V-LEOS: Investigating mission concepts for industrialized satellite platforms for Very Low Earth Orbit applications

Ashvij Narayanan[1], Jan-Christian Meyer[2], Moitrayee Chakraborty[3] , Andreas Wiegand

[1] Berlin Space Technologies GmbH
Max-Plank-Str. 3, 12489, Berlin, Germany

[2] Berlin Space Technologies GmbH
Max-Plank-Str. 3, 12489, Berlin, Germany

[3] Berlin Space Technologies GmbH
Max-Plank-Str. 3, 12489, Berlin, Germany

[3] Astos Solutions GmbH
Meitnerstraße 8, 70563 Stuttgart,Germany

Abstract

Berlin Space Technologies (BST) is investigating the feasibility of an industrialised VLEO satellite platform, focusing on adapting its existing LEOS platform rather than designing from scratch. The study prioritises industrial viability over traditional system engineering by exploring which mission scenarios are achievable using a modified LEOS platform. Trade-offs are assessed between operational benefits and the cost of adapting current technology, considering variables like payload needs, orbit altitude, and constellation size.

Among the concepts explored is a hybrid mission model: satellites operate at standard LEO until end-of-life or customer request, then descend to VLEO for enhanced performance before re-entry. Although not fully optimised for VLEO, this approach could offer commercial advantages and increase platform reuse.

The study also examines modular platform configurations, allowing for flexible adaptation of power and propulsion systems. Funded by the DLR Raumfahrtagentur, the project spans nearly two years, with Astos Solutions GmbH supporting orbital and atmospheric analysis. This paper presents initial findings, with further phases refining selected scenarios toward a production-ready baseline.

1 Introduction

Satellite applications in very low earth orbit (VLEO) have been investigated in the literature for a long time. One of the very few realised missions is GOCE to measure Earths gravity potential. It is evident that there is a discrepancy between theoretical possibility and the practical implementation.

One of the reasons have been the high satellite and launch costs. With the NewSpace approach this hurdle is getting lower. New business models become viable. Today, various startups and established companies are developing platform, satellite and mission concepts for VLEO. This includes funding by the European Defence Fund. It is thus evident, that VLEO applications have important potential that originates in the close proximity to Earth: For Earth observation the shorter distance increases resolution. For communications, signal time-of-flight is reduced.

2 Project overview

Contrary to past approaches that focus on the application and derive mission and system requirements in the classical systems engineering way, the approach in the given study focuses on industrial viability. This means that the starting point for the investigation is BST's LEOS satellite platform. A primary question to be answered is which application and mission scenarios are possible with the LEOS platform when adapted to VLEO. The resulting trade-off balances operational benefit of a given scenario against the cost of adapting an existing technology.

This trade-off varies parameters such as payload type, performance and resource needs, VLEO altitude, mission duration and constellation size.

Various mission scenarios are investigated in an open-minded approach. Several dedicated VLEO concepts are derived. One concrete VLEO business case that they are compared against is a VLEO extension of a LEO satellite. The idea is to operate a commercial Earth observation satellite at classical LEO altitude. After its end of life or at the request of a high-value customer, the satellite's altitude is reduced to VLEO to increase its performance (e.g. optical resolution). Here, the satellite can operate for a given amount of time before it re-enters the atmosphere. In this scenario the satellite is not fully optimised for operations in VLEO. this will limit its orbital lifetime, but at the other hand also enable other commercial benefits by increasing the number of satellites built on the same platform.

Other scenarios leverage the modular nature of the LEOS platform to investigate to which extent a dedicated VLEO platform is a viable option. The ability to modularly change the capacity of the electrical power subsystem and accommodate multiple different propulsion systems enables an optimisation of the mission design parameters.

The study is funded through the DLR Raumfahrtagentur and will last for almost two years. This paper presents the first phase of the project. In subsequent phases, promising mission and system scenarios will be investigated in more detail before a single baseline will be designed up to production readiness at the end of the study.

BST is supported in this work by Astos Solutions GmbH who contribute their capabilities in orbital mechanics, mission analysis and the interactions between the VLEO atmosphere and the spacecraft.

3 Implementation plan

The goal of this study is to define a VLEO capable satellite system architecture. Secondary goal is to describe sub-system requirements and the development of relevant mission scenarios.

Based on the special requirements of VLEO, typical sub-systems required are: propulsion, attitude control, electrical power, thermal control, data handling, communication, electrical, structure, and payload.

Apart from the production aspects, environmental condition of VLEO has a major influence on industrialization of the satellite platform. Hence this task requires complex systems engineering to meet system level requirements of the mission.

System trade-off exploration is closely linked to technical aspects of the VLEO mission. The choice of mission parameters such as lifetime and payload characteristics greatly influence the platform design.

The following diagram illustrates the structure of the project and shows how the individual elements are linked together and build on each other to define the mission scenario.

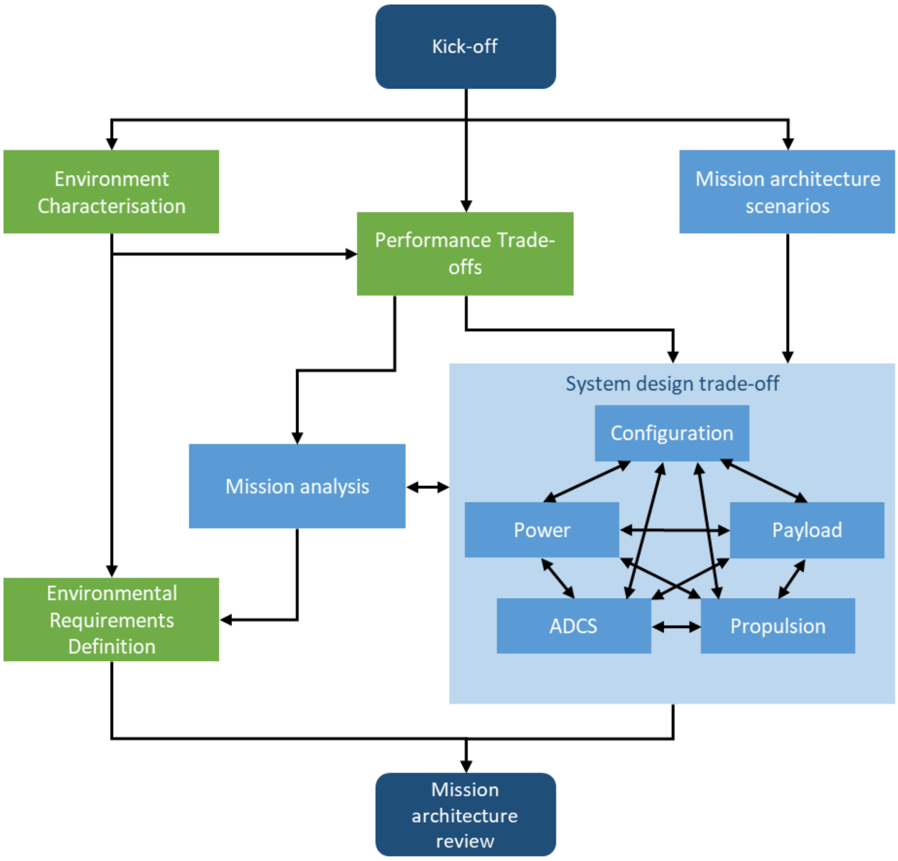

Figure 1: Systems Engineering process until mission architecture definition.

Over the course of three phases, the project is refined from a high-level trade-space evaluation to the design of a specific solution.

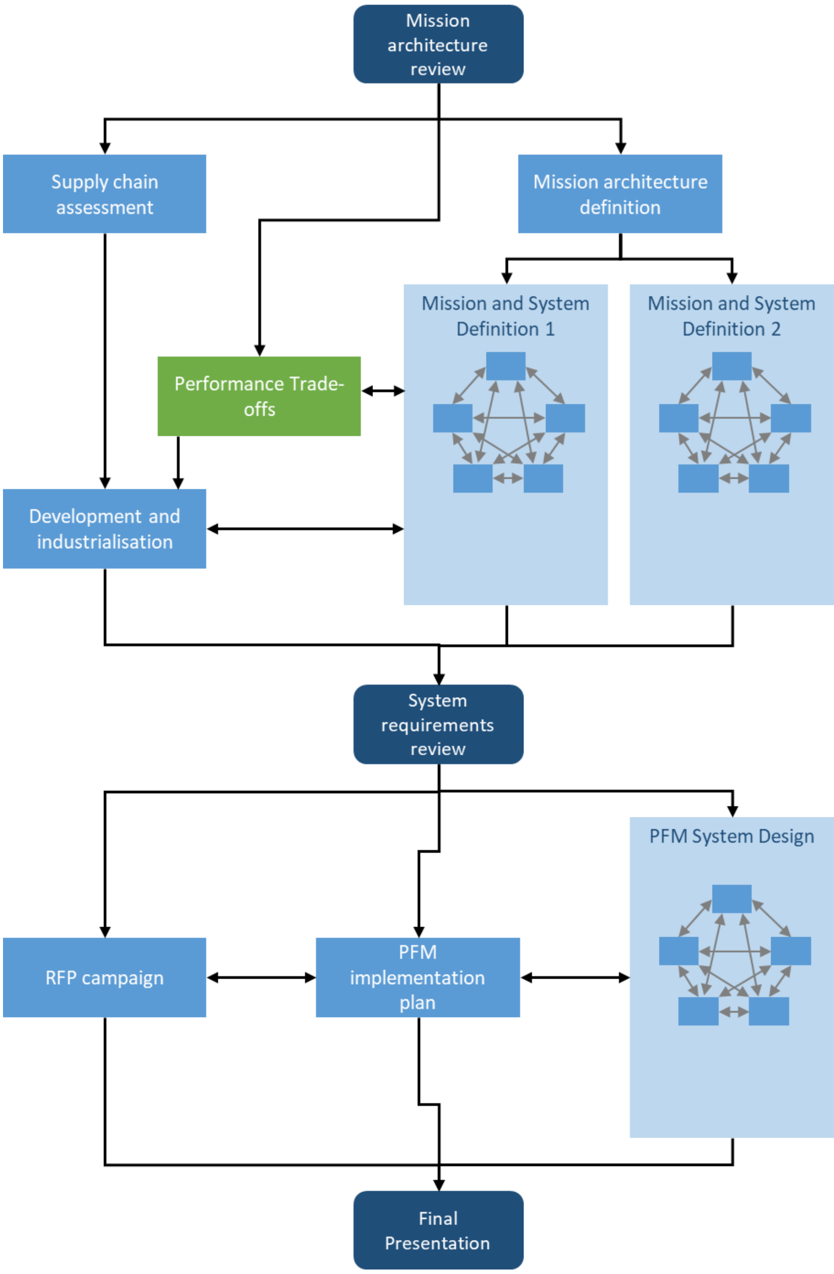

Figure 2: Definition of system requirements and PFM implementation.

3.1 VLEO Mission Examples:

3.1.1 Past and Successful Missions

Satellite Mission	Key facts	Feature	Application
GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) [1]	ESA ~ 225 km alt. Ops: 2009-2013	• Fully symmetric, non-moving parts • Used ion propulsion to counteract drag • Fixed solar panels, shaped to act as fins	• High-precision gravity field mapping, determine gravity-field anomalies and geoid with high accuracy • Achieve spatial resolution better than 100 km
Tsubame (Super Low Altitude Test Satellite, SLATS) [2]	JAXA 271 - 167 km alt. Ops: 2017-2019	• Ion engine • Canted solar panels • Additional Optical Sensor	• Understanding effects of high-density atomic oxygen on the satellite (Atomic Oxygen Fluence Sensor) • Measurement of material degradation in the 200 km orbit (Material Degradation Monitor)

3.1.2 Upcoming Missions

Satellite Mission	Key facts	Feature	Application
Skeyeon Near Earth Orbiter [3]	ESA 250 km	• Concentric Folded Lens Telescope • low drag satellite shapes • patented atomic oxygen-resistant materials • patented high-data-rate satellite downlink system	• Delivering 1m resolution images that enable low latency Earth monitoring. • development of a high value image database.
Skimsat platform [4]	Thales Alenia + Qinetiq < 300 km	• Used in collaboration with University of Birmingham and Teledyne e2v's cold atom interferometry technology	• Quantum Accelerometer Climate Explorer (Q-ACE) mission - Will measure density of Earth's thermosphere to improve climate projections
Phantom [5]	Redwire < 300 km	• Electric propulsion • Aerodynamic design uses less propellant	• Earth Science, ISR, SDA, RF signal monitoring, Communications

SabreSat Orbital Drone [6][7]	Redwire < 300 km	• To be used for Darpa's Otter program • Modular in size • air breathing or electric propulsion	• Intelligence, Earth science and communications missions
Stingray Satellite constellation [8]	EOI space 250km Launch exp. 2025	• NIR optical imager offering 0.15 m spatial resolution imagery • relaying imagery directly to the user – no need of ground stations • HET-X Electric Propulsion System (EPS) for orbit maintenance at 250km	• multispectral (MS) near-infrared (NIR) imagers delivering high resolution imagery

4 Conclusion

With the present study, BST will start the evaluation and development of an industrialised VLEO satellite platform. Contrary to other approaches, a strong focus is put on the commercial viability of the selected concept.

5 References:

1. https://www.esa.int/Enabling_Support/Operations/GOCE
2. https://www.eoportal.org/satellite-missions/slats
3. https://skeyeon.com/technology/
4. https://www.thalesaleniaspace.com/en/press-releases/thales-alenia-space-and-qinetiq-pave-way-small-multimission-satellites-very-low
5. https://redwirespace.com/capabilities/phantom/
6. https://redwirespace.com/capabilities/sabresat/
7. https://spacenews.com/redwire-wins-darpa-contract-for-vleo-demonstration/
8. https://www.eoportal.org/satellite-missions/stingray#mission-capabilities