328 small satellites were launched in 2017, and the 2018 forecast for microsatellite launches across the globe, according to SpaceworksSEI, falls between 263 and 413. Those 328 small satellites referred to satellites of mass up to 500kg, but according to the Satellite Applications Catapult, some 89 percent of these were less than 10kg (nanosatellites). The 2018 forecast figure specifically references the term microsatellite, rather than small satellite. The term 'small satellite,' or sometimes 'mini-satellite,' is often seen as referring to a spacecraft with a wet mass (including fuel) between 100kg and 500kg but may also be used to mean any satellite under 500kg.

'Small,' 'nano,' 'micro,' 'mini' - There is potential for a lot of confusion. Therefore, we use widely-recognized definitions such as: Small satellites (the catch-all term for spacecraft with mass under 500kg); mini-satellites (mass range 100kg-500kg); microsatellites (mass range 10kg-100kg); nanosatellites (mass range 1.0kg-10kg); picosatellites (mass range 0.1kg-1.0kg); and Femtosatellites (mass range 0.01kg - 0.1kg).

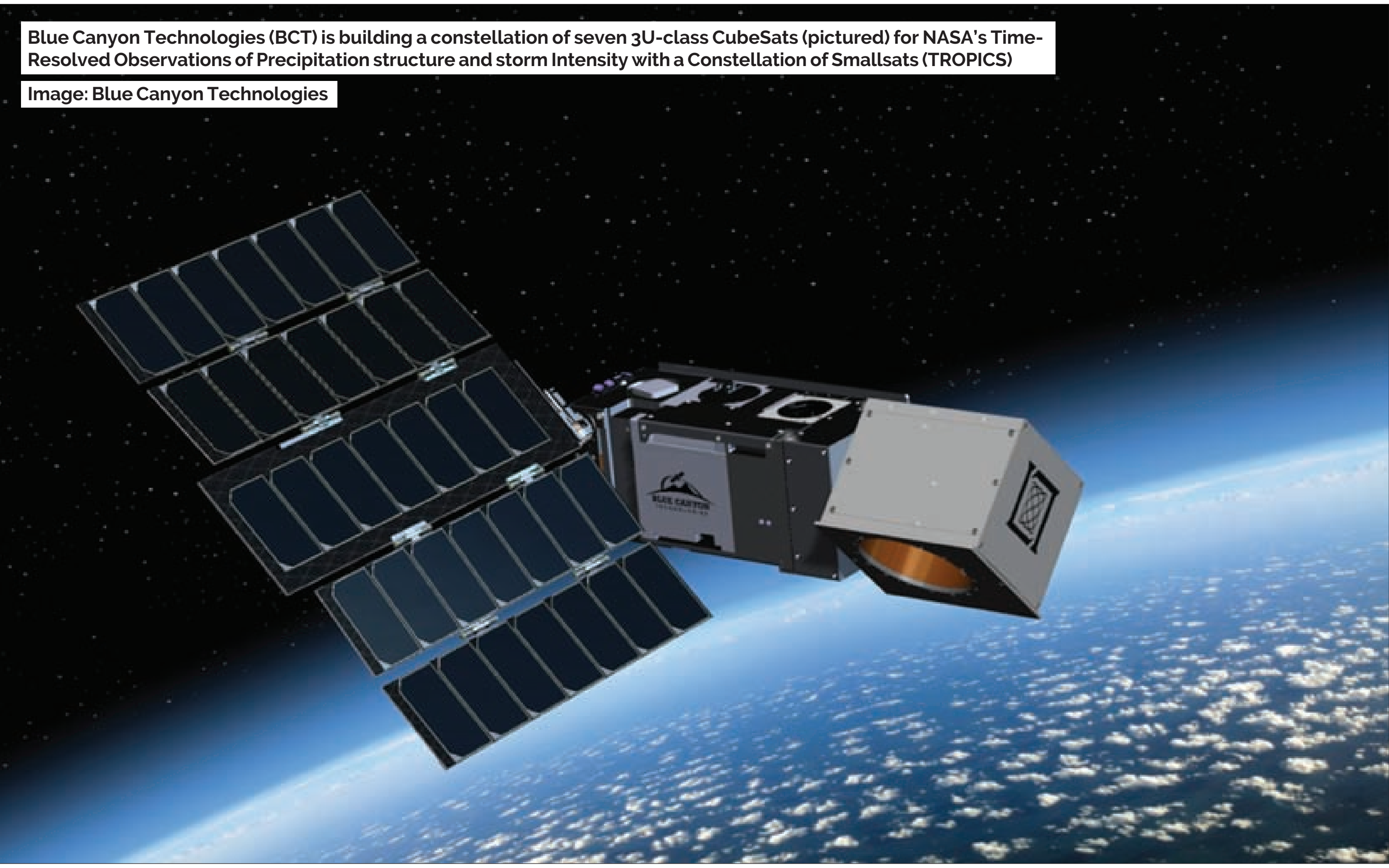
Given the scale of some of these descriptive names/terms (and their associated diminutive mass), it would be useful to provide some contextualisation:

- **Microsatellites:** Designs of this type sometimes have the microsatellites working together or in a formation.
- **Nanosatellites:** Designs of this type may be launched individually, or they may have multiple nanosatellites working together or in formation, when sometimes the term 'satellite swarm' or 'fractionated spacecraft' is used. Some designs require a larger 'mother' satellite for communication with the ground or for launching and docking with the nanosatellites. With advanced miniaturisation and capability in electronics and the use of satellite constellations, nanosatellites are increasingly capable of performing commercial missions previously requiring microsatellites. In Earth imaging/observation, for the same mission cost, significantly increased revisits (high-frequency change detection) are achievable with nanosatellite constellations.
- **Picosatellites:** Designs usually have multiple picosatellites working together or in formation ('swarm'). Some designs require a larger 'mother' satellite for communication with the ground or for launching and docking with picosatellites. The CubeSat design, with approximately 1.0kg mass, is an example of a large picosatellite (or small nanosatellite).
- **Femtosatellites:** Like picosatellites, some designs require a larger 'mother' satellite for communication with the ground. In March 2014, the nanosatellite KickSat was launched on a Space X Falcon 9 to release 104 femto-satellite-sized 'chipsats' called 'Sprites.'

Referring back to the figure of 328 small satellites launched in 2017, a larger total than ever before, it is noteworthy that two thirds of these spacecraft were orbited to deliver Earth imaging/observation applications. Of the remaining 33 percent, only a small proportion (just two percent) were for communications, with 31 percent for technological and scientific applications. This is noteworthy because pre-NewSpace, Earth observation was firmly confined to governments and their various specialised agencies, that is, those with budgets big enough to sustain such – then – expensive programmes. Earth imaging/observation is no longer such an expensive and exclusive club.

This is not, of course, to suggest that the NewSpace/small satellite environment falls outside the scope of communications – indeed, the not so distant future will show us that the truth is very far from that.

In late February, two experimental SpaceX satellites – Tintin A & B – were launched as demonstration platforms to lay the foundation for the forthcoming Starlink constellation that will provide Internet access from low Earth orbit (LEO)/non-Geostationary orbit (NGSO). Tintin A & B were launched with a mass of approximately 400kg each, reinforcing the general expectation that the 4425 satellites of the, now expanded, Starlink constellation will 'weigh-in' in the mini-satellites class. What is significant about the number of satellites in the planned SpaceX mega-constellation and about the planned mega-constellations of others – including OneWeb and Telesat – is not only the fact that so many are needed to deliver on the respective business and service models for providing Internet access from LEO, but that the only way to make the projects financially feasible is to have smaller spacecraft built in a new way. Not the lengthy bespoke process of building a multi-tonne spacecraft destined for geostationary orbit, but using a combination of off-the-shelf components, new satellite system miniaturisation technologies, and mass-production techniques, at low-cost per-unit of functional capability.



Blue Canyon Technologies (BCT) is building a constellation of seven 3U-class CubeSats (pictured) for NASA's Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS)

Image: Blue Canyon Technologies

The emerging IoT world

So, the near-future full realisation of that part of the NewSpace revolution that is the technology of small satellites, and of the full advantages of their scalability to constellation configuration, will be across three principal segments: Communications (including connectivity for the Internet of Things (IoT), and machine-to-machine – M2M, applications), Earth Imaging/Observation, and Scientific/Technological.

Of course, small satellites in constellations operate in NGSO, that is, LEO for communications and Sun-synchronous orbit (SSO), a LEO variant, for Earth imaging/observation. For telecommunications applications (including IoT/M2M), this means being able to take advantage of higher performing link budgets and reduced transmission latency while having the coverage of higher altitude orbits. For Earth imaging/observation, this reduces revisit times/increases revisit frequencies (high-frequency change detection) for the same surface territory.

Small satellite constellations will be a vital element in the success of the emerging IoT world that is one facet of the 5G mobile broadband communications future. In June this year, the GVF's own programme of conferences, organised through its portfolio partnership with UK Event Management Partners (EMP), will address this environment. Satellite connectivity has provided the communications foundation for the requirements of several verticals – including M2M applications – for some several decades, but now it is trending to centre stage for applications and users across the economic and social spectrum. It is no longer regarded by the wider sphere of communications solution provisioning as being stage left, no longer regarded as a niche market-only technology, no longer a solution of last or remote resort.

At no earlier point in the history of mobile communications is the success of the next generation of networking technologies so dependent upon the take-up of network services by industry vertical markets. This is clearly reflected in the qualitative nature of 5G, a quantum leap beyond the person-to-person communications focus of earlier generations of mobile and towards a device-to-device ecosphere characterised, according to the International Telecommunication Union (ITU), as:

- **Enhanced Mobile Broadband (eMBB) -** Aimed at meeting demand for increasingly digital lifestyles, focusing on services with high bandwidth requirements, e.g., high definition (HD) videos, virtual reality (VR), augmented reality (AR);
- **Ultra-reliable and Low-latency Communications (uRLLC)** – Aimed at meeting expectations from digital industry, focusing on latency-sensitive services, e.g., assisted and automated driving, remote management; and
- **Massive Machine Type Communications (mMTC)** – Aimed at meeting demand for a further developed digital society, focusing on services that include high requirements for connection density, e.g., IoT for smart cities, smart agriculture, resources management, infrastructure and utilities monitoring, location-based services (LBS), etc.

The nature of 5G is, therefore, about a world of devices, that is, with the IoT, or rather – in time and with growth and evolution in the market – an Internet of Everything Everywhere (IoEE). Also, a quantum leap – a leap, that is, beyond the realms of the maturing and still expanding M2M connectivity environment which has an already long-standing dependency on, and synergy with, satellite communications links. The world of IoT will be built on a connectivity foundation which will comprise a highly integrated functionality of, and between, terrestrial broadband wireless platforms and broadband satellite platforms.

The 5G networked world of IoT, and related applications, will require that every device is connected wherever it happens to be and whilst Wi-Fi, Bluetooth and today's terrestrial wireless network connections are able to support many IoT applications, these technologies are not, and will never be, ubiquitous and seamless. Thus, they are not readily able to service the many areas of low population density within which economic activities – such as in the agriculture, civil engineering, mining, oil and gas and utilities sectors as well as in transport (human and logistical) between urban hubs – and the provision of social programs – such as education and health services – will benefit from IoT.

IoT coverage, to be truly global in scope in terms of both urban device density and remote device deployment, will require wholesale integration of the terrestrial with the ubiquity and seamlessness that only satellite networks – increasingly coming to include small satellite constellations – can provide.

Networks of networks

Looking to the future, the Euroconsult *Prospects for the Small Satellite Market* report (3rd edition) forecasts that the small satellite market will experience sustained expansion through to 2026 (the forecast period addressed in the report), with the total value (manufacture and launch) of the market reaching as much as US$30.1 billion. Expansion will be driven by the roll-out of multiple constellations mainly for commercial operators.

The report further forecasts that this period will see the launch of over 6,200 small satellites with the Earth imaging/observation segment accounting for over 1,100 of this number and broadband communication expected to exhibit the strongest growth in units launched – with the advent of the constellations from OneWeb, SpaceX, Telesat, and several other operators – comprising 50 percent of the overall number of small satellite orbited.

NSR's analysis of the period 2016-2026 in the 4th edition of their *Small Satellite Markets* report shows that globally the number of small satellites launched will peak in 2022 with around 620 forecast to be launched in that year.

Small satellite constellations will develop as a core element of NewSpace and of the wider revolution in device-to-device communications that will be 5G. As referenced by the 3GPP, the 5GPPP, and other stakeholders, satellite will no longer feature as merely an 'interfacing' technology and service, with a secondary role in the 'network,' but an 'integrated' technology and service, fully part of an evolving and complex 'network of networks.'