GERMAN ORBITAL SYSTEMS

GENA-SAT De-Risk Activity
Executive Summary
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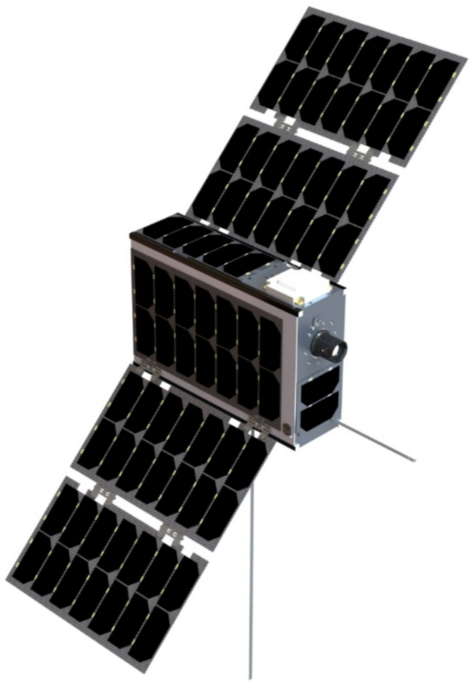

EXECUTIVE SUMMARY

GENASAT de-risk activity

Version 1.0 of 10-02-2021

In the framework of the GENA-SAT De-Risk Activity, German Orbital Systems has consolidated its existing GROOVE IoD/IoV service concept by conducting an in-depth market analysis, by collecting user requirements and by developing a preliminary platform design to meet these requirements. By doing so GOS has significantly reduced the risks for the follow-on activity as well as for the self-standing commercial IoD/IoV service which will be offered subsequently.
The new service will allow to fly technology demonstration and in orbit verification payloads into space for a fraction of today's costs. To achieve this, a novel platform, together with the corresponding ground infrastructure and sustainable business model are developed based on the company's heritage project GROOVE.

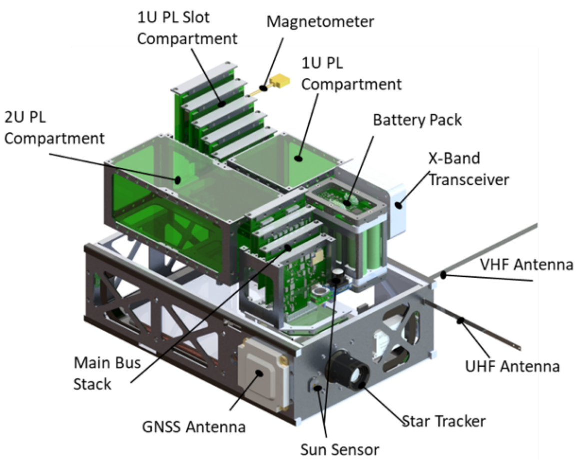

Figure 1 Initial and updated GROOVE concepts

The GROOVE service was introduced by GOS in 2018 at the national conference for space components in Ulm, Germany. The initial satellite platform, which currently builds the backbone of the GROOVE service is based on a 3U CubeSat. It is tailored for IOV and IOD applications. It allows for significant cost reduction through an innovative "shared satellite" approach. Sharing the resources of the 3U CubeSat between up to 10 users reduces the costs by an order of magnitude. Nevertheless, due to the limitations of the 3U form factor, the 3U GROOVE platform does not allow for the provision of advanced supplementary data, such as space radiation measurements, as part of the service. Due to strict budgetary limitations during the fully self-funded development of 3U GROOVE, the required functionality could not be implemented without putting the company (GOS) at a significant economic risk. The main purpose of the 3U GROOVE platform is therefore to be a Proof-of-Concept in order to attract potential customers and to demonstrate feasibility while collecting valuable feedback for subsequent improvements.

Discussions with customers, scientists and academia, in the framework of the preparation of the first GROOVE proof of concept mission, have revealed that the initial concept suffers from several drawbacks. Addressing these imperfections and improving the platform as well as the service will result in a higher market traction and as a consequence lead to a commercially viable and sustainable business model.

Under the GENA-SAT de-risk activity, a new 6U platform is baselined, and its adequacy validated by a broad range of customers. The interest and market traction stimulated by the initial GROOVE PoC is combined with the possibilities given through ESA funding to create an innovative IoV/IoD service concept, which – once implemented – will be appreciated by customers worldwide.

The goals of the **de-risk activity** can be formulated as follows:

1. Analyze the small sat market for IOV/IOD missions
2. In cooperation with a representative group of customers, define a set of user requirements to an ideal small sat IOV/IOD service, allowing (if met) to address a majority of use cases. Map the requirements to market segments (How big is the percentage of the customers, which can only be addressed if a specific requirement is met?)
3. Define the economically most effective and technically feasible delta development, to evolve the existing GROOVE service to an updated service, based on a new 6U platform and meeting at least as many user requirements as needed to achieve long-term commercial viability

The technical objectives of subsequent **fully-fledged development** are driven by the shortcomings of the current state-of-the-art IOD/IOV services, feedback from 3U GROOVE customers as well as experience from previous missions and the results of the de-risk activity.

1. Finalize the development of the 6U platform based on the outcomes of the de-risk activity
2. Demonstrate that this platform is capable to be the backbone of a self-standing, commercially viable and sustainable IOD/IOV service in the framework of a demo mission (GENA-SAT mission)

The de-risk activity (this activity) consisted of two phases: the consolidation and the formulation phases. The activity began with an intensive business model consolidation phase including a market analysis as well as the subsequent identification and selection of representative customers for the participation in customer interviews. The results of the interviews have built the basis for the subsequent formulation phase. This phase consisted of developing and evaluating design concepts the payload interfaces, for the satellite bus as well as for the “End-to-End” service. All concepts are evaluated and iterated according to their economic feasibility.

A mission analysis allowed to evaluate spacecraft ground station access, deorbiting expectations and power generation capabilities. Major user requirements have been verified and it was proven that the selected satellite & mission concept will fulfill the needs of the majority of potential payloads.

The space segment for the GENA-SAT mission is based on the new GROOVE EVO platform which is designed to provide maximum flexibility and functional freedom for payload providers while keeping the satellite bus defined and optimized for cost-effective and quick MAIT. Modularity, a broad interface selection and software defined capabilities guarantee the maximum value for the customer within the boundary conditions of a shared satellite mission. Optional add-ons such as double deployable solar panels or supplementary attitude sensors allow for more complicated mission scenarios if required by customers in future.

The GROOVE EVO platform consists of two main blocks: a bus module and a payload module. The bus module incorporates all the required instrumentation for autonomous functionality on orbit and consists of Electrical Power System (EPS), Command and Data Handling Unit (CDH), Attitude and Orbit Control System (AOCS), and Thermal System. The payload module consists of payload compartments which can be organized in several different configurations and Payload Control Units (PCU) which are responsible for payload communication, control, and monitoring.

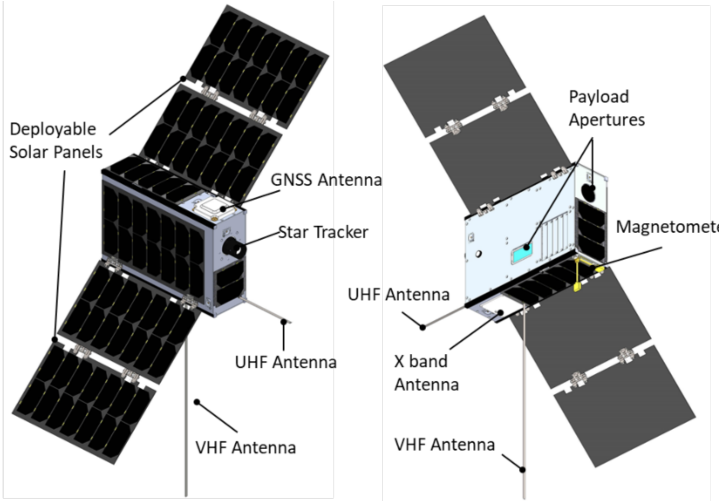

Figure 2 External viw on the GROOVE EVO platform (deployed solar panels)

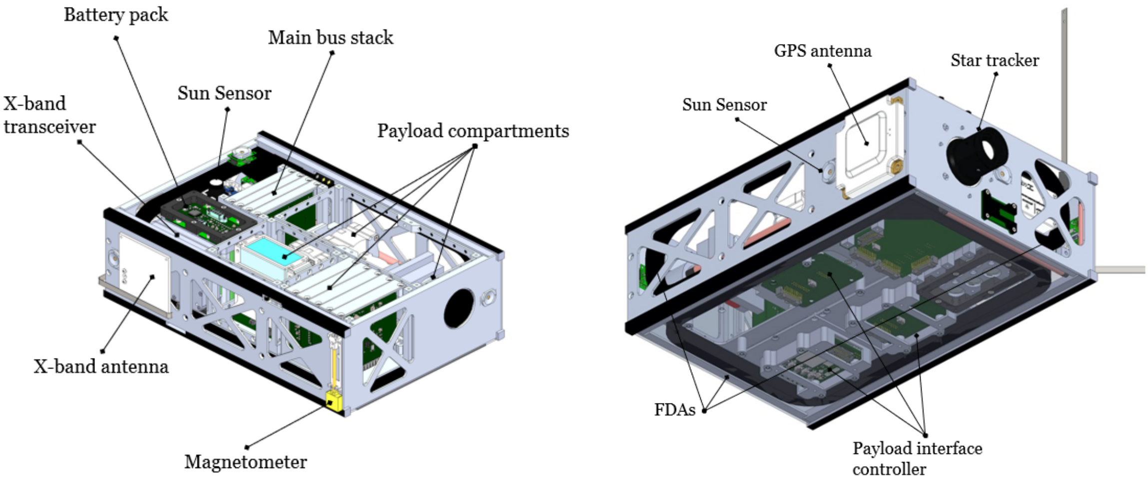

Figure 3 Spacecraft subsystems

The satellites power architecture shall meet the requirements of flexibility and adjustability in order to accommodate payloads of different sizes and purposes. The main challenge of the design is to arrange up to 20 independent power supplies with several selectable voltage levels and current limits each and to keep the system generic. The selected approach thus makes extensive use of software defined features of the EPS to achieve versatility and distributes tasks and responsibilities between the main bus and payload handling unit to reduce complexity.

- A software defined EPS core allows to adjust the power interfaces adjustment after MAIT has been finalized. This allows late payload integration and relaxes the timelines.
- Distribution of tasks between EPS and PDH allows to simplify of the EPS core and to adjust the payload distribution unit in accordance with the requirements of individual compartments.

The design of the communication interfaces follows the principles of payloads and buses separation, protection, and isolation. To ensure the maximum freedom in terms of interface selection, the communication network design approach is also based on the separation of main bus network and isolated adjustable interfaces to each payload.

The satellite structure design is based GOS missions. Similar 6U structures have successfully undergone all required qualification tests and handled the launch loads in several missions.

An active AOCS will ensure the required pointing modes for payloads and platform components as well as determine the orbit with required precision. Most of the selected AOCS components are flight proven. Instead of reaction wheels, the system relied on the utilization of innovative Fluid Dynamic Actuators in conjunction with a highly accurate sensors suite.

Different configurations of GOS EPS have proven their reliability and achieved great performance on board of 10 CubeSat missions. The EPS modules for the GENA-SAT mission will be based on this heritage. It will offer:

- 95% converters efficiency
- 142 Wh of power stored in the batteries
- Up to 115W of power supplied from deployable solar panels
- Software defined adaptive power processing and distribution
- Detection and logging of overcurrent events
- Protection from latch ups, fail-safe architecture

The CDH hardware consists of an OBC computer with failure management functionalities and distributed memory unit to store the payloads and house-keeping data before downlinking it, UHF/VHF module for low data-rate communication with ground station. The software includes a sophisticated housekeeper module and a set of protocols. The satellites main network will be implemented using a modified version of the GOS ProtoPlexer protocol. Regardless of the satellites network protocol each payload will be able to use its own protocol to communicate with the Interface Controller. The interface controller will provide access to the satellite network, nevertheless it will not be required for payload developer to implement or use satellite network protocol in any form.

The CubeSat Payload Data Handling system is a modular system distributed between powerful PDHU, several payload compartments with local power management MCUs and individual payload Interface Controllers. This system allows smooth and easy payload control as well as payload and main bus data exchange. Since different payloads require vastly different approaches to data handling, a flexible data handling solution is provided. Each payload could use its personal Interface Controller with broad set of interfaces to access and control the payload over the satellite network. An automatic resource allocation scheduler as a part of PDH manages the switching-on of onboard payloads to ensure that all payloads use the platform as efficiently and evenly as possible. The scheduler guarantees the possibility of conflict-free switching on of the payload for a given duty cycle in required conditions.

The user requirements have indicated that each payload will generate approx. 100 MB of data per duty cycle. They further indicated that customers require access to this data within a week after it has been generated. To comply with these requirements as well as to allow for payload scripts upload an X-band communication channel was baselined in the design.

While the bus concept mainly makes use of standard design patterns, the payload bay concept is truly innovative. The platform provides up to 4U of volume in a 6U CubeSat for various payload experiments. The satellite can be configured with an optimal payloads configuration and split into compartments based on the customers' requirements. Possible combinations include following unit types: Slot payload (a PCB type payload), 0.5U compartment, 1U compartment, 2U compartment, 4U compartment. A Payload Power Controller Unit is integrated in each one of the five different compartment modules to provide flexible power selection for each payload. There are 5 available buses which can be selected based on the payload requirements. Adjustable power lines can vary their voltages on the command from the Payload Power Controller Unit. Each payload will have its own payload interface controller to establish required communication protocols as well as payload specific data handling. Each compartment has access to up to 10 external lines, which are traced outside of the satellite. Each compartment is allocating the thermal management and control unit which consists of temperature sensors, radiators and heaters. Payload developers may use any protocol with payload controller. The payload controller provides access to the chip peripheral interfaces using Lua library. Payload developers may adjust Lua scripts to create complicated individual communication scenarios. The scripts can easily be updated and changed after launch.

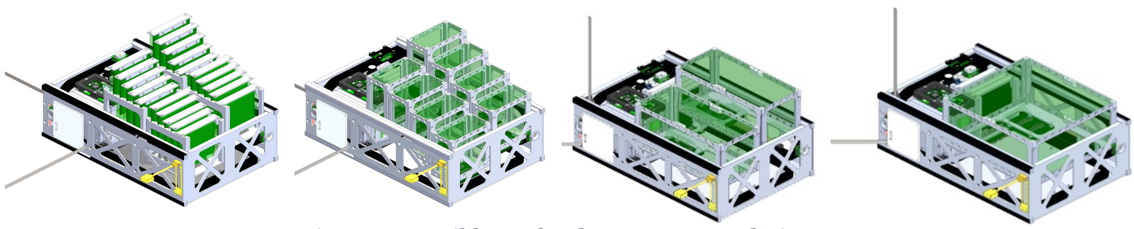

Figure 4. Possible payload compartment designs

Technical budgets have been assessed to verify the satellites capabilities to meet user requirements. Power budget assessment has shown that the the bus is able to provide at least 50W of power to a payload. The deployable short solar panel configuration could achieve this for a limited payload configuration. As compared, the deployable large solar panel configuration has a robust margin and could be used for even more sophisticated use cases. The Link budget assumed the worst-case scenarios for propagation losses and transceiver losses at different elevations showed that even at the low elevations the link margin is still above the threshold for the UHF / VHF channel. The X-Band link budget assuming worst case scenarios for propagation losses and transceiver losses also showed an acceptable link margin at different elevations at a data-rate of 15 Mbps. It was also shown, that depending on the ground station conditions the communication data-rate can be increased. A data budget of the spacecraft assessed to validate how much data can downlinked during a pass has shown that using the KSAT ground station service will allow a large data margin when high amounts of data need to be downlinked throughout the day. The satellites mass budget further showed that a maximum available mass of 5328 g can be distributed between the payload compartments. Several maneuvers times for different satellite configurations were evaluated during the dynamics budget assessment, resulting in an estimated min. duration of 30 seconds per 180° rotation maneuver around X (largest) axis.

The ground segment for the novel IoD/IoV service will consist of two main node types: Berlin-based GOS Ground Station and KSAT LITE Ground Station Station Network. This combination provides solid access to satellite telemetry and telecommand lines as well as flexible access to payloads data. Decentralized mission operation center will include cloud-based control server and will be independent of ground station or operator location. All ground stations will be operated through unique interface software. Interface software will convert unique API for the selected ground station type to unified API used by control server. User interface will be available on the mission portal connected to the control server. User interface will allow logged in users to operate with all the data related to their payload.

The GROOVE web portal will be the main interface for the customer throughout the whole mission lifetime. The web portal will offer access to all necessary functional modules:

- booking of capacity on board of a scheduled mission, inspired by airline booking systems
- online data analysis and visualization tools
- satellite and payload health monitoring platform
- online mission control center (script upload)
- customer support module.

The GENA-SAT de-risk activity has brought the GROOVE service concept a big step forward, allowing for the detailed analysis of existing technological possibilities, adding innovative solutions to existing concept and verifying the initial approach. Throughout the project GOS team has evaluated technical tradeoffs for the satellite design, service concept and business model for IOD/IOV mission. The main outcomes of the study are outlined in the final report. With this results in mind GOS is looking forward to the follow-on activity and to the GENA-SAT mission.