

A sustainable path for high performance science satellites

High performance scientific satellites are currently the exclusive domain of government funded agencies. The team behind the Twinkle Space Mission is developing a new class of small and sustainable science satellites that leverages recent innovations in the commercial space sector.

Scientific missions delivered by space agencies have had a transformational impact on science and society. Missions such as Voyager have revealed valuable information about our solar system and beyond, while Earth observation satellites such as Envisat have provided long-term temperature trends confirming global warming. These pioneering missions have led to innumerable discoveries and set a high technical standard for space instrumentation.

General space science observatories, such as the Hubble and Spitzer Space Telescopes and XMM-Newton, typically cover a multitude of scientific use cases. The high-performance science instruments within these satellites often require complex and cutting-edge technology uniquely developed for each mission. With long development time scales and high implementation costs, there are a relatively low number of operational science satellites compared to other sectors such as commercial Earth observation. As a result, the scientific community has so far had to compete for time on vastly oversubscribed space-based telescopes.

Ground-based observations and new small robotic telescope networks are often more accessible, with facilities built and managed by intergovernmental and private organisations. Many of these facilities have developed innovative data access models, including the sale of telescope “nights” and membership-based survey collaboration models. Over time, the community has become accustomed to this novel approach and there has been an associated increase in funding grants to purchase “telescope time”.

Unfortunately, ground-based observations have their own challenges and limitations, with large parts of the electromagnetic spectrum blocked due to absorption and scattering in the Earth’s atmosphere. In addition, the thermal background from the sky and telescope are strongly variable, making high-precision ground-based observations impossible at infrared wavelengths. Space instruments can overcome these issues, but it is a well-known fact that sending satellites into space is difficult and expensive. Many universities and research institutes around the world have challenged the current model by building in-house scientific “cubesats” (satellites with a mass of a few kilograms¹). However, instruments compatible with the cubesat format are often too small to address broad science questions. To date, these have only been addressed through flagship missions built by government agencies.

Innovative approaches to change the status quo

Driven by a strong market demand for communications, Earth observation and navigation, the private sector has increased access to formerly expensive technologies and commoditised satellite platforms. This has resulted in the acceleration of timescales for in-orbit delivery and a lowering of costs. In recent years there has been a boom in companies offering innovative solutions in the “new space” domain, in part enabled by cubesats. Commercial successes such as Planet Labs² have in addition fuelled a growth in the space-funding ecosystem, increasing access to the capital required to get major projects off the ground. This increased demand has helped drive down the cost of launchers with new companies established such as SpaceX³, ISAR⁴, and Rocket Lab⁵. While building satellites is still complex and expensive, the increased reliability and the lower cost of platforms and launches has changed the environment sufficiently to try new approaches.

Blue Skies Space was founded in 2014 to challenge the current paradigm of scientific space missions, and will launch a series of cost-effective satellites to meet the demand for more space data in specific areas of science. Data from these satellites will be delivered to scientists through a membership access model similar to that used by many ground telescopes (e.g. surveys such as SDSS⁶). The first mission, Twinkle⁷, was selected to investigate the exciting fields of exoplanet and solar system science through infrared spectroscopy.

Blue Skies Space is not alone in looking at new ways to enable more space-based instruments; the seeds of change are definitely being seen around the world, with scientists finding creative ways to obtain data through small cubesats (such as CUTE⁸, Skyhopper⁹ and ASTERIA¹⁰). National space agencies also recognise the need to accelerate science and are offering launch opportunities for cubesats (e.g. NASA’s CubeSat Launch Initiative¹¹) whilst trialling faster and smaller mission categories such as ESA’s F-class mission¹².

As Twinkle’s new delivery model has never been done before, scientists, satellite manufacturers and financial supporters had to be convinced that this will work. Blue Skies Space has assembled a unique team with the right skills to overcome the hurdles and deliver a complex satellite. Science performance analyses, technical studies, funding campaigns and global market studies had to be completed to provide evidence that this new model was viable.

A technological sweet spot

Flagship missions built by intergovernmental space agencies are not only necessary to push the boundaries of feasibility for cutting edge science, but also to drive technical developments for space instrumentation. But demanding science requirements – such as high redshift galaxy observations in the case of the James Webb Space Telescope¹³ have often led to large, highly customised satellites in expensive to reach orbits costing orders of magnitude more than their low earth counterparts. While the role of agencies is critical for advancing science and technical innovation, scientists worldwide have expressed their desire to the Blue

Skies Space team to see flagship missions complemented by less ambitious, but more cost-effective and frequently launched satellites. This is visible in the current satellite selection process, where for every satellite built by space agencies, many are proposed by the community. Three to five are usually studied in detail but never get built.

The Blue Skies Space team postulated that through carefully considered trade-offs, a technological “sweet spot” can enable the launch of highly capable satellites using cost-effective technologies for a range of science topics. To capitalise on the lower price points of getting into space, satellites orbiting the Earth at an altitude of 700 km and a mass of 350kg are ideally suited. The focus is on the maximum reuse of existing subsystems and products whilst harnessing the performance of available, flight-proven components. However, the most challenging part of a scientific satellite is the instrument on board, which has to be carefully designed to carry out sensitive observations. While research and development is minimised through the use of existing component-building blocks, the assembled satellite will always contain some mission specific elements, which requires highly experienced manufacturers to design and build them. Similar to the model developed by the satellite telecommunications industry, the construction of Blue Skies Space’s satellites is outsourced to experienced suppliers. In the case of Twinkle, the initial feasibility was carried out jointly with UK organisations (including RAL Space, UKATC and Surrey Satellite Technology Ltd.), and was followed by an industrial validation phase led by Airbus Defence and Space¹⁴ and ABB Canada¹⁵ to enable the commercial procurement of relevant components minimising bespoke and expensive R&D.

Space is expensive

Some universities can afford to develop cubesats, but building bigger satellites requires significant capital and specialist laboratory facilities. F-class missions, whilst faster to build (under ten years) and cheaper, are still developed by a space agency at a cost of 100’s of millions of US dollars. The approach with Twinkle on reusing existing capabilities and minimising R&D costs reduces the required budget by an order of magnitude. The challenge is that Twinkle’s budget still falls between two extremes, too expensive for a university project but too small to fit within existing space mission programmes. Blue Skies Space has had to create a new funding path to develop this new class of mission.

Blue Skies Space addressed this challenge by implementing a commercial, service-based model, where scientists can join multi-year collaborative surveys at a fraction of the cost of a satellite. While the sale of annual memberships - an offering similar to that used by independent ground telescopes - will recover the costs of Twinkle, the majority of these revenues will only be obtained once the satellite is launched and delivering data. Twinkle has to be fully funded upfront, and it is a large one-off investment. This upfront cost would normally be a major barrier to entry for anyone attempting such an endeavour. As a private company who re-invests its revenues in future missions, Blue Skies Space has the flexibility to use multiple routes of funding including private and government investment, as well as the ability to fully insure the satellite, removing a significant risk normally associated with science satellites.

With this clear vision beyond the first mission, the European Space Agency and the UK Space Agency decided to back this project, which in turn unlocked further private funding.

Blue Skies Space will enable the construction and launch of many more science instruments, as long as they can be incorporated in a cost-effective platform, and there is a sufficient demand for the data in the community. With a funding programme running to plan and an expert team assembled to successfully deliver Twinkle, the team is now preparing for the build of the satellite and its launch by January 2024.

Enabling more science satellites

The idea of taking a commercial approach to enable more science satellites was exciting but uncharted territory, so Blue Skies Space engaged the global scientific community early on to validate the model. Despite initial scepticism from a fraction of the community, many scientists are now excited by the opportunity and in fact the collaborative survey proposition was conceived thanks to their feedback. Twinkle's Founding Members have profiles varying from small university research groups to major established research teams and consortia. These members are now involved in shaping the science programme, even before the construction of the satellite has begun.

This model for a new class of science satellites was initiated by scientists who wanted more data and its success will be measured by its science output and the continued participation in its research programmes by the scientific community. For now the focus is very much on delivering Twinkle, but naturally Blue Skies Space is also looking ahead with a call¹⁶ for the second generation of satellites opening soon. Twinkle will show that a carefully delivered sustainable approach can provide value to the science community as a whole, while complementing flagship satellites delivered by space agencies. This will open a new era of convenient data access from more space-based instruments.

Richard Archer and Marcell Tessenyi work at Blue Skies Space, the company delivering and managing the Twinkle space mission.

Contact: richard@bssl.space , marcell@bssl.space

References

- 1 <https://www.cubesat.org/about>
- 2 <https://www.planet.com/>
- 3 <https://www.spacex.com/>
- 4 <https://www.isaraerospace.com/>
- 5 <https://www.rocketlabusa.com/>
- 6 <https://www.sdss.org/>
- 7 <https://www.twinkle-spacemission.co.uk>
- 8 <https://lasp.colorado.edu/home/cute/>
- 9 <https://skyhopper.research.unimelb.edu.au/about/>
- 10 <https://www.jpl.nasa.gov/cubesat/missions/asteria.php>
- 11 https://www.nasa.gov/directorates/heo/home/CubeSats_initiative
- 12 <https://www.cosmos.esa.int/web/call-for-fast-mission-2018/>
- 13 <https://www.jwst.nasa.gov>
- 14 <https://www.airbus.com/space.html>
- 15 <https://new.abb.com/products/measurement-products/analytical/space-defense-systems>
- 16 The call will be made available on the Twinkle homepage at www.twinkle-spacemission.co.uk