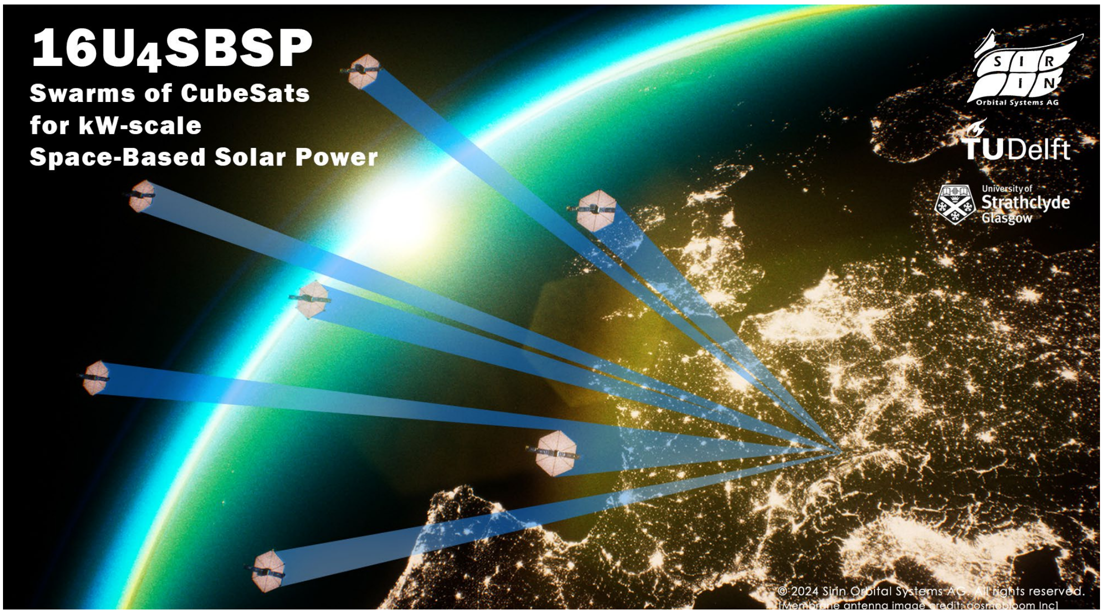


# Swarms of CubeSats for kW-scale Space-Based Solar Power (16U4SBSP)

## Executive Summary Report (ESR)

**Study**

*Open Space Innovation Platform (OSIP) campaign,*
*"Innovative Mission Concepts Enabled by Swarms of CubeSats"*

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### Activity summary:

The "16U4SBSP" mission concept is a fundamental technology demonstration step for the realization of kW-/MW-/GW-scale Space-Based Solar Power (SBSP) based on flight formation, a distributed or aggregated swarm of small satellites contrary to conventional concepts of monolithic giant SBSP satellites. In this mission, a swarm of 16U CubeSats collaboratively supply wireless power via Radio-Frequency waves to end-users in different locations on the ground, for instance to provide backup power for emergency situations, and also for space-to-space commercial use-cases.

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# 16U4SBSP – EXECUTIVE SUMMARY REPORT

The "16U4SBSP" mission concept is a fundamental technology demonstration step for the realization of kW-/MW-/GW-scale Space-Based Solar Power (SBSP) based on flight formation, a distributed or aggregated swarm of small satellites contrary to the conventional concept of monolithic large SBSP satellite. In this mission, a swarm of 16U CubeSats collaboratively supply wireless power via Radio-Frequency waves to end-users in different locations on the ground, for instance to provide backup power for emergency situations, and also for space-to-space use-cases.

## I. MISSION CONCEPT & PURPOSE

In the proposed demonstration mission, a swarm of CubeSats collaboratively supply power to clients and end-users in different locations, e.g. remote/strategic areas on Earth's surface or in-orbit power supply to data-centers or other in-orbit modules with auxiliary power requirements. This mission concept is a fundamental technology demonstration step for the realization of GW-scale SBSP, aimed to provide clean and limitless energy from space through wireless power transmission toward the middle of 21st century. Nonetheless, the original GW-scale SBSP requires large-scale transportation and robotics for the construction of km-scale infrastructure in space, whereas the proposed 16U4SBSP mission can be realized cheaper, faster and easier in short-term. The full mission consists of three segments: launch segment (to launch the CubeSats to the selected orbit), space segment (the swarm of CubeSats), ground segment (to collect the transferred energy and provide it to the end-user). Mobile and portable ground segments can be envisaged for emergency operations in the blackout zones affected by natural or manmade hazards. The key technologies which enable the mission concept are: (1) the power transmission system (which, on each CubeSat in the space segment, consists of a phased RF antenna and the corresponding DC-RF conversion unit); (2) a robust propulsion system with high total impulse capabilities, to ensure formation flying and station keeping for the whole lifetime; (3) an orientable solar array system, to maximize the available on-board power.

In KW-/MW-class space-based solar power generation ranges, the use of CubeSat swarms instead of a monolithic space power satellite is significantly advantageous for the following reasons:

1. **Development Cost and Time** – CubeSats can be developed in a shorter time in a cost-effective production line;
2. **Launch Opportunities and Cost** – CubeSats can be launched and deployed with many existing launchers which fit 16U satellites;
3. **Maintenance and Operation** – CubeSats can be maintained and operated relatively easier;
4. **Mission Life Time** - CubeSats can be replaced and expanded, which makes the mission to last longer;
5. **Time to Market** - The proposed mission concept can be realized in a relatively short time (by 2029) and serve the market, as CubeSat technologies are mature enough and only wireless power transfer subsystem shall be enriched in terms of technology readiness level (TRL4/5)

The added-value of the proposed mission concept is the realization of a SBSP demonstrator at smaller scale, which can be considered as technology demonstration for the realization of GW-class SBSP. In long-term, wireless transfer of solar power from space to Earth for household and industrial applications is considered as an aid for Europe's transition to Net Zero. Recent studies conclude that SBSP is a possible novel answer to the environmental challenge and energy crisis our generation is facing. The realization of SBSP within SOLARIS or similar programs follows 2040-2050 timeline.

Figure 1 Artistic sketch of a hexagonal formation flight for the 16U4SBSP mission, beaming wireless electric power from space to a position on Earth.

It may be rational to realize in a much shorter time with a much lower cost a lower power class SBSP for specific commercial and strategic applications using a swarm of CubeSats in a Sun-synchronous orbit. Nonetheless, the two main disadvantages of multiple satellite SBSP system compared to monolithic SBSP are the beamforming efficiency performance and the formation flight challenges, which are addressed in the present 16U4SBSP mission study.

Table 1 Features of 16USBSP mission concept based on swarms of CubeSats compared to a monolithic SBSP system.[1]

| feature | Monolithic SBSP Satellite | SBSP CubeSat swarms |
|---|---|---|
| In-orbit structure deployment | Difficult, requires in-orbit robotics assembly | Easy, small size structures to be deployed directly in orbit |
| Start of power transmission | Delayed, Only after full-structure deployment | Early stage, as of launch and orbit deployment |
| Mission expandability/ scalability | Difficult, as the single structure is non scalable | Possible by launch of new CubeSats |
| Mission life | Depends on the single satellite's life span | Long (sequential permutation) |
| Attitude construability | Difficult, larger disturbances due to large structure | Easy, small size |
| Beam efficiency | Good, due to the advantage of large antennae | Not as good, due to grating nature |
| Receiver complexity | Low/Medium, due to a single beam generated by a large antenna | High, due to multiple beams generated by the swarm – the beam shall be controlled to either have coherent combining of the beams or coherent power conversion at the receiver because each beam arrives with a phase shift |
| Satellite navigation & system operation | Easy, one satellite | Difficult, swarms maintenance and formation flight |

## II. PHASE-0 REQUIREMENTS FOR THE 16U4SBSP MISSION

A comprehensive set of more than 400 requirements for the 16U4SBSP mission has been elaborated by the consortium, divided in various categories (Mission, System, Ground, Technology Demo, ADCS, C&DH, Communications, Mechanisms, Navigation, Payload, Propulsion, Power, RCS). It was agreed within the consortium to provide an as extensive as possible list of requirements, also including some which are not entirely pertinent to the current stage of the study and are therefore in many cases still formulated using (TBC) and (TBD) statements. This proved to be very useful to better put the mission in its context and gather a clear idea of all aspects to be taken into account for the design of the mission, system and sub-systems. The following Table presents a selection of the key mission, system and sub-system requirements elaborated for the mission.

Table 2: Key mission, system and sub-system requirements for the 16U4SBSP mission.

| ID | Title | Requirement |
|---|---|---|
| MIS.010 | Mission scope | The scope of the mission shall be to design, develop, commission and launch a commercial space-based solar power (SBSP) demonstrator based on CubeSats in a distributed swarm configuration. |
| MIS.011 | Wireless transmission | The wireless power transmission demonstration shall be performed using RF waves. |
| MIS.012 | Mission cost | The total cost for the whole mission shall be not higher than 100 MEUR. |

[1] Adapted from original comparison analysis by "*Izumi Mikami (2006). Study on new concept of space-solar power station (SPS) (Doctoral dissertation, Kyoto University - Mitsubishi Electric).*"

| | | |
|---|---|---|
| MIS.013 | Primary mission objective | The primary mission objective shall be to validate with a small-scale mission the beamforming power transmission model developed by the consortium and, in this way, confirm that it is feasible and convenient to provide SBSP by means of a larger constellation of spacecraft (larger both in terms of number, and size). |
| MIS.014 | Secondary mission objectives | The mission shall include as many secondary mission objectives as possible (e.g. technology demonstrations, complex formation flight concepts), provided that they are not functional to the success of the mission and the achievement of the primary mission objective. |
| MIS.090 | Launch date | The mission shall be launched in the period from Jan 2028 (TBC) to Dec 2031 (TBC). |
| MIS.110 | Initial orbit | The initial operational orbit of the swarm shall be a Sun-synchronous circular orbit at an altitude of 500 km (TBC). |
| SYS.010 | Mission Lifetime | The system shall have a design life longer than 1.5 years (TBC). |
| SYS.050 | System mass | Each spacecraft shall have a wet mass of no more than 36 kg. |
| SYS.060 | Spacecraft format | Each spacecraft shall be based on the 16U CubeSat format. |
| ADCS.010 | De-tumbling | The ADCS shall be able to de-tumble the spacecraft from tip-off rates of 30 deg/s (TBC) on each axis down to at least 1.5 deg/s on each axis. |
| ADCS.032 | APE power transmission | The spacecraft shall provide an Absolute Performance Error (APE) with respect to the body-fixed frame lower than 0.05 deg 1-sigma half cone (TBC) when performing wireless power transmission. |
| ADCS.070 | Slew rate | The ADCS shall perform slew maneuvers with a maximum slew rate of 3 deg/s (TBC). |
| COMM.020 | Inter-satellite link | The spacecraft shall support radio communication link with the other spacecraft in the swarm. |
| COMM.030 | Uplink and downlink frequency | The spacecraft shall support X band and S band frequency (TBC), for both uplink and downlink communication links. |
| NAV.020 | Knowledge uncertainty relative position | The knowledge uncertainty on the relative position between two CubeSats in the swarm shall be 0.05 m 1-sigma (TBC). |
| NAV.030 | Relative position controllability | While performing wireless power transmission, the relative position between two CubeSats in the swarm shall be controlled with an uncertainty of no more than 1% (TBC) of the inter-satellite distance. |
| NAV.050 | Control window relative velocity | The relative velocity between two CubeSats in the swarm shall be kept in the range 1-10 cm/s (TBC). |
| PLD.010 | Transmission frequency | The payload shall transmit power at a RF frequency of 5.8 GHz (TBC). |
| PLD.020 | DC-RF conversion efficiency | The DC-RF conversion efficiency shall be no less than 60% (TBC). |
| PLD.030 | Transmission efficiency | The RF transmission efficiency (excluding free space losses) shall be no less than 90% (TBC). |
| PLD.071 | Thermal control payload | The payload thermal control system shall be able to dissipate a maximum power of 132 W (TBC) while the payload is active. |
| PROP.001 | Main propulsion tasks | The main propulsion system shall be used to perform slow orbital control maneuvers, for which no specific maximum maneuver duration is required. |
| PROP.010 | Overall total impulse | The main propulsion system shall provide a total impulse of at least 30000 Ns (TBC) for nominal orbital manoeuvres during the spacecraft lifetime, plus end of life manoeuvres including space debris mitigation. |

| | | |
|---|---|---|
| PROP.020 | Max Thrust | The maximum thrust delivered by each thruster shall be no more than 5 mN (TBC). |
| PROP.022 | Min Thrust | The minimum thrust delivered by the propulsion system shall be at least 0.5 mN (TBC). |
| POW.010 | Solar panels tracking mechanism | The EPS shall be equipped with a solar panels tracking mechanism. |
| POW.020 | Total power generated | The EPS shall allow for power generation of at least 100 W (TBC) BOL while in sunlight with the solar panels at 340 K (TBC), measured at the flight connector of the solar panel tracking mechanism. |
| POW.030 | Power storage | The EPS shall allow for a power storage capability of at least 200 Wh BOL (TBC). |
| RCS.001 | RCS propulsion tasks | The RCS propulsion system shall be used to perform 6DOF reaction control tasks (including support to de-tumbling and RWs desaturation), and for orbital control maneuvers requiring fast response time, such as collision avoidance maneuvers. |
| RCS.010 | Overall Total Impulse | The RCS propulsion system shall be able to provide a minimum total impulse of 70 Ns (TBC). |
| RCS.020 | Thrust | The RCS propulsion system shall be able to guarantee a thrust of no less than 10 mN (TBC) per thruster. |

## III. 16U4SBSP SPACECRAFT DESIGN

Propulsion and RCS

An initial trade-off for the main propulsion system showed that, given the high total impulse requirement and its implications on the mass and volume of the system, the final selection shall necessarily converge towards **electric propulsion**. In a second trade-off stage, among specific COTS propulsion systems available on the market, the **Enpulsion Micro R$^3$** was selected for 16U4SBSP, since this was the only system potentially capable of meeting all key requirements, in particular the total impulse one.

In the current spacecraft configuration, the presence of a RCS system is not strictly necessary, since not directly functional to the accomplishment of the mission needs: attitude control tasks can be fully accomplished by the reaction wheels, and wheels desaturation is performed by magnetic torquers. Nevertheless, a RCS system has been included in the spacecraft for additional 6DOF control authority (for example, to support detumbling and reaction wheel desaturation if needed), and as a higher-thrust system for emergency collision avoidance maneuvers. Similarly to the main propulsion system, an initial trade-off for the type of propulsion in the RCS system showed three possible candidates: **cold gas**, **warm gas** or **resistojets**. The specific COTS system selected in this case was the **IANUS 6DOF system** (cold gas) designed by t4i for the Milani mission.

ADCS

The trade-off for the ADCS sub-system was focused on a selected list of fully self-standing ADCS assemblies, not requiring additional component in order to perform all required functions. The **EnduroSat 16U system** (based on the CubeSpace Generation 2 ADCS system) including an attitude control computer and three **CW5000** reaction wheels was selected. The control system has already been flown and the reaction wheels are expected to be qualified by the end of 2025. The momentum storage capability of each wheel is 500 mNms, which allows to perform all de-tumbling and slew maneuvers only by means of the reaction wheels. The maximum wheel torque is 37 mNm, sufficient to meet with large margin all torque requirements for ground tracking and for counter-acting disturbance torques (the maximum expected disturbance torques are in the order of 1 mNm or less). The ADCS design also includes two star-trackers to meet the required pointing accuracy under eclipse. The **Sodern Auriga CP** has been selected as already supported by the CubeSpace Generation 2 Cube Computer: this system provides a pointing accuracy better than 0.1 deg/s, while meeting a rotational rate of more than 1 deg/s (compatible to the 0.86 deg/s required for ground tracking during the power beaming phase).

Navigation

For navigation, a first higher-level trade-off was performed to define which navigation technique is best suited to meet the given requirements. This trade-off led to the conclusion that **realtime GNSS** (either absolute or relative) is the only possible choice to this respect, due to its performance features combined with still acceptable mass and volume characteristics. The final selected GNSS receiver is the **FUGRO SpaceStar**, which allows for an absolute positioning error of 10 cm RMS, which is already compatible with the mission requirements and can be further improved to approximately 5 cm by employing a "relative" link with differential GNSS using the data available from the inter-satellite link.

Power

Batteries are considered the most critical EPS component in the 16U4SBSP spacecraft, due to their heavy requirements in terms of power storage and power peak/instantaneous power. Therefore, the first performed trade-off has allowed to select the **Kongsberg/NanoAvionics 8S1P** battery, due to its particularly favorable combination of capacity, mass, volume and peak power. Consequently, for the EPS electronics, the **Kongsberg/NanoAvionics EPS electronics** has been selected, to ensure maximum compatibility with the selected batteries. A total of 4 stacked Li-ion battery units are used, which allows for a total battery capacity of 340.8 Wh BOL. Each battery unit provides a peak power of 100 W, which allows to achieve a total of 400 W peak power with 4 units.

To optimize the power generation capabilities of the spacecraft in function of the specific needs of the 16U4SBSP mission,  the consortium has opted for a fully customized design of the solar array wings, built upon the 30% Triple Junction GaAs Solar Cell Assembly from AzurSpace. The final solar arrays configuration designed for the 16U4SBSp spacecraft consists of 2 separate wings, each with a total of 60 cells; additionally, in one of the two wings, 25 cells are present on the back side. With this configuration, a total power generation capability of 144 W (72 W per wing) is available from the deployed wings, while 30 W are available in folded position before deployment.

Communication

Since the sub-system requirements leave the door open to two possible frequency bands (S band or X band), the main trade-off performed for the communications sub-system was to decide between these two frequency bands. Data throughput in either downlink or uplink conditions did not represent a major driving factor for the selection, considering that the primary mission objective is not associated to generating specific science products, thus only basic telemetry and telecommand information will need to be exchanged. For this reason, **S-band** was selected as preferrable option. The selected S-band radio is the **Syrlinks EWC31** model, capable of operating in the 2200-2290 MHz frequency range (transmission) and the 2025-2110 MHz range (while receiving). The data rate can be in the range from 8 to 512 kbps, and the output power can be in the range from 27 to 36 dBm. This radio has been selected in combination with the **Anywaves S-Band TT&C patch antenna**, having a peak boresight gain of 6.5 dBi. Preliminary link budgets for the downlink, uplink and inter-satellite link showed that, in spite of the very conservative assumptions used, all links close with a margin higher than 3 dB, even when using the S-band radio at its maximum available data rate of 512 kbs.

Structures, Deployer and Mechanisms

A representative 16U CubeSat structure has been chosen for the current 16U4SBSP spacecraft architecture, provided by the company EnduroSat and built in Aluminium 6082 with hard-anodized surface. The deployer selection will mainly depend on the finalized mass budget for the 16U4SBSP spacecraft, and could range from a conventional 16U deployer such as the 16U QuadPack dispenser from ISISpace to the recently developed EXOpod NOVA 16U S1 dispenser from ExoLaunch, qualified for a spacecraft mass up to 36 kg.

Apart the payload antenna deployment system, the other main mechanism included in the current architecture of the 16U4SBSP spacecraft is the solar panel tracking mechanism (or SADA, Solar Array Drive Assembly), which is also in charge of solar arrays deployment at the beginning of the mission. The **mSADA system** produced by the company IMT has been selected for the 16U4SBSP spacecraft. This system is designed for a 12U form factor, but for a similar solar array size and power as in the 16U4SBSP case. It is based on a pointing mechanism with ± 0.3 deg pointing accuracy and full 180deg rotation capabilities of both wings in both directions.

Thermal Control

A preliminary thermal analysis for the 16U4SBSP spacecraft has been performed, focusing on two aspects: a simplified single-node steady-state balance for the whole spacecraft, to predict the range of temperatures expected during operation and define a coating strategy on the external surface of the spacecraft for passive thermal control; and the definition of a strategy and sub-system design for dissipating the significant amount of heat produced by the payload during the power beaming phase.

The simplified single-node analysis showed that, with a spacecraft external coating made by 65% of vapor-deposited Silver coating, 30% Silvered fused silica and 5% Aluminized aclar film, the expected balance temperature in the spacecraft ranges from -8.9 °C (eclipse conditions) to 43.5 °C (sunlight conditions). For the solar array wings, a similar analysis showed a temperature range between -72.3 °C and 89.8 °C.

With the given input transmission power while beaming (331 W) and the assumed 60% efficiency of the DC-RF conversion process, a total power of 132.4 W is dissipated on board of the 16U4SBSP spacecraft, with assumed maximum duration of each power beaming demonstration of 10 minutes. Dissipating this power with radiators would require a radiator area of approximately 0.3 $m^2$, incompatible with the available external surface on the 16U4SBSP CubeSat. Therefore, a deployable radiator would be required. Given the presence of other mechanisms and deployables on the spacecraft, and the intrinsic design complications associated to the use of a deployable radiator, this solution has been considered too risky in terms of reliability and therefore discarded. The alternative option, eventually selected for the 16U4SBSP spacecraft, assumes that a phase-change material is used to store the dissipated energy. The phase-change material selected for the preliminary design of the heat management system is Tetracosane ($C_{24}H_{50}$), a paraffin characterized by a good compromise between melting temperature (50.6 °C) and latent heat for melting (255 kJ/kg). The total estimated volume of the payload heat management box is 0.584U, for a mass of 0.802 kg.

Command ad Data Handling

The **Argotec FERMI OBC** has been chosen as OBC for the 16U4SBSP spacecraft, mainly due to its superior data storage properties which might result in a good added value in case particularly high data-demanding science goals are chosen as possible secondary mission objectives.

CubeSat Integrator and Launch Provider

The launch provider currently used as baseline for the 16U4SBSP mission is RFA. Based on the discussions carried out by the consortium with this launch provider, their envisioned launch service would be fully compatible with the orbit, mass/volume and deployment needs of 16U4SBSP. In case the development of their RFA-1 launcher is delayed to such an extent that it will not be possible to consider this launch provider anymore for the mission, several alternatives could be explored, including for example the Falcon 9, Vulcan, Electron, or Ariane 6 launchers.

The current baseline for the CubeSat integrator is EnduroSat, with which the consortium already has preliminary agreements and has carried out an initial discussion on the viability of the spacecraft architecture choices and the current mission planning. Possible alternatives include Space Inventor (Denmark), Tyvak or Argotec (Italy), with whom some of the consortium members have already collaborated in past projects.

Spacecraft Configuration and Technical Budgets

The spacecraft configuration resulting from the components selected in the trade-offs of all subsystems is presented in detail in the next Figures 2–4. The margined spacecraft mass is **35.3 kg**, and the power budgets show that at Beginning of Life the 16U4SBSP swarm is capable of beaming power to ground every 2 orbits (in case multiple power receiving stations are available on ground), with battery DoD equal to 34%.

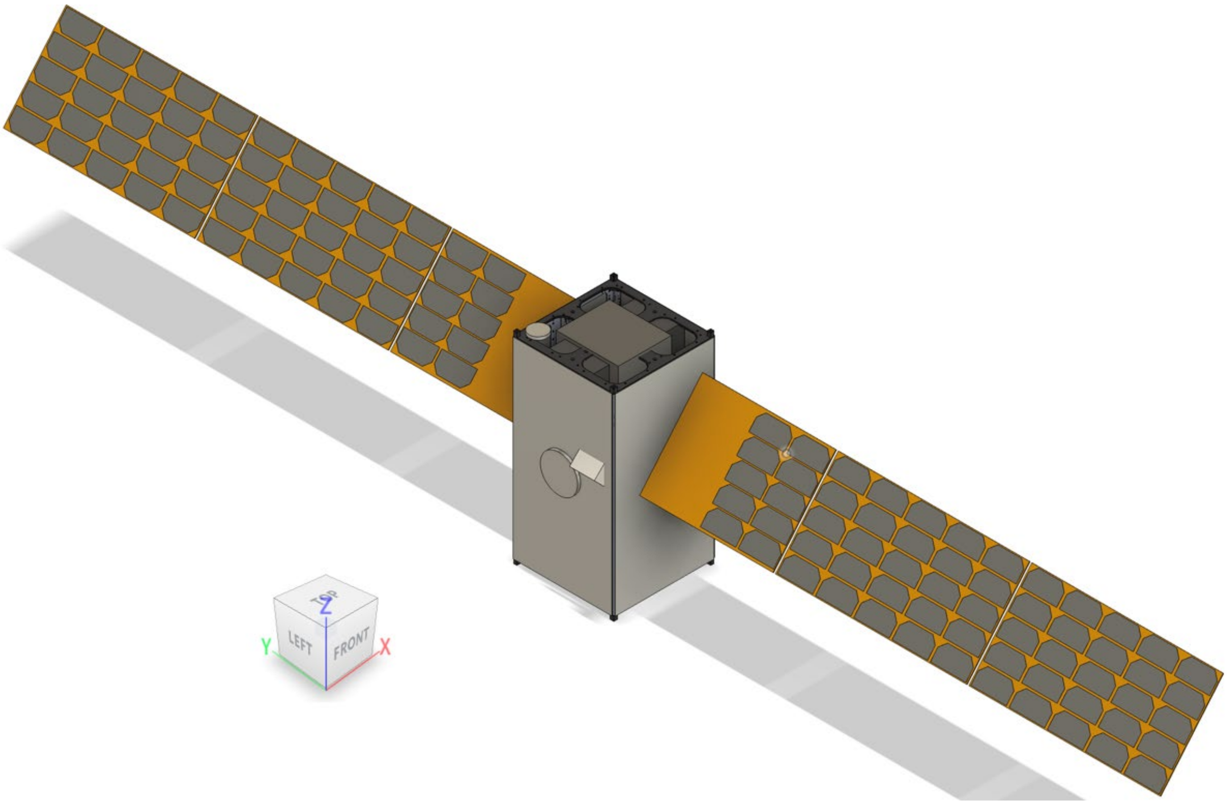


Figure 2: 16U4SBSP spacecraft with cover panels, solar array wings deployed.

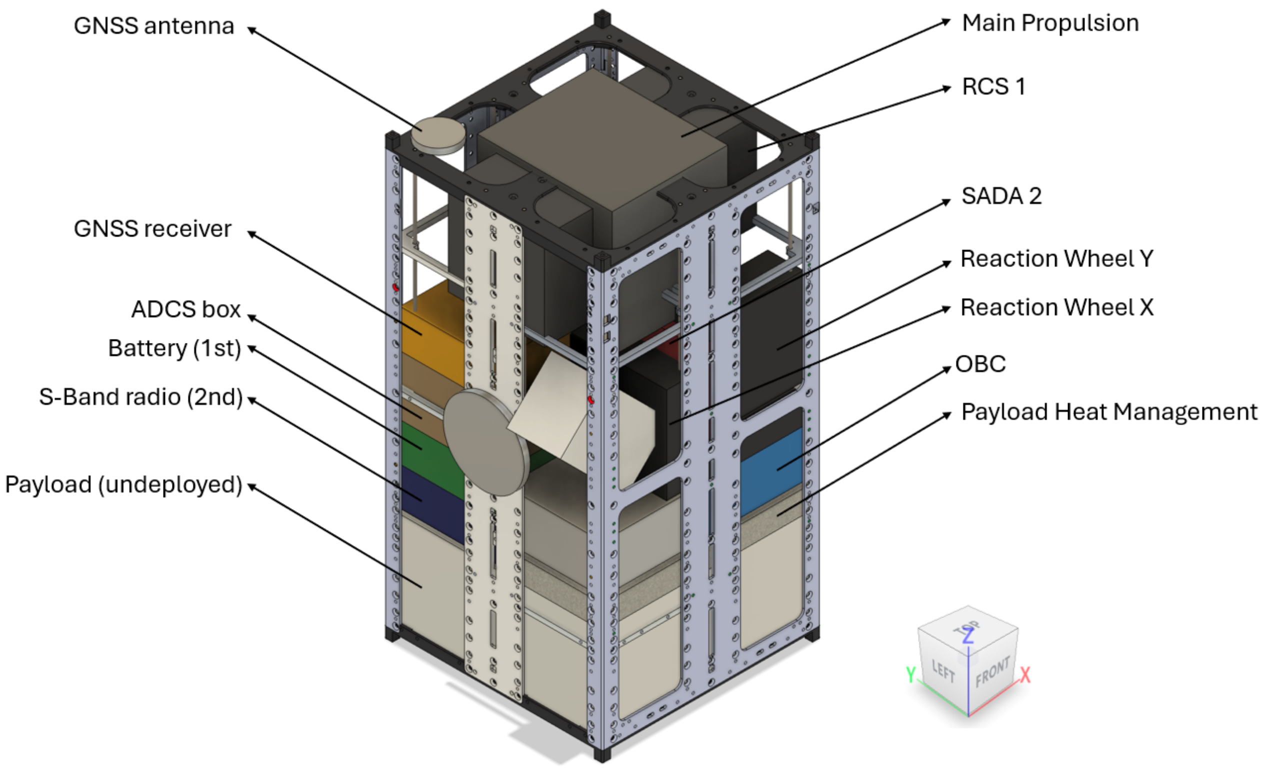


Figure 3: X-/Y- view of the 16U4SBSP spacecraft without cover panels and solar array wings.

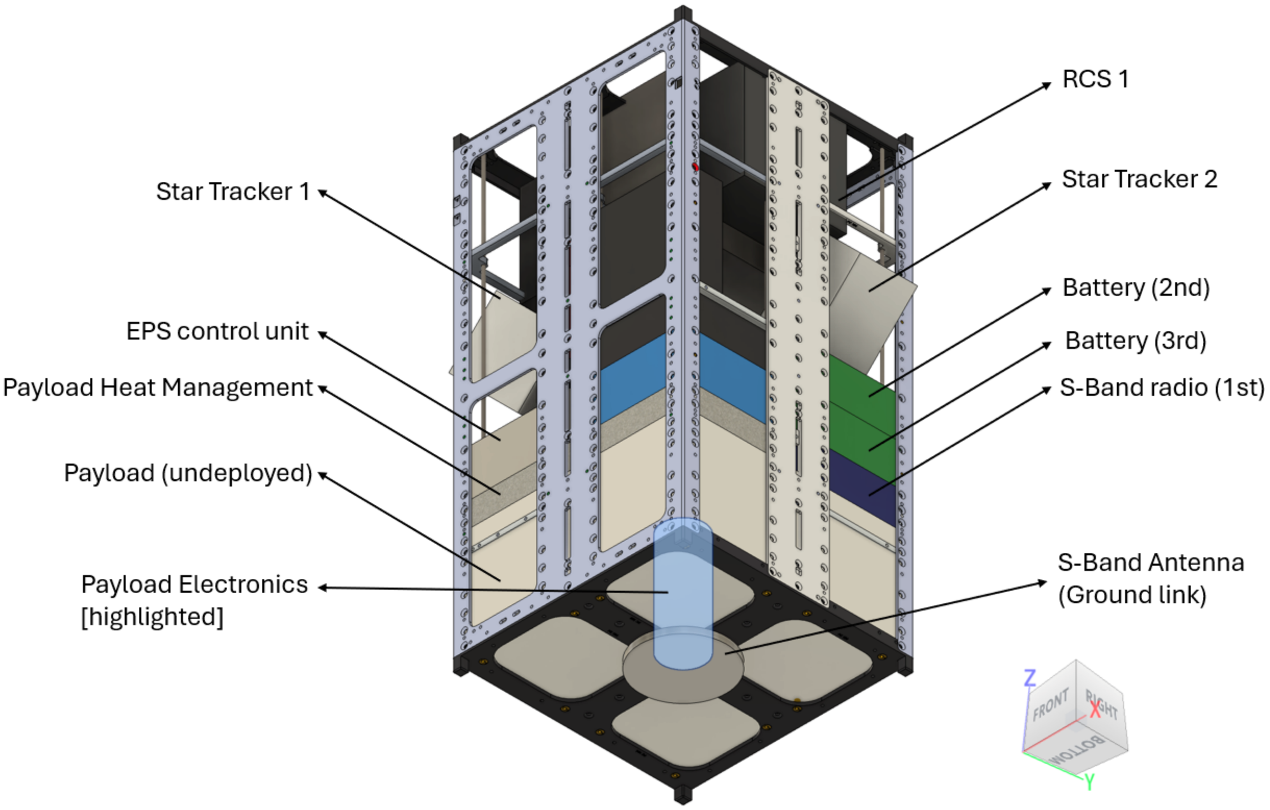


Figure 4: Z- view of the 16U4SBSP spacecraft without cover panels and solar array wings.

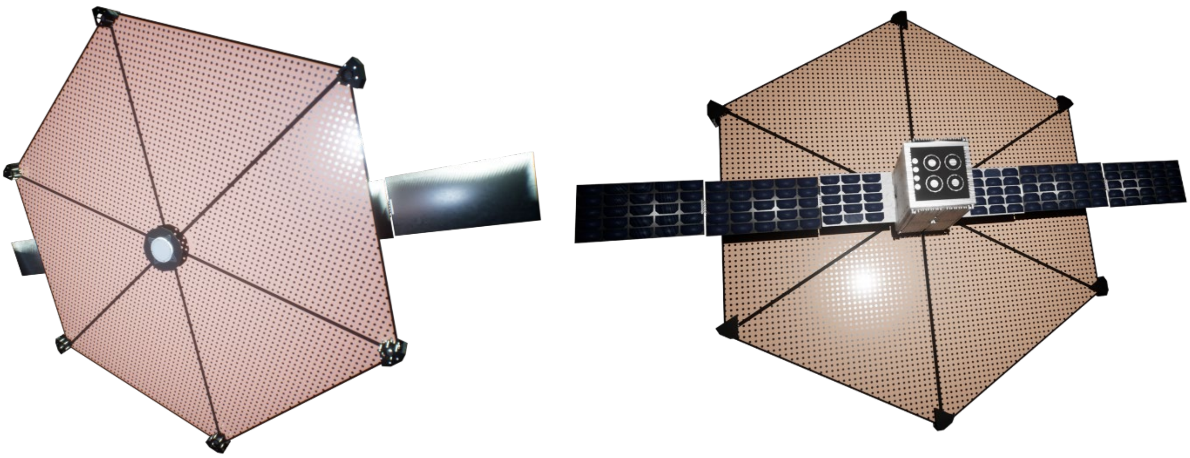

Figure 5 One spacecraft with deployable membrane antenna (™cosmobloom) for enhancing the beamforming capabilities.

## IV. PRELIMINARY DEVELOPMENT AND INTEGRATION PLAN

A preliminary Development and Integration Plan for the 16U4SBSP mission, including all phases from A to launch, is presented in Figure 6. According to this plan, the mission would be launched in February-March 2029.

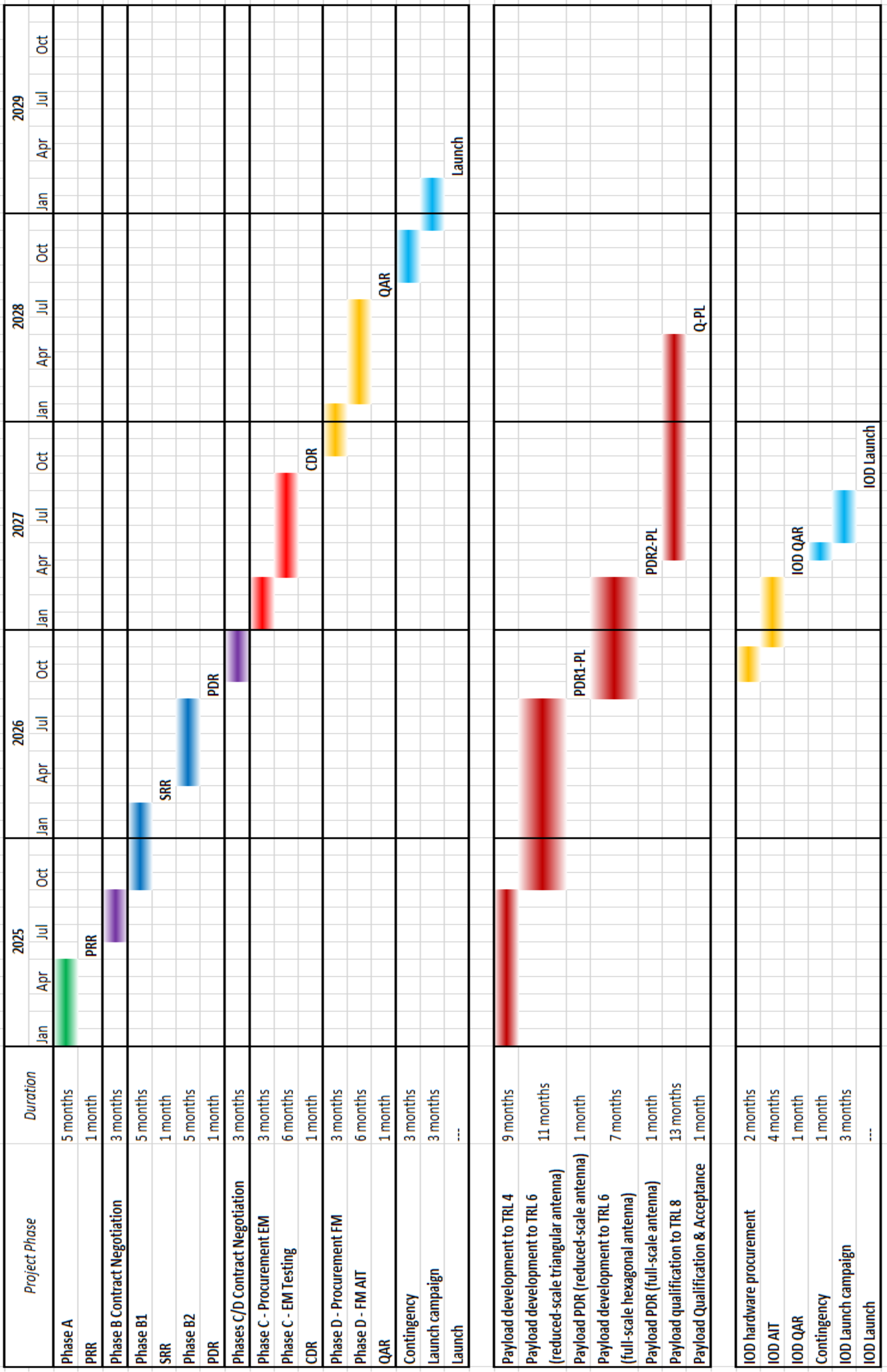


Figure 6: Development and Integration Plan for the 16U4SBSP mission.

## V. 16U4SBSP MISSION KEY FINDINGS

Key findings from the mission analysis reveal the impact of gravitational perturbations, solar radiation pressure, and atmospheric drag on the spacecraft dynamics. The selection of a sun-synchronous orbit (SSO) is justified for optimal power generation and efficiency in power delivery.

The study highlights the necessity of optimal launch dates and initial conditions to minimize $\Delta v$ requirements across various mission phases, thus reducing propellant use. The analysis of the operative phase under different degrees of attitude uncertainty emphasizes the importance of precise formation control to ensure mission objectives are met. The End-of-Life phase analysis demonstrates compliance with space debris mitigation guidelines, highlighting the mission's sustainability.

The study analysis has shown that it is possible in principle to integrate the beams from multiple transmitters so that higher gains are achievable. The increased gain would therefore allow for higher power levels received by the rectenna and enable it to be activated even with relatively low transmitted power from the individual satellite and at an operational stage ensuring higher activation efficiency.

It was realized that the use of pilot calibration is an efficient strategy to compensate for uncertainties in position of the platform as long as these are in a fraction of the relative distance and attitude control angle. Another relevant aspect is the fact that increasing the number of satellites would increase the benefits in terms of gain and Side-Lobe Level (SLL). Additionally, it was observed that tapering based SLL mitigation strategies would not be effective in the proposed hexagonal configuration as there are too radial layers in the 2D virtual array on which the tapering could operate. Finally, last analysis showed that by using a much larger antenna with more elements the overall beam gain would increase significantly with also much lower SLL.

In summary, it was identified that the best formation would need to have the larger number of satellites as possible and operating at close distances. However, these might be unpractical at this stage of the technology readiness and reasonable demonstration requirements would see a small number of satellites operating with an intersatellite distance between 10 and 100m.

Another requirement is that the system would need to operate in circular polarization, as it would remove the issue of polarization mismatch that would have a significant impact on the wireless power transfer capability of the system.

On the ground segment, the use of the pilot calibration strategy introduces the requirement to have cooperative transmitters on the ground that would send pilot signals to calibrate the array. This requirement is not particularly stringent as does not require the pilots to operate at the same time, additionally sources of opportunity could be used, such as GNSS signals to perform the calibration.

On the receiver side, no requirements are identified other than the need to operate in circular polarization and to have the large possible gain. The option to steer the receiver antenna (mechanically or electronically) is discarded at this stage as it is impractical for the size of the receiver antenna.

## VI. 16U4SBSP MISSION SUMMARY & RECOMMENDATIONS

It was concluded that with 16U4SBSP mission we can take a fundamental step toward the realization of kW-scale SBSP using a distributed or aggregated swarm of 16U CubeSats. With the current number of satellites in the 16U4SBSP swarm, namely seven 16U CubeSats, we can: (I) de-risk key technologies required for the kW-/MW-scale wireless power beaming in the SBSP-concept based on the flight formation; (II) we can demonstrate space-to-ground Wireless Power Transfer (WPT) by using large parabolic antennas on the ground, that are sensitive enough to detect limited delivered power, to perform signal measurements in selected points using accurate devices for calibration of the system, and (III) we can perform additional space-to-space WPT experiments by finding synergies with other space missions what may carry onboard a rectenna package.

The 16U4SBSP will be the first small-scale rapid in-space demonstration mission and a critical key technology de-risking phase for the realization of space-based solar power in Europe, which shall provide sustainable Clean Energy for the future generations, an aid for Europe's transition to Net Zero by 2050.

– End of Document –