The first Vega ride-share mission flight

F. Caramelli, F. Battie, A. Scaccia (ESA); S. Corbo (SAB Aerospace); A. Dalloneau, F. Fabiani (Arianespace); A. Fontana (Avio); M.Mariani (SAB LS); P. Guerrieri (D-Orbit); A. Cramarossa, A. Gabrielli (ASI)

ABSTRACT

The first European ride-share mission will be carried out by the Vega launch system in September 2019.
The VEGA PoC (Proof of Concept) flight using the SSMS (Small Satellite Mission Service) hardware was conceived in the context of ESA LLL Initiative. This paper reports on the highlights of the preparation of the first European ride-share mission with Vega launcher and on the development of the related launch system.
Based on Vega flights accumulated experience, the development of multi-Payload mission concept started from analysis of the activities currently foreseen to fly a single payload mission adapted to the needs of multi payload ride-share missions. After evaluation of impacts in terms of technical feasibility, missioning schedule and related programmatic and cost elements for the missioning of the Light Sats launch service, the implementation phase was initiated and description of its major tasks is the focus of this paper.
The described hardware development and processes to reach SSMS PoC flight using the Vega launch system, are the first step towards the ultimate goal of a finally optimized process for Light Sats ride-share missions applicable to all European launchers.

1. INTRODUCTION

Purpose of this document is to report on the preparation of the first European ride-share mission to be carried out by the Vega launch system in September 2019.

Several multi Payload flights have already been implemented with the Vega system (e.g.: VV02: Proba-V, VNredsat, Cubesat; VV07: Skysat (4 off), Perusat;….) demonstrating the system flexibility to successfully support complex missions.

The ESA LLL (Light satellite, Low cost, Launch opportunities) Initiative, approved by European. Ministers at CM-16 in Lucerne, includes SSMS (Small Satellite Mission Service) PoC (Proof of Concept) flight, whose goal is to demonstrate reached capability to aggregate, prepare, launch and deliver into orbit a set of Light Sats; enabling timely, standardized and guaranteed access to space to Light Sats Institutional and commercial Users community by means of a dedicated and optimized European launch service.

This flight was made possible thanks to the key role played by the 4 VERTA 3 Programme European participating States and by the European Commission (EC).

To reach this goal, design-to-cost approach has been applied to both development of launcher hardware and launch preparation processes; in the following section the major elements are described together with up-to-date preparation status of the fisrt European ride-share mission with Vega launcher.

2. POC INDUSTRIAL ORGANISATION

The Launch System Prime AVIO is in charge of the development and qualification of the SSMS system and the definition and implementation of the processes to flight preparation; Arianespace in their role of European Launch Operator are in charge of the definition of the Spacecraft aggregate, the preliminary mission studies to confirm the feasibility of the PoC mission and they have the leadership of the coordination of AVIO activities towards the launch preparation. To this end, Arianespace defined the new role of European Cubesat aggregators for all the Customer Spacecrafts flown on PoC. Among possible candidates, Arianespace selected D-Orbit and SAB Launch Services gave both the task to support Arianespace in the definition and implementation of the services offered to Institutional Cubesat Customers. SAB-LS took the task to carry out the Cubesat/deployers assemblies Launch Campaign operations with the SSMS, performed in Europe instead of at the Launch Base for the first time. D-Orbit has contributed to the campaign providing end-to-end premium launch services for some of the customers, as well as providing the ION CubeSat Carrier, a free-flying CubeSat deployer that will extend the level of launch services by fast dispersing and precisely deploying customers' CubeSats.

Small satellite company ISIS - Innovative Solutions In Space BV (Netherlands) is CubeSat deployer providers for this mission. In addition ISIS provide a supplementary avionics module to the SSMS system. The so-called deployment sequencer module is the interface between the Vega upper stage and all the various CubeSat deployer types from multiple suppliers that are manifested on board the SSMS mission. On cubesats RTAFSAT-1, DIDO-3 and SIMBA, ISIS is either platform provider or had responsibility for delivering the satellite as a turn key mission. Tyvak is 6U platform provider for FSSCAT satellites and is in charge of preparation of the spacecrafts with the NLAS 6U deployers.

3. SSMS POC AGGREGATE

In this section the spacecraft selected for composition of PoC Aggregate are reported. Among them, the Institutional Payloads pre-selected by ESA following a joint EC/ESA Announceement of Opportunity are: UPMSat-2, ESAIL, NEMO-HD, FSSCAT, SIMBA, PICASSO, TRISAT, TTU100. The commercial customers reported in the following were selected by Arianespace.

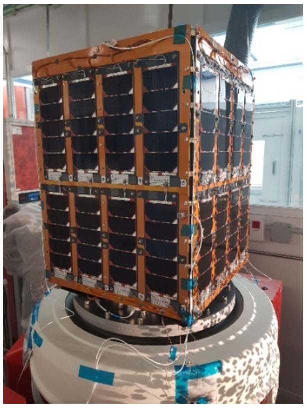
ION

ION CubeSat Carrier is the innovative platform developed and operated by D-Orbit, its mission will focus on two main targets: the deployment of several CubeSats, some of them provided by Planet and to perform in orbit demonstration of its new propulsion system in view of its employment onboard subsequent ION missions.

UPMSAT-2

UPMSat-2 is an educational, scientific and in-orbit technological demonstration satellite. Its first goal is to give Technical University of Madrid – Universidad Politecnica de Madrid (UPM) students the competences for designing, building, testing, integrating, and operating a small satellite, but whose execution involves all the complexity of a complete space system. The satellite and the different subsystems correspond to dedicated designs, far from standards like the Cubesat. The platform has a volume of 0.5 x 0.5 x 0,6 m3, of which about 40% are available for payloads, and a total mass of about 50 kg. It will operate in a Sun-synchronous orbit at 600 km.

The purpose of UPM is to take full advantage of the development and operation of a microsatellite oriented to in orbit demonstration purposes, considering the multi-role these projects play within the University (educational, research, industrial spin-off, international cooperation, etc.)."



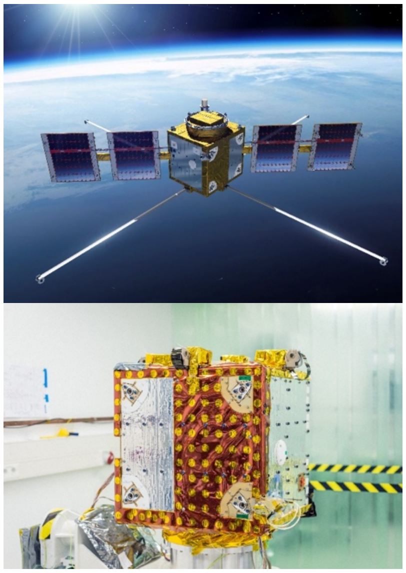
UPMSAT-2 picture

ESAIL:

ESAIL spacecraft was developed to enhance the next generation space-based services for the maritime sector. The spacecraft will track ship movements over the entire globe as it orbits the planet, this monitoring coverage by satellite is essential as about 90% of global trade takes place on the oceans. It opens the door to enhanced safety, ships tracking and route previsions for industry, government, maritime authorities and will create new business opportunities.

ExactEarth Canada is the commercial mission prime and operator for the next generation of global ship tracking services. LuxSpace is developing the new high performance microsatellite platform for ESAIL. ESA is implementing the project on behalf of the Luxembourg Space Agency and other ESA member states, de-risking partners' investments to meet market needs.

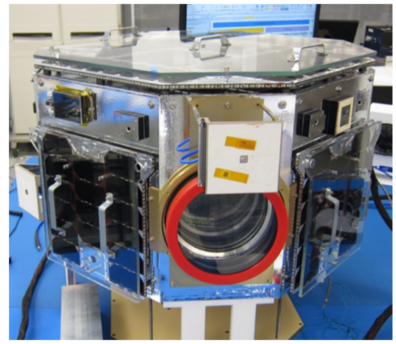
The high-performance ESAIL satellite is enhancing the current exactEarth satellite constellation, providing advanced antenna beamforming and ground signal processing capabilities. The LuxSpace ESAIL microsatellite is designed within the 100 kg and 100 W class range, to accommodate demanding payloads with high-speed downlink requirements. ESAIL's flexibility allows deployment in different orbits, making it compatible with several launchers.



ESAIL pictures

NEMO-HD

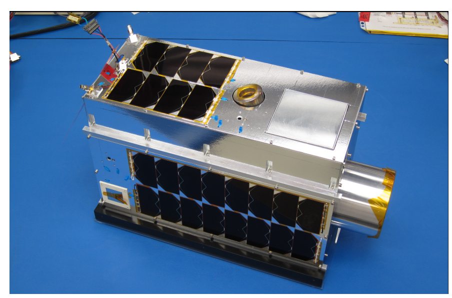
NEMO-HD is a 65 kg microsatellite capable of interactive real-time video streaming and multispectral imaging, which will be operated by the Slovenian Centre of Excellence for Space Sciences and Technologies SPACE-SI, and it was developed in collaboration with the University of Toronto Institute for Aerospace Studies - Space Flight Laboratory (UTIAS - SFL). The satellite carries two optical instruments. The primary instrument is capable of imaging at a GSD of 2.8 m in four spectral bands. Secondary instrument produces images at a GSD of 40 m GSD in a much wider field of view. Both instruments are capable of recording high definition video at 25 frames per second. The satellite is equipped with a 50 Mbps X-band downlink. With NEMO-HD in the orbit a very compact and cost effective remote sensing system will be achieved combining the agile microsatellite with mobile ground station system STREAM and advanced data processing chain STORM. Primary applications will be aimed at monitoring of river basins and smart cities as well as areas with highly fragmented urban and natural environments.



NEMO-HD picture

GHGSat-C1

GHGSat-C1 is the first of two microsatellites as the commercial follow-on to the GHGSat-D (CLAIRE) demonstration satellite developed and launched by SFL in 2016. All three spacecrafts are based on SFL's NEMO bus that is capable to provide highly accurate attitude control and ground target tracking. GHGSat monitors industries greenhouse gas (GHG) and air quality gas (AQG) emissions, including: oil & gas, power generation, mining, pulp & paper, pipelines (natural gas), landfill, chemicals, metals & aluminum, cement, agriculture, and transportation. Each GHGSat satellite provides periodic, high-precision measurements of emissions from thousands of such sites. Targeting of measured emissions is confirmed with visual imagery from the same satellite. GHGSat instruments are calibrated regularly, and measured data is verified and validated against known sources.



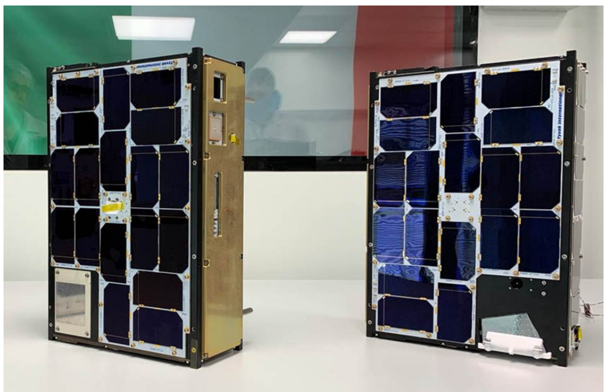
GHGSat-C1 picture

FSSCat mission and Phi-Sat-1

FSSCat, or “Federated Satellite Systems on Cat” is the winner of the 2017 Copernicus Master “ESA Sentinel Small Satellite Challenge (S^3)”. Proposed by the Universitat Politèctica de Catalunya (UPC) and developed by a consortium composed of UPC (ES), Deimos Engenharia (PT), Golbriak Space (EE), COSINE (NL) and Tyvak International (IT).

Phi-Sat 1 is the first on-board ESA initiative on Artificial Intelligence (AI) promoted by the Φ Department of the Earth Observation Directorate and implemented as an enhancement of the FSSCat mission.

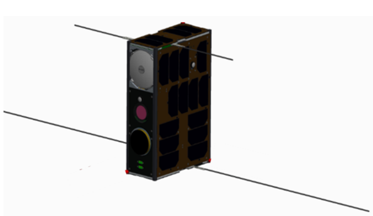
Among mission objectives, scientific goals are Polar Ice and Snow monitoring, soil moisture monitoring, terrain classification and terrain change detection (i.e. hazard detection and monitoring, water quality), while techological goals are optical Inter-Satellite Link (O-ISL) demonstration, federated Satellite System Experiment (FSS-Exp) to demonstrate constellation resource sharing using an RF Inter-Satellite Link (RF-ISL), combined Hyperspectral imaging in the VNIR and TIR, together with Phi-sat 1 mission for demonstration of on-board Artificial Intelligence (AI) for cloud recognition and cloud detection



FSSCAT picture (2 S/Cs)

RTAFSAT-1

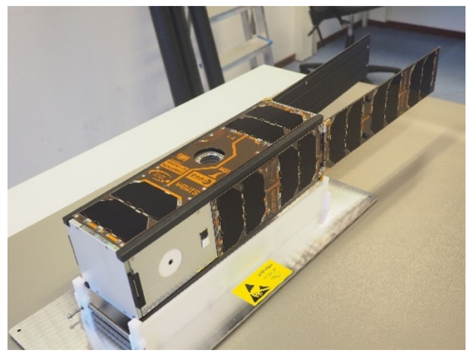
The RTAFSAT-1 mission is the first remote sensing CubeSat mission for Thailand. The satellite will carry out an Earth Observation Demonstration mission with SCS Gecko Camera and Simera TriScape-100 payloads; the designed lifetime is 3 years.



RTAFSAT-1 picture

SIMBA

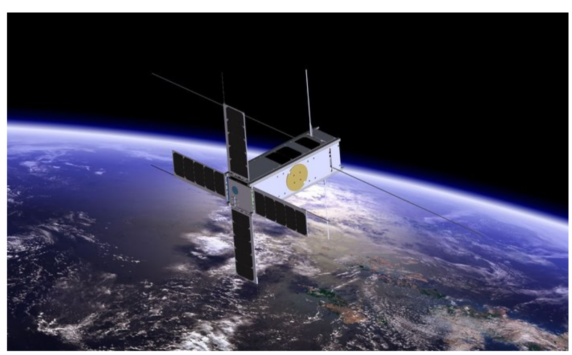
The SIMBA cubesat from the Royal Meteorological Institute of Belgium will be placed into orbit to compute for the first time the Earth radiation budget with the same instrument. This mission will help in the study of the global warming. This science mission will have a design lifetime of 3 years and the satellite performances will be monitored from ground station located in The Netherlands.



SIMBA picture

PICASSO

PICASSO cubesat has been developed by the Belgian Institute for Space Aeronomy (BISA). The satellite has sensors and a pair of atmospheric sensing payloads (a hyperspectral imager, four Langmuir probes) that will carry out scientific measurements for the duration of its lifetime in Low Earth Orbit (LEO). The spacecraft will be nominally sun-facing such that the hyperspectral imager can image the sun through the Earth's atmosphere as the spacecraft enters and leaves eclipse.



PICASSO picture

DIDO-3

SpacePharma from Israel will be is on board of SSMS POC with DIDO-3 Nanosatellite to perform biological experiment under Microgravity for several customers involved in pharmaceutical business, supported by Italian Space Agency (ASI) and Israeli Space Agency (ISA). Dido-3 will be monitored from the Ground Station developed by SpacePharma in Switzerland.

The DIDO-3 mission is the latest commercial microgravity mission by ISIS' customer SpacePharma, the design lifetime of the space craft is 1 year.

DIDO-3 picture

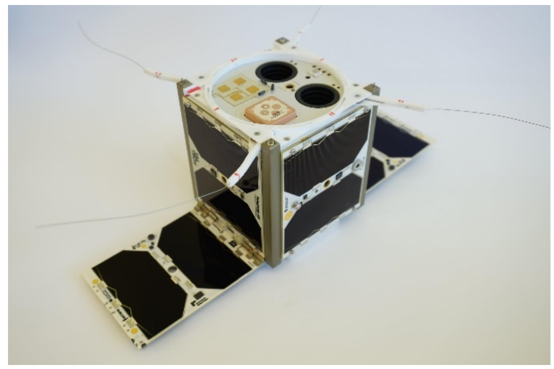
TRISAT

The TRISAT cubesat is developed by the University of Maribor. Its main goal is to provide an in-orbit demonstration of Slovenian space technologies. The mission is focused on remote sensing by incorporating a miniaturized multispectral optical payload as the primary instrument, providing affordable multispectral Earth observation in up to 20 non-overlapping bands in NIR-SWIR (Near to Short Wave Infrared) spectrum.

TRISAT picture

TTU100

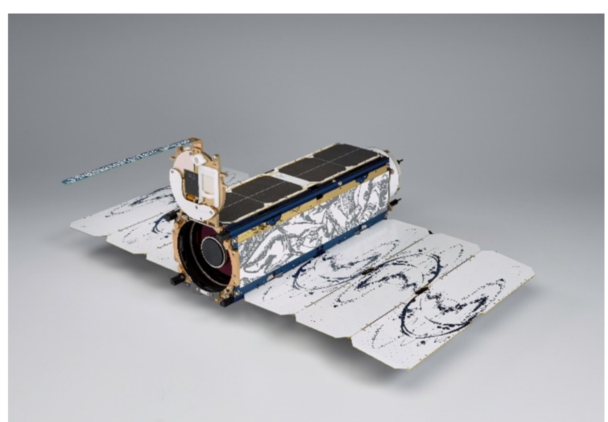
The TTU100 satellite is the only 1U cubesat launched on the SSMS POC flight. It is an Estonian Satellite developed by Tallinn University of Technology to perform an Earth Observation mission. The main payload is composed by 2 cameras: RGB and NIR with 20mm aperture and 5MPx sensors each. In addition there is an x-band downlink transmission radio for achieving 2-3 Mbit/s download speed.



TTU100 picture

PLANET satellites

Planet is flying a total of 26 Dove-series satellites, Flock 4V, on the Vega SSMS-POC mission. Fourteen of those satellites will be deployed by SSMS dispenser from ISL QuadPacks, and twelve will be deployed from D-Orbit's ION freeflying platform. Planet is a private company headquartered in San Francisco, USA that operates the world's largest fleet of remote sensing satellites. Planet's Flock of 100+ medium-resolution Dove-series satellites image the entire Earth's landmass every day, and enable government, commercial, scientific and non-profit customers across a wide range of applications, including agriculture, mapping, and disaster response



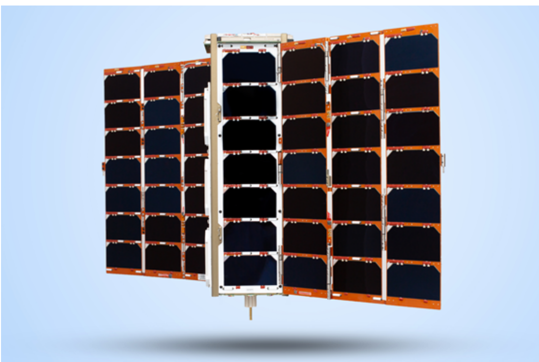
Dove picture

SPIRE satellites

The LEMUR-2 spacecraft is a multi-mission remote sensing platform, housing three (3) payloads: Automatic

Identification System (AIS), Automated Dependent Surveillance-Broadcast (ADS-B) and GPS Radio Occultation.

These payloads provide data for maritime and aviation tracking, and atmospheric weather, respectively.



LEMUR-1 picture

Finally, two additional microsats and two additional cubesats will be brought to this mission Aggregate by Spaceflight.

4. SSMS POC FACTS AND FIGURES

The SSMS system PoC version will be lifted from Kourou European Space Port in September 2019 by the launcher system Vega and it will deliver into Sun Synchronous Orbit at 500 Km altitude, 41 Spacecrafts; among them, 7 microsatellites whose mass ranges from 30 to 160 Kg and 34 cubesats ranging from 1U to 6U, arranged on 12U deployers. In addition, one of the microsats, ION, will carry a number of cubesats as a free flyer and it will deploy them after separation from Vega.

The delivery system and the specific mission preparation process were developed under ESA leadership by the launcher Vega Prime AVIO, the dispenser design authority being SAB Aerospace and it is conceived as a fully modular system, enabling finalisation of mission architecture at the latest possible time before flight date and provide unprecedented flexibility on the mission preparation process.

Infact, the dispenser system is composed essentially by two major elements; Lower Part and Upper part, eventually suitable for independent accommodation on the launcher. The Upper part provides a number of possible configurations described in more detail in the following sections.

The mass of the dispenser varies between 160 to 360 Kg, depending on the configuration complexity; the system maximum load capabilities by design are depending on the chosen configuration; maximum mass for a single microsat is 500 Kg., maximum number of spacecrafts 9 microsats and 24 12U deployers.

The majority of avionic services to the spacecrafts are provided by the launcher avionics system, separation commands, monitoring, telemetry and Spacecraft services are centrailised using the existing or upgraded launcher avionics; autonomous additional separation commanding functions are implemented directly on the dispenser by means of 2 dedicated sequencers.

5. THE SSMS SYSTEM

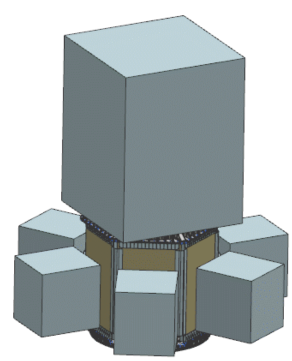
5.1. What is an SSMS aggregate

The aggregate is the upper configuration of the launcher including:

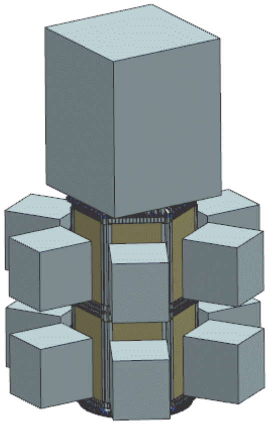
1) **The S/Cs selected for the mission**
2) **The chosen SSMS configuration**

The SSMS is a modular concept, allowing to interface small satellites in several configurations based on the same structural elements:

- *Piggy back configuration*
  Based on one our two hexagonal modules

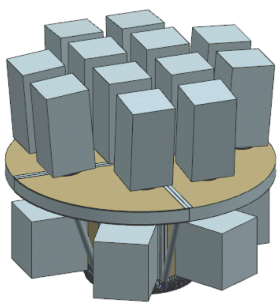


HEX1 Configuration

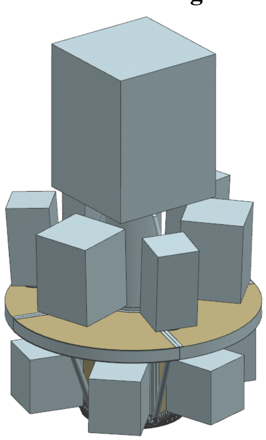


HEX2 Configuration

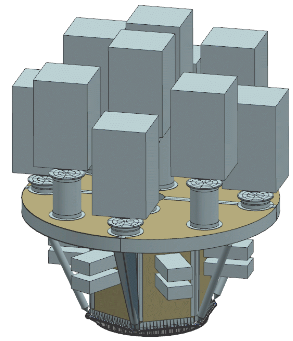
- *Ride Share configurations*
  Based on one hexagonal module and a platform, equipped with or without spacers, a central column, and/or tower module.



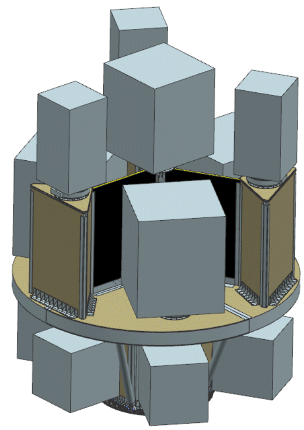
PLAT-1 Configuration



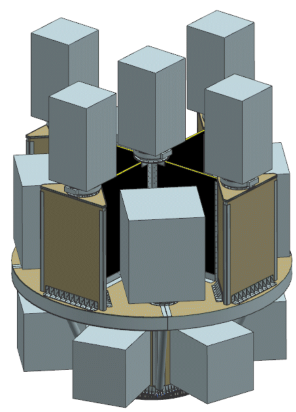
PLAT-2 Configuration



PLAT-3 Configuration



FLEXI-3 Configuration



FLEXI-4 Configuration

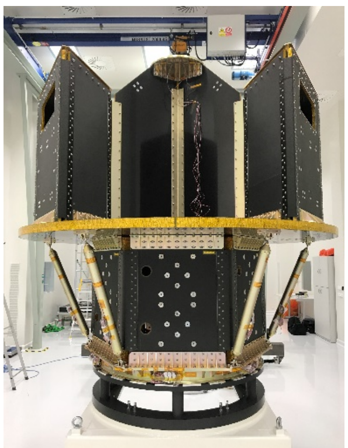
The SSMS hardware is consisting of a dispenser structure accommodating the P/Ls to be deployed, the related separation systems and avionics.
The structure is made of sandwich panels with aluminum honeycomb core and CFRP skins. In addition to these composites parts, it is made up of an aluminum machined I/F ring towards the VEGA launcher 1194 PL adapter and aluminum machined brackets.

6. THE SSMS POC DISPENSER

6.1 PoC FInal Design

The POC model of the SSMS is conceived as a FLEXI-3 configuration featuring:

- 1 Lower Module:
  - Lower IF Ring
  - Hexagonal Module Assy
  - Main Deck Assy (OD ø2300mm)
  - External Rod Assy
- 3 Tower Modules
- 1 Shear Web Module

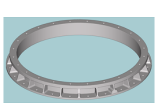


Flexi-3 Configuration (PoC)

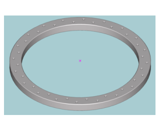
A detailed accommodation analysis has been carried out in order to guarantee the proper separation angles to each S/C included in the PoC aggregate and at the same time to guarantee the accessibility to mechanical and electrical interfaces in each phase of the assembling flow from mechanical mating of the upper and lower part of the dispenser, from the integration of the Satellites up to the final connection of the Electrical S/S and Functional S/S.

To meet this objective, dedicated spacers for each spacecraft have been developed as illustrated below, in particular for the S/Cs located between the Tower Modules.

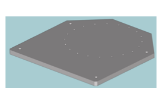
Spaceflight S/C1



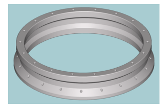
UPMSAT2 Spacer



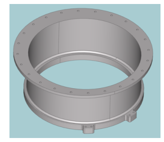
GHGSAT Adapter



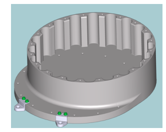
NEMO HD Spacer



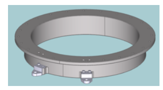
ESAIL Spacer



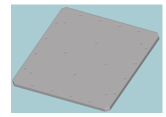
ION FULL Spacer



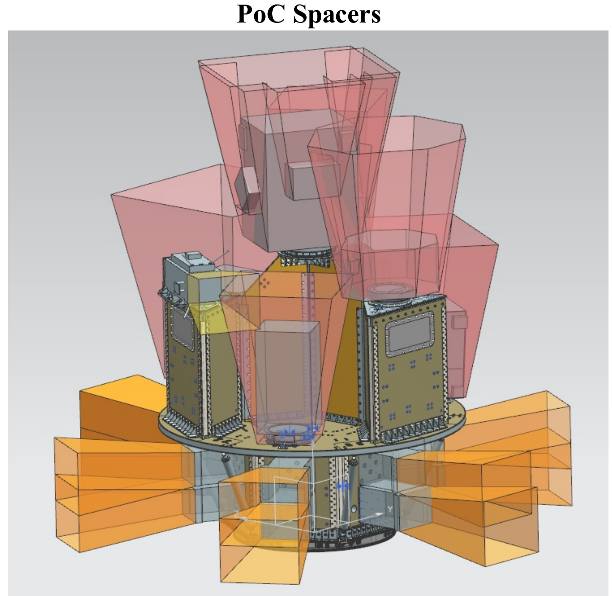
Spaceflight S/C2



Astrofein adapter



PoC Spacers



Flexi-3 PoC Separation angles study

The equipment allocated on the PoC Dispensers consists of:

- Thermal Batteries
- Sequencers
- ALT-VISIVA units

The Thermal Batteries are used to activate the S/C separation systems and have been located on the external side of the Tower Modules in order to dissipate the heat power at activation in the best way.

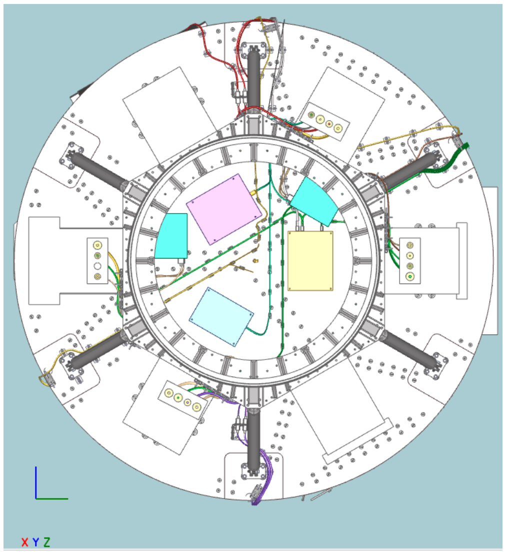
The Sequencers for the activation commands to the cubesats deployers have been located on the internal side of the Hexagonal Module walls.

The electronic units of the VISIVA systems, composed by a telemetry unit, a battery and processing unit have been allocated on the bottom side of the main deck, inside the HEX.

The accommodation above gives the following advantages:

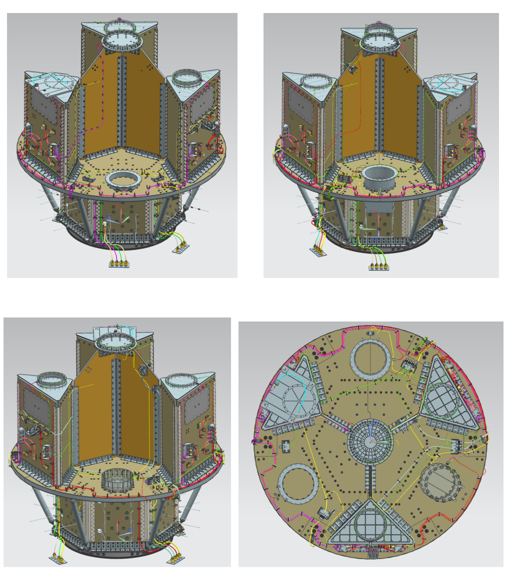
- Accessibility is granted up to membrane integration
- Units will not be exposed to environmental loads

Picture below shows the accommodation of these units.



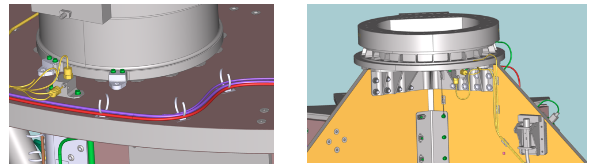
Flexi-3 Equipment accommodation

Once the positions of each item of the SSMS PoC Dispenser aggregate have been finalised the final routing of the harness has been frozen.
Sketches of the connections are reported in the pictures below.



Flexi-3 Electrical S/S routing

Electrical S/S of the PoC Dispenser also includes a set of sensors for the monitoring of the accelerations, shocks and temperatures at the P/L interfaces and at critical location on the structures.



P/L interface sensors

6.2 PoC QualiFICATION CAMPAIGN

A pre-development test campaign was performed for critical manufacturing processes related to CFRP panels to validate suppliers. Test at specimen level were performed both considering laminates and sandwich with inserts taking into account the environmental conditions that the SSMS Dispenser shall withstand, specimens were tested considering room temperature, vacuum environment and cycling test within the temperature range that will be experienced during orbital life.

Development test campaign was conducted focused on specimens having representative characteristics (skin thickness, lay-up, honeycomb thickness and inserts dimensions) of the final design of the dispenser in order to extrapolate allowable values to be considered in the mathematical models used for mechanical analysis.

In addition to the test campaign performed at S/S level (Harness and Functional S/S) the SSMS PoC Dispenser went through a complete qualification campaign at System level which included:

- Mechanical tests: static load test, modal survey test, sinusoidal vibration test, acoustic test, fit check.
- Electrical tests: bonding, grounding, pin to pin verification, isolation, double retention test

The qualification campaign of the SSMS PoC Dispenser has been split in 2 phases.

In the first one, the Mechanical S/S underwent to Environmental Test campaign and in the second phase the Electrical S/S has been qualified.

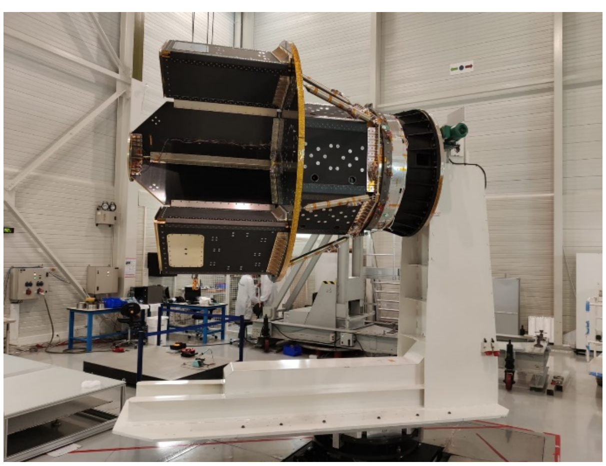
The mechanical test programme has been established to cope with the following aspects:

- Derive MCI Data of the SSMS PoC Dispenser PFM1
- Proto-qualify the SSMS PoC Dispenser PFM1 under quasi-static loads
- Proto-qualify the SSMS PoC Dispenser PFM1 under sine environmental loads
- Proto-qualify the SSMS PoC Dispenser PFM1 under acoustic environmental loads

The purpose of the test programme can be briefly summarised as follows:

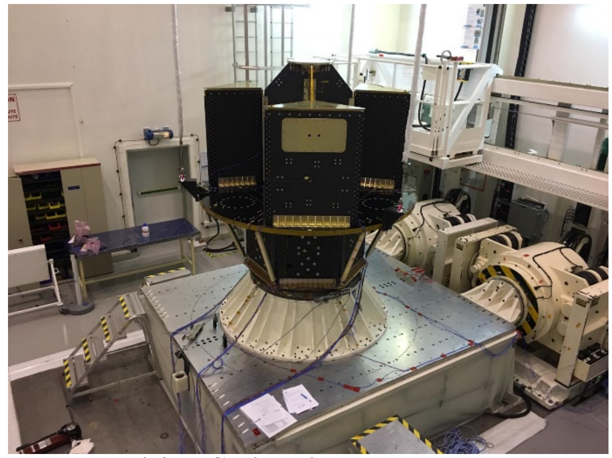
- Validation of the overall design concept
- Characterisation of the dynamic behaviour of the test item and consequent FE Model validation
- Compliance of the test items with the respective mechanical environment
- Verify no critical stress on the structure
- Verify the compliance of the test items to the applicable design, manufacturing and performance requirements.

In May 2018 the mechanical test campaign started with the determination of the mass properties (CoG and MoI) of the unloaded structure to verify the compliance with the system requirements and to gather additional data for a proper FE model validation and correlation.
Measured data are in line with CAD estimation.



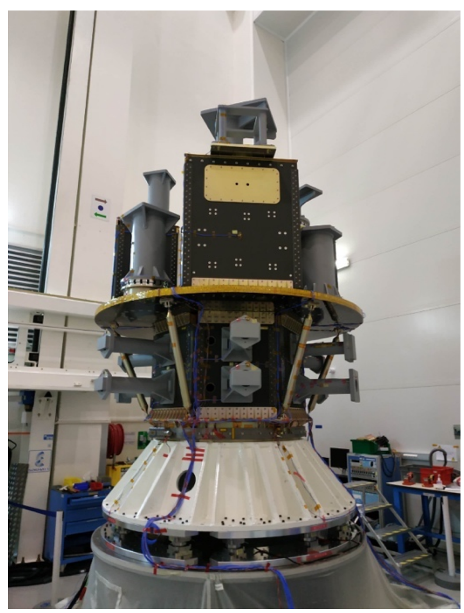
Flexi-3 PoC MCI measurements

After the MCI tests, vibration tests along the 3 axes with empty structure have been run in order to verify its dynamic behavior without external influences.



Flexi-3 PoC Vibration Tests Unloaded

After the unloaded tests the PoC configuration has been changed and the structure has been loaded with spacers and dummy masses of Spacecrafts and Equipment representative of the final configuration of the PoC mission in order to qualify each interface to the required load levels.
Also for the loaded configuration, tests along 3 axes have been performed.



Flexi-3 PoC Vibration Tests Loaded

As last step of the test campaign Acoustic tests have been performed.

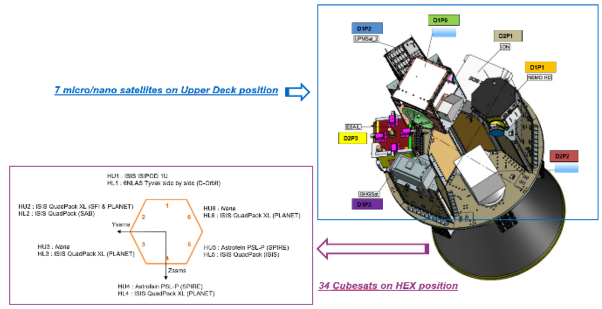
Flexi-3 PoC in Acoustic Chamber

Mechanical tests results confirmed FE predictions and qualification levels has been reached both at LV adapter interface and at P/L interfaces.

After the mechanical tests, the finalization of the harness routing around the structure has been performed.
Electrical S/S underwent specific tests both at single bundle level in terms of bonding, grounding, pin to pin verification, isolation, double retention test and at subsystem level.
In details, due to the complexity of the system and to the fact that the Upper and Lower Part of the dispenser will be transport to CSG in separate containers, also specific addressing tests have been performed in order to validate the solutions implemented to avoid connectors mismatch after re-assembly of the complete dispenser.

7. THE MISSION

For this first POC mission (Proof of Concept), the SSMS dispenser is in the Flexi-3 configuration with microsatellites on its upper part and Cubesats on its hexagonal lower module.



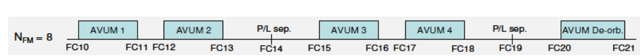
Microsatellites on upper part will be released on the following targeted orbit:

Parameter	Mean
a : Semi-Major Axis (km)	6893.137
e : Eccentricity	0.0012
i : Inclination (deg)	97.4585
ω : Argument of Perigee (deg)	90
LTDN	10:30:00

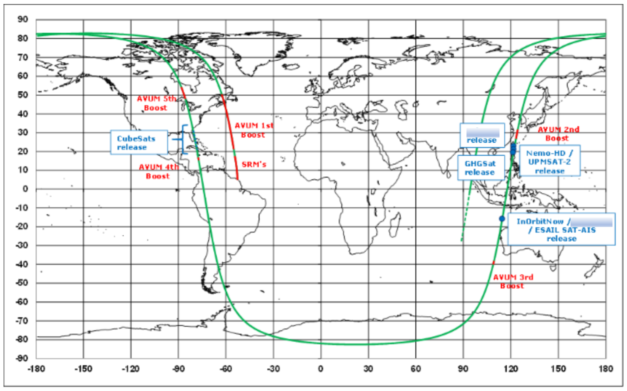
Cubesats on lower part will be released on the following targeted orbit:

Parameter	Mean
a : Semi-Major Axis (km)	6908.137
e : Eccentricity	0.0012
i : Inclination (deg)	97.5158
ω : Argument of Perigee (deg)	90

As two different orbits are requested, the mission definition is built with 5 AVUM boosts.

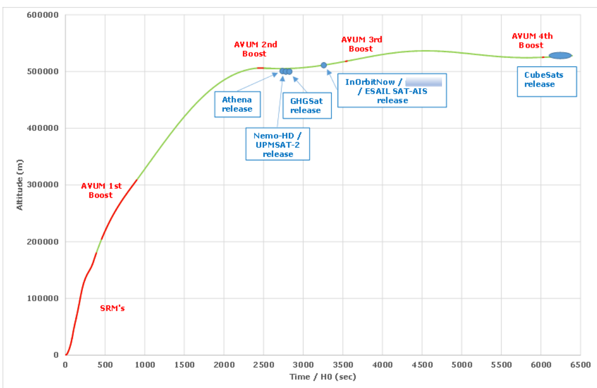


The ground track of the trajectory, from H0 to the end of the mission, is presented in the next figure (green line), with thrusted phases in red.



The altitude profile evolution is the following:

.

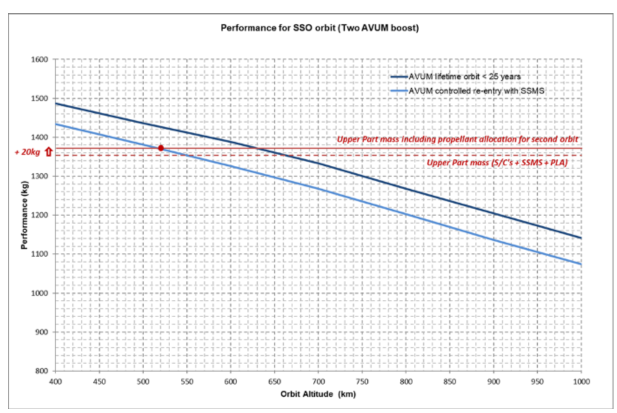


The sequence has been optimized to meet the mission requirements as far as the system constraints allow.

Phase : 1 **L/V Orientation** To reach required attitude for separation		Target for launcher LV axis pointing Xssms (XL) / V = 0°
Phase : 2 **Separation (FC14)**		Longitudinal separation
Phase : 3 **Nemo-HD and UPMSAT-2 Separation**		Longitudinal separation
Phase : 4 **GHGSat Separation** Followed by stand-by (no thruster activation)		Transversal separation inside the orbital plane Stand by duration : 10s

Phases : 5-6 **L/V Orientation** Before RACS boost		Xssms (XL) / V = 40°
Phase : 7 **L/V distancing boost** To increase distance between bodies		Delta V = 2 m/s
Phase : 8 **InOrbitNow, and ESAIL SAT-AIS Separation** Followed by stand-by (no thruster activation)		Longitudinal separation Stand by duration : 10s
Phase : 9 **L/V Orientation** Before 3rd AVUM boost		
Phase : 10 **L/V Orientation** To reach required attitude for separation		Target for launcher LV axis pointing Xssms (XL) perpendicular to orbital plane
Phase : 11 **CubeSat separation sequence (34 separations one by one)** Followed by stand-by (no thruster activation)		Sequence duration : 250s Stand by duration : 10s
Phases : 12-13 **L/V Orientation** Before RACS boost		
Phase : 14 **L/V distancing boost** To increase distance between bodies		Delta V = 3 m/s
Phase : 15 **L/V Orientation** Before 5th AVUM boost		

The performance requested for this mission is compatible with last stage direct-reentry:



The present Mission Analysis, performed for SSMS POC mission on VEGA SSO mission in multi launch configuration, shows that the trajectory has been optimized to meet all the S/C requirements, the constraints of the launcher and the flight safety rules specifications.

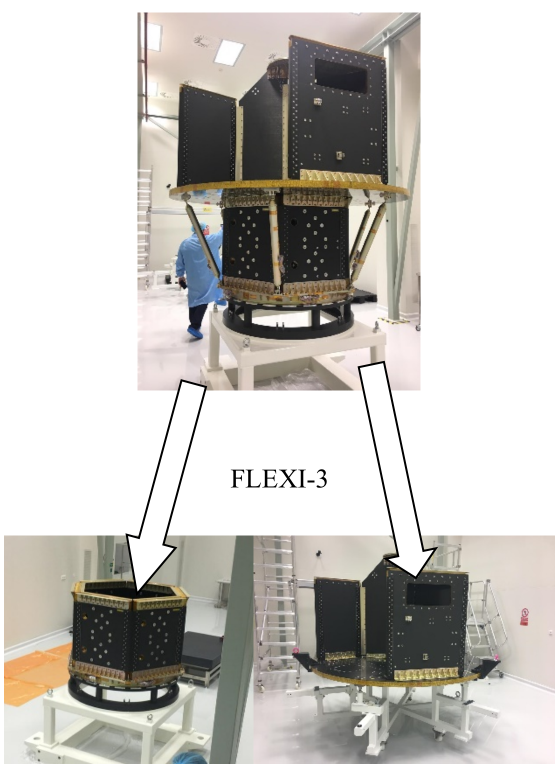
8. PREPARATION FOR FLIGHT

8.1 Integration flow concept

In order to standardize the launch preparation operations and reduce the mission costs, the activities related to the integration of the spacecrafts with the dispenser structure in Europe shall be maximized.

For the same reasons, to shorten the integration time and to have the possibility to work in parallel with the integration of the S/Cs also in different locations, it has been decided to design the dispenser in such a way that the upper and lower part can be integrated and transported separately with dedicated transport containers.

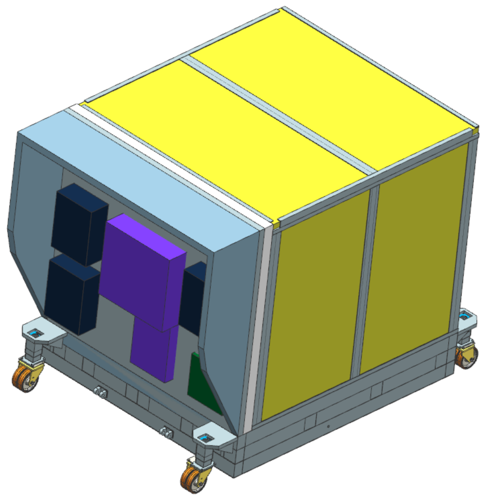
As sketched in the pictures below, for instance, a FLEXI-3 configuration is divided in a Lower Part (made by the Hexagonal Module and the Lower I/F Ring) and in an Upper Part (made by the Main Deck, the Towers modules and the Shear Web Module)



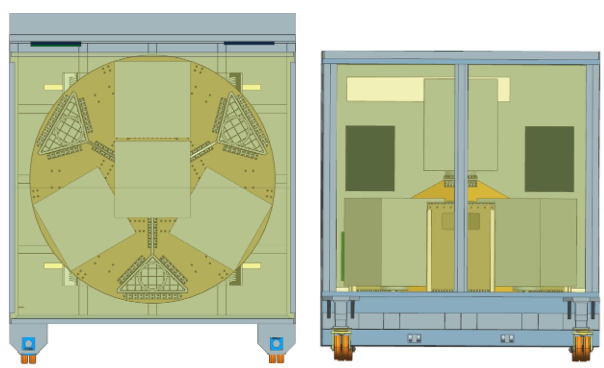
FLEXI-3 Configuration

8.2 SSMS Transport Containers

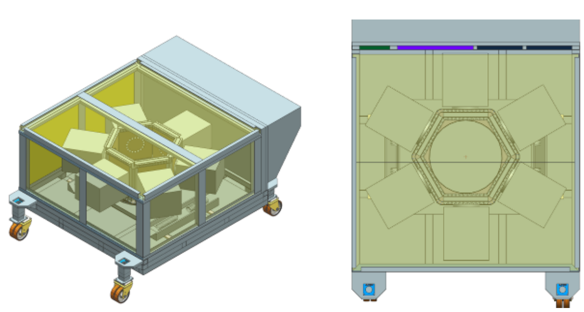
Two dedicated transport containers equipped with Air-conditioning units able to guarantee ISO 8 Environmental conditions have been developed. Dampers systems and conditioning/monitoring systems have been also included in order to attenuate the transmission of the transport loads, monitor and condition internal environment where needed.



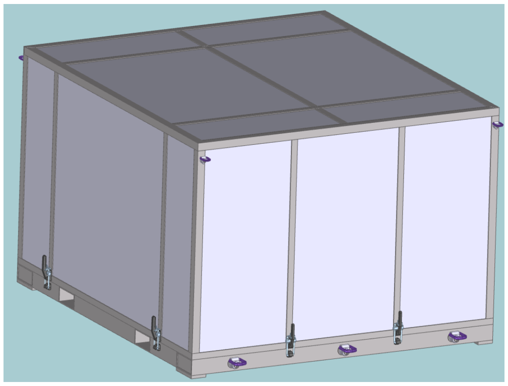
Upper Part Container



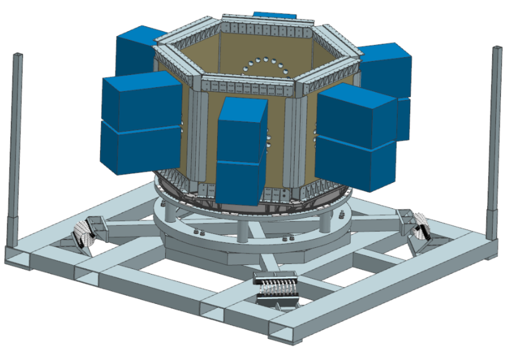
Upper Part Container – Internal view



Lower Part Container



Lower Part Container – Internal view



Lower Part Container – Internal view Loaded

SSMS transport containers

These containers have been sized according to final VEGA C SSMS Dispenser dimensions and will be refurbished after the use for the VEGA PoC Flight.

8.3 SAB Integration Facility

SAB Aerospace facility located in Brno has been selected for integration of the Payloads on the SSMS Dispenser structure.

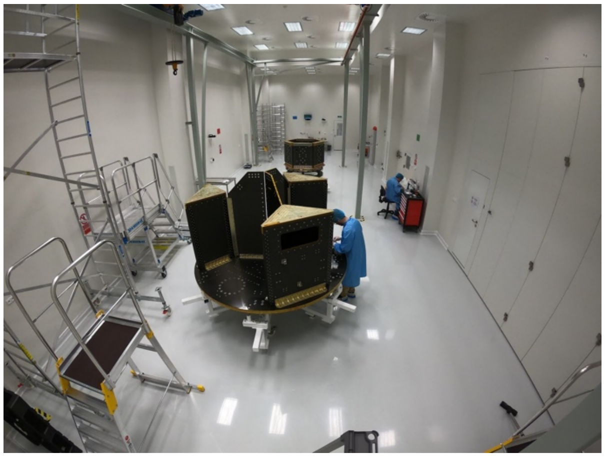
For the PoC flight only the S/Cs to be mounted on the Lower part of the dispenser will be integrated, however the facility is equipped to perform the integration also for the upper part for the future VEGA C SSMS Dispenser. The facility plan is reported in the picture below.

SSMS Dispenser Integration Facility

There are about 300 square meters of ISO 8 clean room environment, which will be dedicated to the SSMS activities during S/Cs integrations.

8.4 SSMS Integration Flow

The integration of the P/Ls with the SSMS structure will be performed in the Area 4 (blue area in the picture above). In this area, equipped with lifting crane, there will be the SSMS structure ready for integration fixed on a dedicated integration stand.



SSMS Dispenser Integration Facility

The P/Ls Transport container will be received in Area 7 and after a cleaning of the container will be moved in the Grey area (Area 6).

According to the needs of the satellite, the container and the satellite can be moved directly in area 4 to perform integration or in Area 3 to perform functional and electrical checks before integration. Indeed the Area 3 is equipped with standard instrumentation for electrical checks and with workbenches for any need of the customer before integration on the structure.

SSMS Dispenser Integration Facility

Once the activities in Area 3, if performed, are finalized the P/L can be moved through Area 5 in the integration area. In such a way the P/L will never leave the ISO 8 environment.

8.5 S/Cs and SSMS Lower Part Integration

The SSMS PoC flight Launch Campaign, for the first time on European standards, will be partially carried out in Europe as part of the Proof of Concept goals of the SSMS PoC mission; all the Cubesat/deployers assemblies will be integrated onto the lower part of the SSMS dispenser in SAB European Facility in Brno (The Czech Republic0 by SAB-LS,

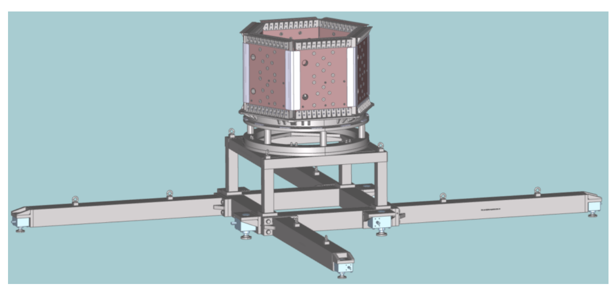
After SSMS Dispenser qualification, the dispenser upper part will be shipped by boat to CSG, while the Hexagonal module (Lower part) will be kept at Brno facilities to carry out the above described launch campaign operations.

All the deployers will be delivered to SAB-LS already populated with cubesats for a streamlined flow of operations lasting maximum two weeks. After standard mechanical and electrical fit checks, harness routing final parts will be laid down on the HEX Module.

The deployers integration sequence has been defined as follows:

- Tyvak NLAS
- ISIS QuadPacks on the HEX Lower Level
- ISIS QuadPacks on the Upper Level
- 1U ISIPOD
- Astrofein PSL-P

Before the handling of the P/Ls, the Hexagonal Module (HM) will be ready for integration and fixed on the dedicated integration stand as illustrated below.



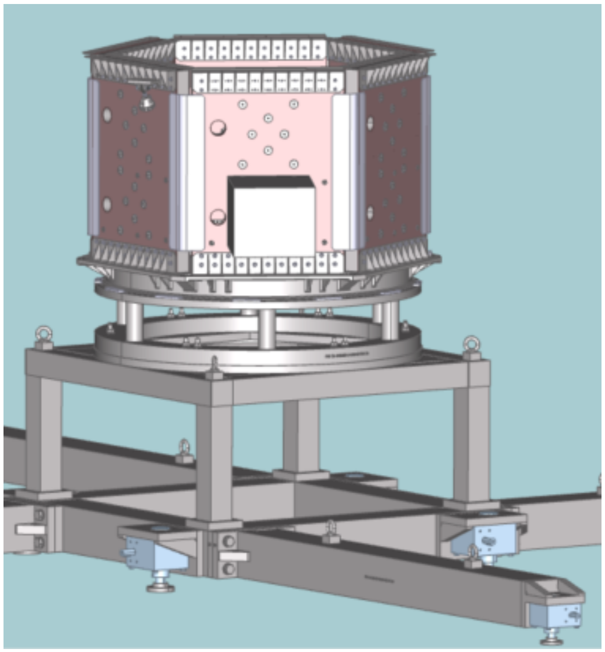
HM on the integration stand

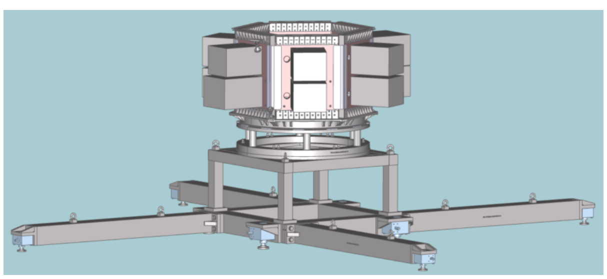
The sequence for the cubesat deployers is:

1. The cubesat deployer according to its dimensions will be handled and lifted by crane (from 12U) and moved close to their interface on the HM panel.

2. An operator will be inside the HM and will connect the screws with the I/F holes in the deployer base plate thanks to the thru holes inserts on the HM panel.

As needed a dedicated adapter plate will be used to connect the deployer to interface holes.





Cubesat Deployers integration on HM

Up to 2 deployers 12 U per panel can be fixed, the integration flow foresees to start the integration from the one assigned to the lower position for the use of the crane, but in case of need accessibility to the lower position and dismounting of the deployer is guaranteed up to encapsulation in the fairing. In case of need a dedicated trolley with adjustable height can be used as support during deployer removal.

The stack composed by SSMS Hexa, deployers and sequencers will be then stored in a dedicated transport container equipped with specific shock absorber and devices for environmental parameter control and then shipped to CSG by a commercial Airfrance flight. Safety was guaranteed in compliance of IATA rules: Lithium batteries in satellites will be in compliance with Section II of PI 967. SAB-LS verified that each CubeSat integrated on SSMS HEX Module uses Lithium batteries that comply with following limits:

- cell battery < 20 Wh
- battery < 100 Wh
- mass of battery < 5 kg.

At Guyana Space Centre, the European Space Port, the last preflight operations will be carried out. Among them:

- Sequencer checks
- Sequencer batteries charging
- Deployers flight preparation
- HDRM setting
- RBF removal
- ABF application

After finalization, the SSMS Hexa will be mated with the SSMS Upper Part.

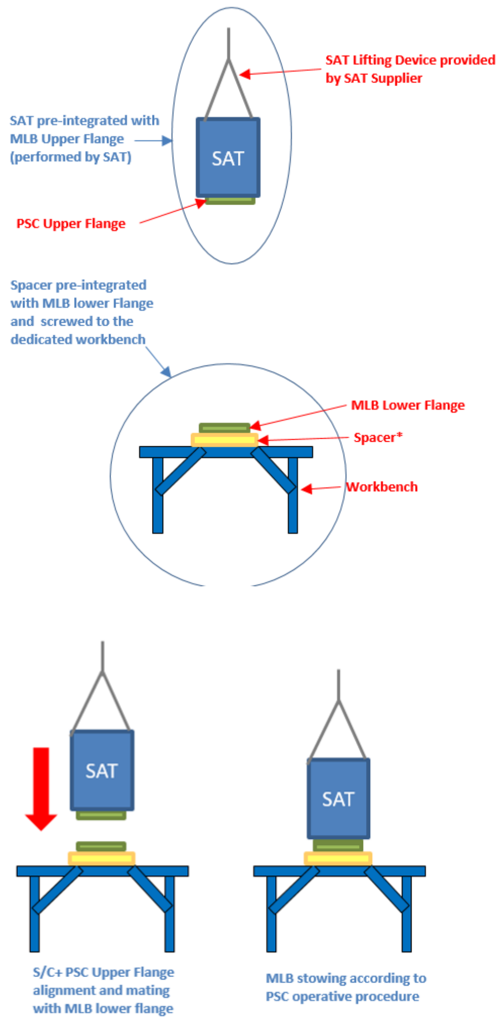
8.6 S/Cs and SSMS Upper Part integration

The integration of satellite is more complex because before the integration with the SSMS structure the satellite shall be connected with the separation system. For the PoC flight, the PSC Lightband separation systems have been selected.
With these separation system the sequence will be the following:

1. The upper ring of the separation system will be mechanically connected to the S/C and the S/Cs umbilical connectors will be fixed in the related position on the ring.
2. The satellite spacer (I/F towards SSMS panels) will be secured on a dedicated workbench
3. The lower ring of the PSC system will be fixed to the satellite spacer and the separation connectors LV side and the separation switches (if present) will be locked in their position.
4. The satellite will be lifted and moved for the mating with the lower part of the separation system.

5. Once the part are in contact the stowing and the set for flight for the separation system will be performed.
6. The separation system will be secured with additional mechanical safety clamps before lifting.

These steps are schematically depicted in the figure below.

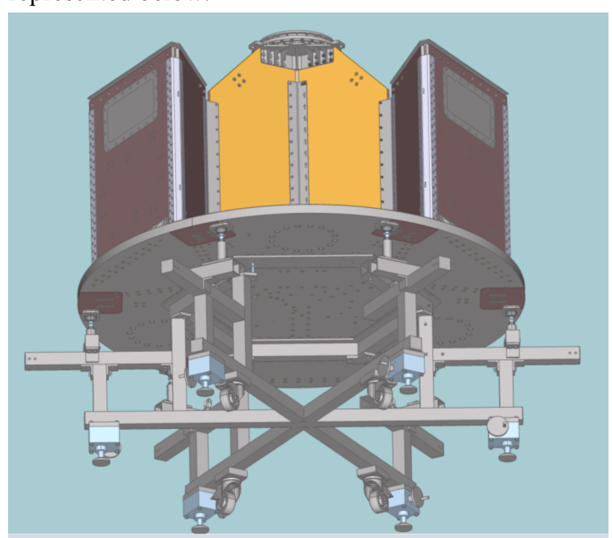


SmallSat integration on dispenser Upper Part

The reported sequence above is similar for both P/Ls to be integrated on the Lower Part and for P/Ls to be integrated on the Upper part of the SSMS dispenser.
For the PoC flight launch campaign the SSMS Upper part will be integrated in EPCU in Kourou. In the context of multi-satellite missions AIT process standardization and refinement, future missions of SSMS feasibility and constraints of SSMS Upper part integration in Europe is under development. To this aim the transport containers have been already designed to fulfil this integration approach. The integration of the P/Ls to be accommodated on the Upper Part of the SSMS Dispenser will proceed in a similar way of the flow of the Lower Part, but it will require dedicated stands and scaffoldings to operate in a safe way at the height of the different decks.

The integration of the Upper Part in FLEXI-3 configuration is described below, because this configuration has the more complex aggregate to be loaded.

The Upper part will be secured on the integration stand through the HEX I/F holes located at the center of the Main Deck and additional supports will be fixed to sustain the cantilevered part the deck as schematically represented below.



Integration stand

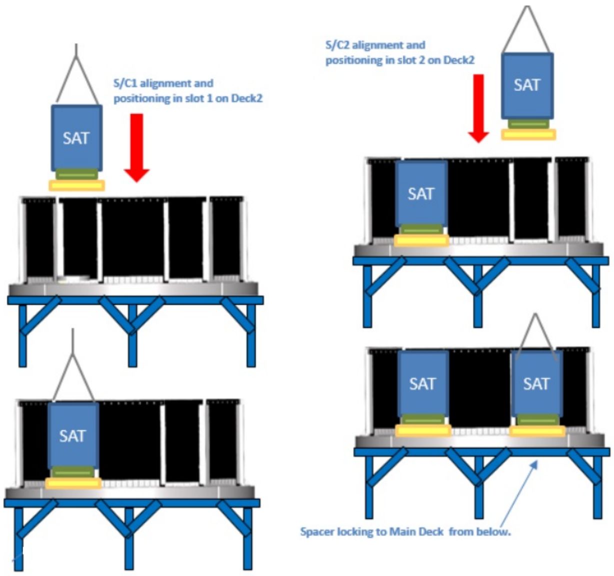
The S/C will be connected to the PSC separation systems as for the Lower Part as described above on a dedicated workbench before mating with the Dispenser.

In order to reduce the risks of interference between the different S/Cs, the loading sequence will be the following:

1. Fixation of the P/L to be mounted on the Main Deck (MD)
2. Fixation of the P/L to be mounted on the SWM Deck (Upper Central Deck)

3. Fixation of the P/L to be mounted on the Tower modules (TM)

The P/L will be lifted, aligned and put in position on the MD. The spacer will be fixed from below the stand thanks to the thru holes available on the MD.

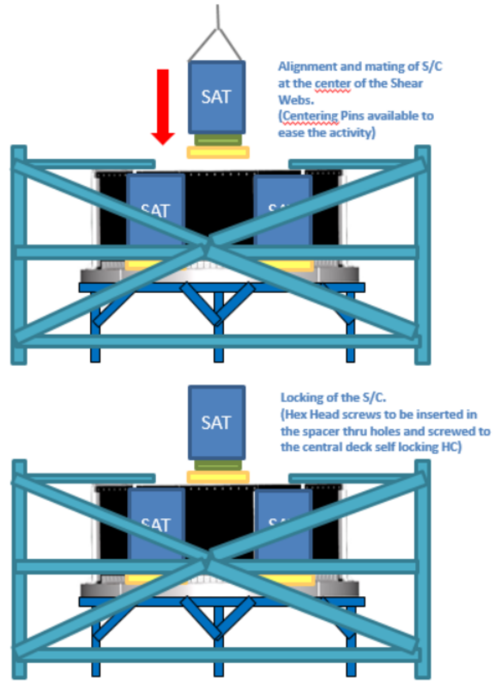


Upper Part integration sequence

The sequence will be repeated for all the 4 P/Ls to be embarked on the MD

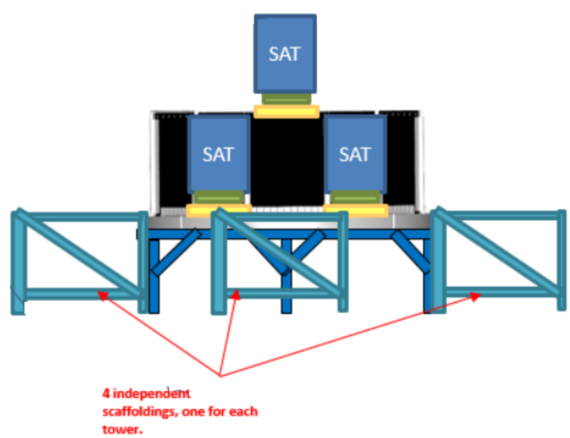
The integration of the central Satellite positioned on the Shear Web Module (SWM) deck is the more complex integration. It will require the use of a dedicated scaffolding to reach the related interfaces towards the Dispenser, both electrical and mechanical.

The spacer of this satellite will be mounted from the top with hexagonal head screws to improve the accessibility, centering pins are present on the deck to ease the alignment and the positioning of the S/C.



Upper Part integration sequence

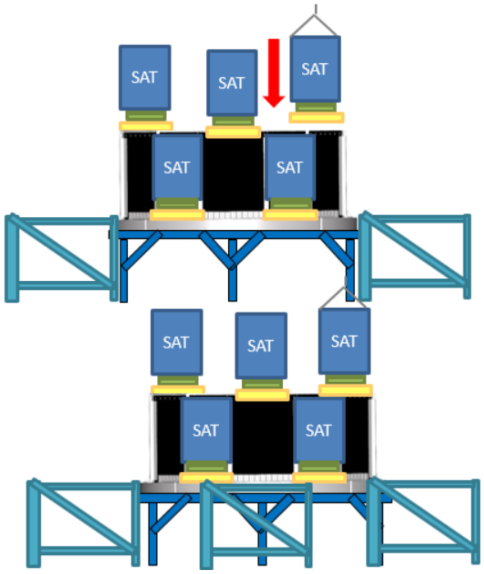
After the integration of the central P/L the scaffolding will be removed and smaller platforms will be placed around the dispenser to reach the TM interfaces.



Upper Part integration sequence

The P/L will be positioned on the TM deck one by one up to the completion of the aggregate integration.

In order to ease the integration of the P/L on the TM deck, a dedicate access window has been defined on the Tower Module external panel.



Upper Part integration sequence

8.7 SSMS Final Integration

The final integration of the SSMS Dispenser will be completed at the Guiana Space Centre (CSG) in Kourou before mating with PayLoad Adapter PLA. The Lower Part loaded with its satellites will be fixed and secured on the Integration stand.

The loaded Upper Part will be removed from its TC or from its stand, depending in which location the assembly with the S/Cs has been finalized, and it will be aligned with the lower part.

The connection between the 2 SSMS parts will be performed with the specific brackets available on the HEX module.

Once the brackets have been fixed, the last step is related to the integration of the external bracing rods assy.

Electrical connections of the Harness bundles on the intermediate brackets will be performed and the SSMS will be ready for the integration with the LV P/L adapter.

9. FUTURE PLANS

9.1. Mission analysis process optimization

The characteristics of the Ride Share mission experienced during the preparation of the PoC flight (late definition and potential later evolution of the aggregate) make it critical to optimize the process to make it more efficient and flexible. One of the important goals of the VEGA SSMS PoC flight in that respect is to revise the process and implement a streamlined approach.

The potential improvements shall focus on:

- **Simplification:** by using the return-of-experience from eleven VEGA flights, remove all the analyses that are not strictly necessary, for example some CLA load cases could be revisited
- **Standardization:** define standard manoeuvers - for example, collision and contamination avoidance manoeuvers after the separations, or the ascent profile of the first stage of VEGA - independently from the S/C characteristics ; define a standard sequence for the Cubesat separations
- **Increased genericity** of the studies: through an ad-hoc margin policy, try to cover the changes of mass properties connected to S/C aggregate evolution.

Avio, as Prime Contractor to Arianespace for the Vega Launch System, will be in charge of future SSMS mission services.

After the PoC Flight on board of the current Vega launcher, Avio will adapt the SSMS concept to the next, evolved version of Vega, namely the Vega C. Flying a Vega C equipped with the adapted SSMS structure will offer an extra 700 kg capacity and enlarged volume inside a wider launcher fairing.

Regular SSMS-equipped-Vega C flights is part of the Vega Programme strategy to ramp up to a stable yearly rate 4. The fast growing LEO market will offer many opportunities to fly 1 to 400 kg SmallSats. Moreover, SSMS is considered the European workhorse for future IOD/IOV missions that will be performed in the frame of Horizon Europe of the European Commission.

Based on current knowledge and Prime (AVIO) studies, it is believed that a regular 1/y rideshare to orbit, serving both commercial and European customers, is viable and is planning to fly accordingly.

10. ACKNOWLEDGMENTS

The authors acknowledge the key role played by the 4 VERTA 3 Programme European participating States and by the European Commission (EC) who together made this flight possible and to the continuous effort made by all the members of the Industrial team to ensure the progress of LLL Initiative and SSMS development.