xSPANCION: Extended Satellite Production and Constellation Operations

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Abstract

The demand for space data is booming across the globe. The need to utilise and access space infrastructure in a timely and cost-effective manner for a variety of space data users, without the need or desire to understand it, is increasing. The New Space revolution, powered by small satellites with reduced costs and timelines to access space, is enabling an increase in the number and variety of organisations utilising space-based data sources.

The xSPANCION project will address the global demand for simplified access to space to stimulate industry growth by catalysing a new generation of applications previously not possible. The programme elements are designed to enable AAC Clyde Space to deliver 'Space-Data-as-a-Service', through the production of nanosatellites at low-cost and high-volume, and in becoming a constellation operator to provide interfaces for customers to access their mission data without technical and financial complication unrelated to their business core.

xSPANCION is a project within the European Space Agency (ESA) Pioneer Partnership Programme and is a public private partnership between ESA, the UK Space Agency and AAC Clyde Space with industry and academic partners including Bright Ascension Ltd, the University of Strathclyde, D-Orbit UK, the Satellite Applications Catapult and Alden Legal UK.

1 INTRODUCTION

The recent 'New Space' revolution has attracted a new wave of entrepreneurs who have demonstrated the successful delivery of a variety of business cases relying on data generated from space. The need to utilise and access space infrastructure in a timely and cost-effective manner for a variety of space data users, without the need or desire to understand it, is increasing.

According to the Euroconsult *Prospects for the Small Satellite Market* [1], 84% of the future small satellite demand will be driven by constellations, with approximately 13,910 satellites <500 kg to be launched in the next 10 years. Telecoms small satellites are expected to exhibit the strongest growth in terms of units to be launched.

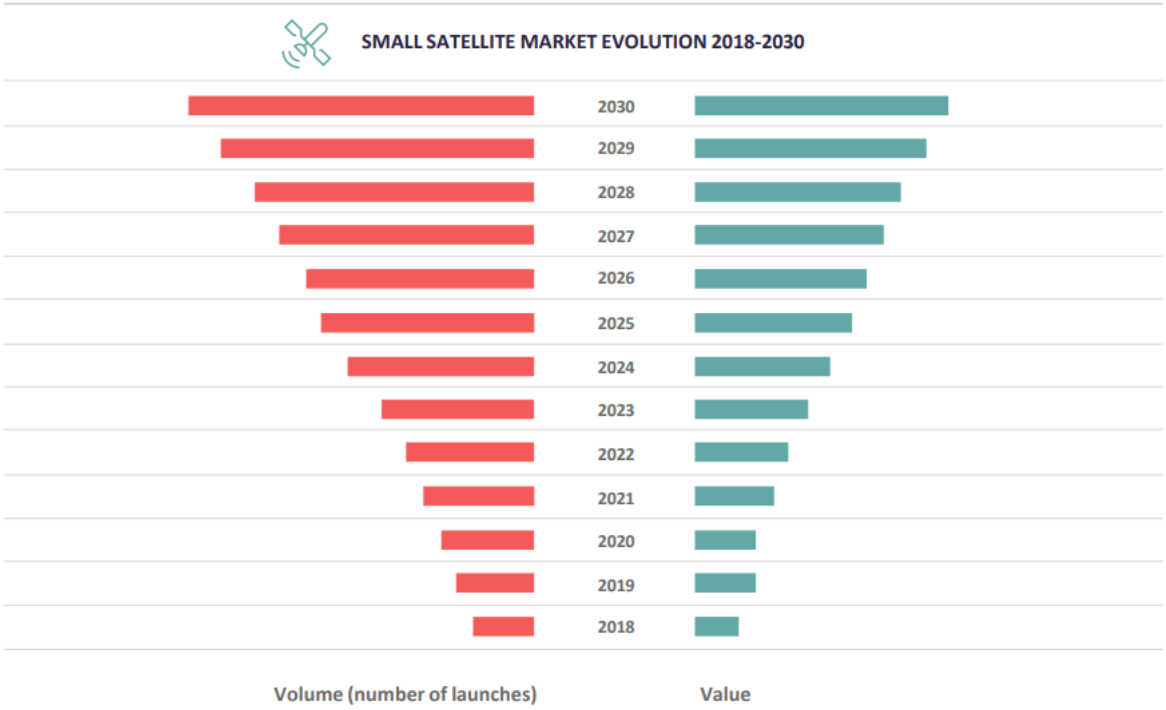

Figure 1. Small satellites to witness significant revenue growth [2]

The xSPANCION project will address the global demand for simplified access to space to stimulate industry growth by catalysing a new generation of applications previously not possible. The project is transformational. It lays the groundwork for AAC Clyde Space to respond to the growing market need for the provision of space data and services quickly and at low cost. The xSPANCION project will allow industrialisation of the satellite lifecycle to respond to the need for satellite constellations to enable a wide range of applications including satellite communications, Earth observation and remote sensing.

This will establish AAC Clyde Space as a Space Mission Provider (SMP). It will revolutionise the mechanism by which AAC Clyde Space delivers products and services to customers. This will enable more effective access to space for Proof of Concept (PoC) missions, efficient commercial delivery of satellite constellations, as well as the generation of a new Space-Data-as-a-Service offering. This will be achieved through an Integrated Product and Process Development (IPPD) approach to generate a flexible, constellation-ready spacecraft design, an optimised production process capable of high-volume satellite delivery, an innovative framework to operate large-scale constellations, licensing and launch coordination, and customer-facing interfaces, all fully integrated with a model-based approach.

The project, which kicked off in 2020, has progressed through the Preliminary Design Review (PDR) into the second spacecraft manufacturing preparation phase. The third and final phase of the project, expected to commence in 2022, includes manufacturing of ten spacecraft and the launch of four demonstration spacecraft.

The satellites will have a standardised and modularised architecture and will combine cutting edge technology, including intersatellite links (ISLs), propulsion and articulated solar arrays, together with constellation ready production.

This paper will provide an overview of the innovative developments taking place under xSPANCION. It will summarise the benefits of public private partnerships, through the ESA Pioneer Partnership Programme, and the power of collaboration to drive innovation.

2 xSPANCION OVERVIEW

2.1 Objectives

Together with partners, the project will:

- Develop a step-change in the process for mission design and satellite production, incorporating end-to-end traceability and automation delivering high-volume capacity;
- Develop new technologies for future constellations, including responsive propulsion, enhanced power generation and intersatellite communication architectures;
- Coordinate management of licensing and launch at scale;
- Utilise on-orbit assets, and ground station infrastructure to collect and package data to respond to customer requirements through a constellation operations platform;
- Enhance the AAC Clyde Space SDaaS solution further for the safe and secure transmission of data, not only including the collection and processing of satellite data but also safeguarding data from corruption, compromise, or loss;
- Develop data interfaces, which will provide access through secure, cloud-based data portals and offer advanced data analytics capabilities to clients.

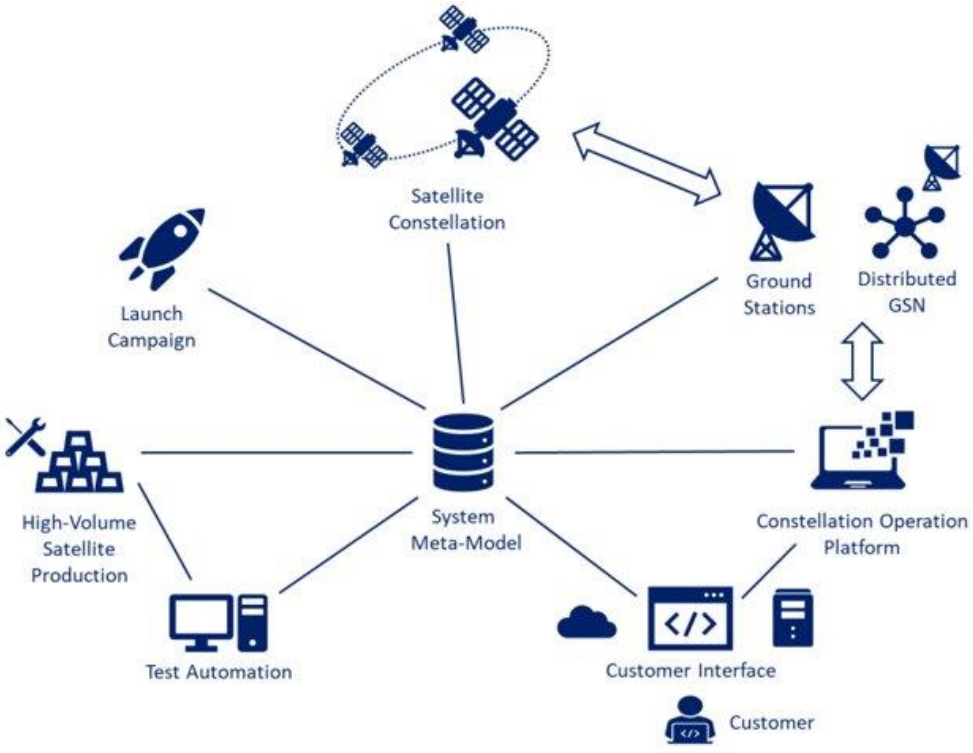

Figure 2. Integration of the value chain via a model-based approach

2.2 Project Partners

xSPANCION is a project within the ESA Pioneer Partnership Programme and is a public private partnership between ESA, the UK Space Agency and AAC Clyde Space with industry and academic partners including Bright Ascension Ltd, the University of Strathclyde, D-Orbit UK, the Satellite Applications Catapult and Alden Legal UK.

AAC Clyde Space

AAC Clyde Space specialise in small satellite technologies and services that enable a growing number of commercial, government and educational organisations to access high-quality, timely data from space. The organisation has been at the forefront of New Space innovation for over a decade, delivering:

1. **Space Products and Components** - standardised and bespoke subsystems for cube and small satellites up to around 500 kg.
2. **Space Missions –** comprehensive packages including mission analysis & design, development & integration of payloads, production & testing of flight-ready platforms, access to space, operations, and data delivery for spacecraft up to around 50 kg.
3. **Space Data as a Service (SDaaS)** - AAC Clyde Space build, own and operate the satellites, delivering only the data or communications required by customers to allow them to focus on their core business.

Bright Ascension Ltd

Bright Ascension is a space software company providing software products, software development services and R&D consultancy.

Direct involvement with a number of CubeSat missions, including technology demonstrators and science missions, and spanning both flight and ground, has allowed the organisation to build up a large amount of relevant experience and to mature software products. Bright Ascension's software is now being used for more than twenty missions and customers across the world.

D-Orbit UK

D-Orbit is a New Space company offering solutions covering the entire life cycle of a space mission, including mission analysis and design, engineering, manufacturing, integration, testing, launch and end-of-life decommissioning.

The D-Orbit team is dedicated to developing cutting edge and innovative solutions to support any aspects of a space mission. Committed to pursuing business models that are profitable, friendly for the environment, and socially beneficial, D-Orbit is the first certified B-Corp space company in the world.

Alden Legal

Alden is a unique law firm, specialising in providing the highest quality of legal, regulatory and policy advice to businesses, Governments, regulators and organisations working in the space, satellite, telecommunications and applications sectors.

Alden have unique and specific experience of space and satellite regulations, from spectrum filings to launch and operations licensing conditions and requirements. Alden work closely with regulators and governments to obtain required licences and shape the licensing regime.

Satellite Applications Catapult

The Catapult's primary purpose is to promote, develop and facilitate the commercialisation and advancement of the satellite applications industry. The Catapult helps organisations make use of and benefit from satellite technologies and brings together multi-disciplinary and skilled teams to generate ideas and solutions in an open innovative and collaborative environment. They also have a wide range of facilities, platforms and laboratories to enable the best businesses, researchers and end-users to work together to develop new satellite-based products, services and applications - translating ideas from concept to market.

University of Strathclyde

The University of Strathclyde is the birthplace of modern engineering education, instructing on mechanics and the applied sciences since 1800.

Key personnel undertaking this work are based in the Centre for Signal and Image Processing (CeSIP) who have a world class reputation for innovative research into new algorithms, architectures and applications. CeSIP are part of the wider Institute for Sensors, Signals and Communication within the Electronic and Electrical Engineering (EEE) department. In addition, other key personnel undertaking this work are based in the Advanced Forming Research Centre (AFRC), a part of the National Manufacturing Institute Scotland. The AFRC is recognised internationally for successful project delivery resulting in process efficiency gains across manufacturing.

3 xSPANCION DEVELOPMENTS

3.1 Constellations

As outlined in Section 1, the future delivery of services from small satellites will rely heavily on constellations. Although the CubeSat revolution has demonstrated how it is possible to reduce the cost of manufacturing, launching and operating spacecraft, it still demands significant investment to realise a mission with tens or even hundreds of satellites which imposes a heavy burden on application and service developers.

Analogous to other industries, significant cost reductions to drive the next wave of innovative applications is only possible with more vertical integration, and true volume manufacturing, enabled by more efficient means of satellite production.

The xSPANCION project is therefore developing digital production systems to significantly scale-up the manufacturing capacity to meet the market need for constellations.

3.2 Digitalisation

While the CubeSat market has to-date largely relied on standardisation and miniaturisation to reduce costs, there clearly still exists an element of modification and design for each mission. Despite the recent advancements in small satellite technology, for the most-part, nanosatellite

development still follows a simplified version of Document-based Systems Engineering from the traditional space industry.

Model-Based Systems Engineering (MBSE) can address the complexity which occurs with traditional, document-centric and test-based approaches. The implementation of MBSE is key to digitalising engineering and eliminating documentation to enable the shift to true industrialisation of satellite delivery.

In addition, new entrants to the market, particularly those unfamiliar with space-based applications, require a cost level and lead time of the required products comparable to terrestrial-based services.

The ability of MBSE to streamline the design process, drive efficiency and keep costs, time and quality under control therefore make it an innovative approach to address these ever more important customer requirements.

AAC Clyde Space is modifying the ways to control its production and quality system from paper-based to a digital, cost-saving process. This will enable staff to track, control and modify processes and requirements in real-time with minimal needs of time/resources, and reduce the environmental footprint. The digital implementation will reduce costs, time, storage, information potentially lost, destroyed and materials degradation.

To achieve these goals, a more technologically flexible system must be implemented which will provide for the following:

- Provide real time visibility across the enterprise of production and distribution activities;
- Reduce labour costs for production and administrative functions;
- Automate inventory management;
- Track revision levels and control of component parts;
- Comply with customer requirements for out-bound shipping;
- Automate order fulfilment process increasing product turns, customer service and shipping accuracy;
- Provide managerial reporting and costing information for all distribution activity.

3.3 Constellation Enabling Spacecraft

As described in Section 1, there is a growing reliance on space-based data sources to deliver new applications and services from a range of organisations, including those who have no need, or desire, to procure and operate spacecraft. This future demand for timely satellite data will therefore require SMPs, like AAC Clyde Space, to develop, launch, and operate satellite constellations.

Small satellite constellations can provide customers with cost-effective solutions, over traditional space approaches, and can enable sustainable business models using space-based data. However, the resource constraints associated with small satellites continually places demands on SMPs as the customer requirements evolve and advance. This results in a

continuous evolution of satellite design and implementation of innovative technologies. AAC Clyde Space must therefore continue to identify, develop, implement, and demonstrate enabling technologies to overcome design constraints and meet customer needs.

In order to deliver enhanced space-based services, spacecraft constellations will be required to address a number of challenges facing the market. These include:

- Larger volumes of data generated from more capable payloads, to be transmitted at low latency;
- Faster time to orbit and maximum service lifetime to optimise opportunities for revenue generation;
- Availability, accuracy, and reliability of data.

Often these elements are required to be addressed whilst delivering solutions at costs comparable to terrestrial-based services. While this creates challenges for SMPs it also drives innovation within the overall service delivery architecture, particularly in the space segment. Solutions enabling constellations and addressing these market needs include:

- **Inter-satellite links (ISL)** – to overcome the challenges in data delivery by relaying data throughout the constellation in a time efficient manner, thereby reducing the ground segment size and/or costs and offering timely downlink of customer data.
- **Propulsion** combined with novel manoeuvring techniques – to extend mission lifetime to lower costs and maximise service lifetime, to enable formation flying and new mission concepts and to deliver responsive services.
- **Phased array antennas** – to deliver improved bandwidth within the power and mass constraints of small satellites.
- **Actuated solar arrays** – to maximise available power to enable operation of more capable payloads and subsystems, including other constellation-enabling technologies such as propulsion and ISL.
- **Spacecraft Designed for manufacture and test** – to enable manufacture at scale and in short timeframes.

The spacecraft design and development are based on generating a satellite integrating constellation enabling technologies that can meet customer's technical, time and cost requirements. The spacecraft design is conducted by AAC Clyde Space. Flight software of the generic xSPANCION spacecraft platform is built on Bright Ascension's Generation One framework.

The constellation-ready spacecraft is built around an innovative platform architecture, which consolidates core, size-independent, satellite bus subsystems to provide highly capable, mass/volume scalable avionics to suit a range of CubeSats from 3U to 16U and possibly above. Essentially, this is a standardised hardware unit having a degree of software configurability to suit mission requirements. This system is an integration of platform avionics, including AOCS elements (e.g. algorithms and interfaces), power, and command & data handling subsystems. This integrated system consumes less volume and power within the platform than the traditional configuration of discrete subsystems, thereby increasing available payload capacity.

- **The Platform Functional Unit (PFU)** features a range of interfaces to the payload and the platform systems as well as interfaces to allow connection and expansion to functionalities that are required for constellation operations. This comprises of the Computing and Control Unit (CCU), Array and Battery Regulator (ABR), Payload and Data Switching Interface (PDSI).
- **The Payload Interface Module (PIM)** acts as the interface between the PFU and the payloads. It handles power conditioning and distribution for the payloads, data interfacing and likely data processing and storage capabilities. It can also provide high data throughput channels. It is implemented in the PFU, as a part of the PDSI which is an early version of Payload Interface Module (PIM). It interfaces to the payload, ISL and HDR transmitter.
- **Size-dependent systems** are systems that will change with the size of spacecraft or are required to be moved around the spacecraft due to physical placement and orientation, including radios, reaction wheels, batteries, solar panels, structures, optical sensors, or antennae. Deployable solar panels are compatible with 6U, 12U and 16 sizes and capable of articulation to ensure power maximization.
- **Bright Ascension GenerationOne flight software** has been implemented on a number of AAC Clyde Space missions to-date. The software is built from a library of reusable software components; the work within this activity will add components to this library to incorporate the data routing needs of constellations, together with the necessary interfaces to constellation technology such as inter-satellite links and propulsion.

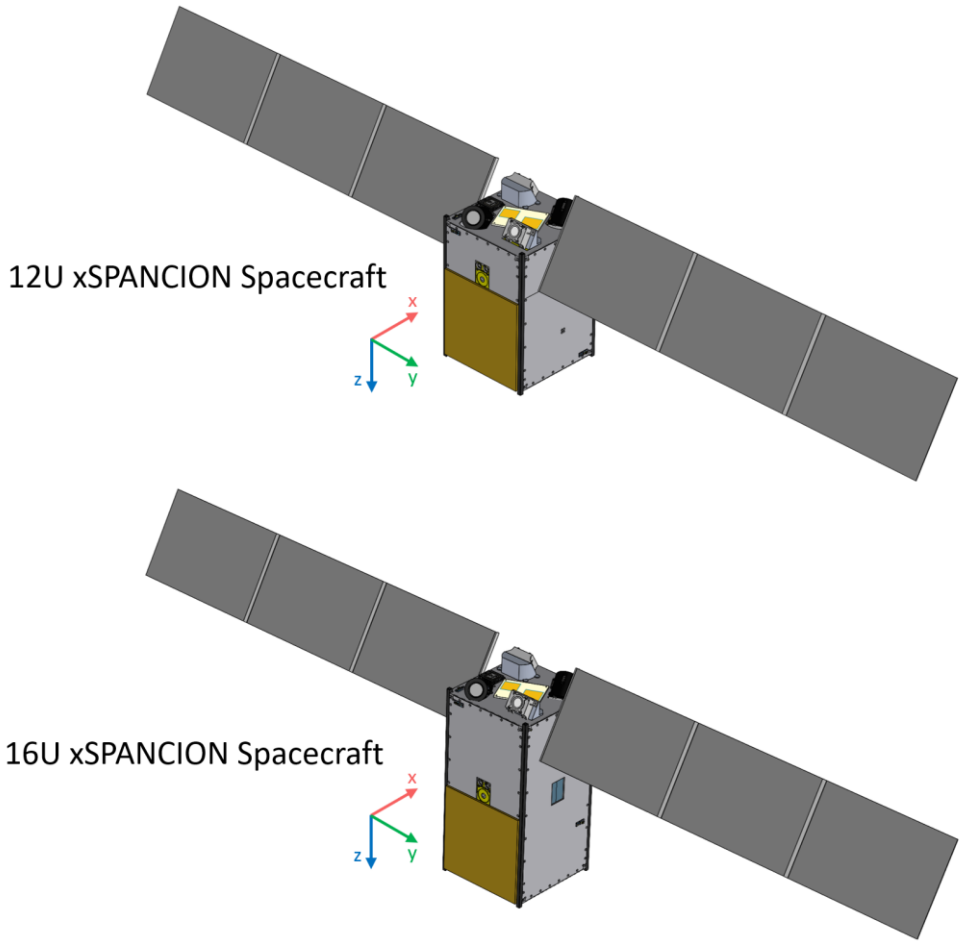

Figure 3. xSPANCION spacecraft platform 12U and 16U configurations

4 PARTNERSHIP BENEFITS

The xSPANCION partnership builds on world leading expertise across industry and academia to facilitate lower cost, shorter lead time access to data from space to facilitate new entrants to the market and the development of new, novel applications and services.

The unlocking of space-based services to a new group of users and developers is ultimately the key to realising the ambitious growth targets for the UK and global space sector in the area of applications. For example, via the establishment of new businesses, growth in exports, job creation as well as wider societal and environmental benefits. Further, the integration of key elements of the space value chain strengthens the commercial offering.

Through xSPANCION an innovative satellite constellation service will be developed which is set to revolutionise the AAC Clyde Space SDaaS offering and provide a step-change in capability. It will enable delivery of low-cost constellation services at scale and in reasonable timeframes to provide compelling constellation delivery to the market. This is critical in fulfilling the market gap which is currently met by service providers becoming vertically integrated to perform their own satellite manufacture.

xSPANCION will advance AAC Clyde Space capability as a Space Mission Provider and one-stop-shop service for Proof-of-Concept, commercial and institutional missions to provide the opportunity for customers to validate new innovative solutions to progress to subsequent stages of their business plans. It will enable effortless access to mission data without technical and financial complication unrelated to core business. The improved capacity to deliver SDaaS as a means of lowering cost and barriers to data access and ultimately enabling earlier revenue generation for customers.

5 CONCLUSION

xSPANCION is a project within the ESA Pioneer Partnership Programme and is a public private partnership between ESA, the UK Space Agency and AAC Clyde Space with industry and academic partners including Bright Ascension Ltd, the University of Strathclyde, D-Orbit UK, the Satellite Applications Catapult and Alden Legal UK.

The developments conducted within xSPANCION will address the global demand for simplified access to space to stimulate industry growth by catalysing a new generation of applications previously not possible. It lays the groundwork for AAC Clyde Space to respond to the growing market need for the provision of space data and services quickly and at low cost.

The integration of constellation enabling spacecraft technology development, digitalisation, scaling of production and operations will provide a step-change in capability with the project delivering benefits across the consortium.

8 REFERENCES

[1] Euroconsult, *Prospects for the Small Satellite Market*, April 2021.

[2] AAC Clyde Space, Company Presentation, November 2021.