Systems Engineering approach for a next generation modular satellite platform ‘Astrocore’

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***Abstract*—The Astrocore project is a strategic initiative by ISISPACE to develop a next-generation satellite avionics suite. It aims to meet the evolving demands of the small satellite market, with a scalable form factor from 6U up to small satellites under 250kg. The development effort is requirement based: User needs from 4 reference missions were identified which encompass expected business needs, including a high reliability platform for ESA’s Earth Observation program as well as secure satellite platforms for commercial and governmental institutions. A strong focus is set towards streamlining the manufacturing/production efficiency through Design for Manufacturing – DFM and AIT efforts on platform and system level.**

I. INTRODUCTION

The project’s technical approach emphasizes scalable and modular design, redundancy, and technology readiness level (TRL) advancement, targeting TRL 7 for all equipment. Key subsystems include Payload Data Handling System (PDHS), Electrical Power System (EPS), Attitude and Orbit Control System (AOCS), Command and Data Handling (CDHS), Telecommand, Telemetry & Control (TTC), and Thermal Control System (TCS).

The resulting avionics leverage the advantages of the NewSpace environment through a cost effective, modular, flexible architecture, enabling reduced development cycles while supporting standardization, scalability, performance and reliability demands in an evolving market.

II. ENGINEERING CHALLENGE

A. Current Status

ISISPACE is a well established satellite integrator in the CubeSat industry, with focus on custom solutions and quick turnaround. A significant strength of the company is that most subsystem equipment have been designed and are produced and tested in-house at the company office in Delft, NL.

ISISPACE typically integrates 10 to 20 satellites per year based on the legacy and flight proven single string avionics.

B. Challenge

Recent developments in the small satellite market, as well as the geopolitical and legislative environment, highlighted the need for an improved satellite platform, focusing on the following aspects:

- Reliable and available – to provide quantified confidence that the end customer can achieve their mission at full performance
- Secure – to provide secure satellite operations to customers in any geopolitical climate
- Support of 6 to 16U CubeSats as well as microsatellites up to 250kg – to enable operations of volume or power demanding payload
- Compliance with Space Debris Mitigation Regulations – to enable launch and operations both under the EU Space Act as well as the US Federal Communications Commission (FCC) guidelines.

To tackle these challenges, ISISPACE launched an R&D project to develop, design and qualify a new set of platform avionics that is able to address all of these requirements.

III. ENGINEERING APPROACH

The Astrocore engineering approach is based on the use of four predefined reference missions. These reference missions aim to represent the foreseen use cases of the platform equipment and are as follows:

- Emission Monitoring: this mission requires a highly reliable 16U platform, capable of Earth Observation. Reliability is expressed by the need for fault tolerant avionics.
- Signal Intelligence: this mission is executed by a single string, 8U platform, carrying a Signal Defined Radio (SDR) to conduct RF signal geolocation. The need for additional security as well as propulsion capabilities is foreseen.
- Synthetic Aperture Radar: this mission foresees high power consumption and redundant implementation. It is executed by a formation of microsatellites, which also defines the need for propulsion accommodation.
- Hyperspectral Earth Observation: the fourth reference mission concerns a single string 12U satellite with partial redundancy.

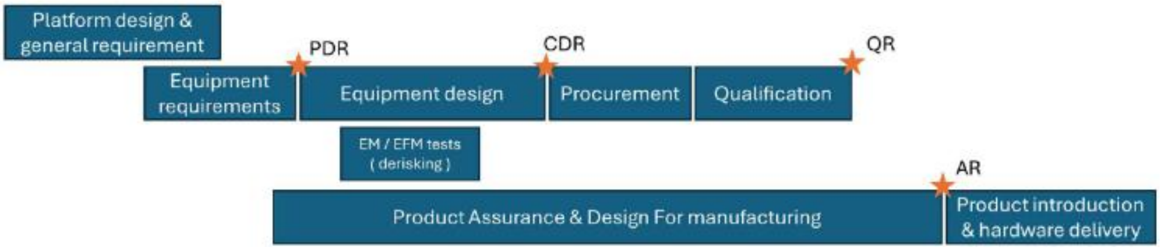

Figure 1 - Astrocore development process

Relevant requirements from these reference missions are imported in the Astrocore project as User Needs, which in turn are flown down within the project to form equipment requirements. Not only do the reference missions have top-down involvement in requirements, but they are also represented at every milestone to provide direct feedback on the equipment design. This way, equipment is derisked throughout the project.

Next to compliance with the four reference missions, Astrocore also aims for scalability on platform level. This is fulfilled by a modular design philosophy that allows individual equipment to serve as building blocks in the platform. High level design goals and guidelines were established as part of an one-year reliability study (SBIR-FACTS), founded by the Dutch Space Office (NSO):

- Equipment uses redundant CAN data bus for interfacing with other Astrocore equipment. This data bus enhances reliability by its automatic error detection and handling capabilities on top of its differential signal nature.
- Equipment is powered by redundant power rails at battery voltage and performs internal power switching to form a distributed power switch architecture.
- Each equipment contains two common connectors, which can establish inter-equipment interfacing via a flexible backplane connector.
- All electrically active equipment is enclosed by aluminum housing to reduce Electromagnetic Interference (EMI) and protect the equipment for Electrostatic Discharge (ESD). Moreover, the enclosure reduces the exposure of the equipment to radiation in-orbit.
- Central points for non-Astrocore equipment interfaces are defined: the EPS Distribution Unit (DU) for power and CAN/I2C system buses, whereas the PDHU handles any other data interface.

Management of the established requirements is done through the use of a requirements management tool. This tool improves visibility of requirement flow down, version control and verification. During the requirements generation process, a distinction is made between generic requirements that are applicable to all Astrocore equipment and equipment specific requirements. This methodology supports efficient and pragmatic requirement generation while maintaining the flow down structure for both generic aspects such as PA/QA, EMC (Electromagnetic Compatibility)/Grounding and environment, and the specific ones flowing down from Astrocore's high-level design goals and reference missions.

For all Astrocore equipment, the process outlined in Figure 1**Error! Reference source not found.** is followed. Each equipment reaches the Preliminary Design Review (PDR) with a set of requirements derived from the User Needs and scalability objective, as well as a preliminary design. Feedback on the design is being collected from all stakeholders to iterate on the preliminary design and reach the Critical Design Review (CDR), where the final equipment design is presented. Qualification testing is executed to qualify the equipment and pass the Qualification Review (QR). To enhance efficiency in the production and Assembly, Integration and Testing (AIT) phase, Design for Manufacturing (DMF) efforts run in parallel.

Astrocore's verification approach is initiated at the start of the project and runs parallel to all development activities. In preparation of PDR, requirements are assigned either or multiple of four high-level verification methods: Test, Analysis, Inspection, Review of Design. In parallel with equipment design, Review of Design and preliminary Analysis are run for the applicable requirements and completed for CDR. Requirement compliancy is checked at every milestone and the verification efforts are finalized at QR.

The model philosophy applied by Astrocore supports the verification strategy and aims at derisking design at early stages. Risks are being identified and Breadboard (BB) models which are procured to address these where possible before PDR. For equipment with a Technical Readiness Level (TRL) below 6, an Electrical Functional Model (EFM) is procured after passing the PDR milestone. An EFM aims to represent the functionalities that are subject to functional Testing, as defined in the verification approach of the applicable requirements. The model, however, does not necessarily comply with all requirements yet. For qualification, an Electrical Qualification Model (EQM) is produced. This model undergoes qualification testing and represents the final hardware configuration.

IV. ASTROCORE PLATFORM IMPLEMENTATION

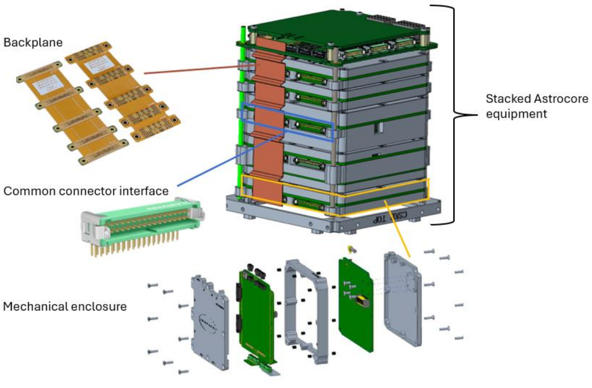

Figure 2. Astrocore equipment stack representation

The Astrocore platform consists of multiple integrated subsystems, each comprising of various equipment elements arranged in a stacked architecture as shown in figure 1. Figure 2 represents the hierarchical flow down from system level to platform, further into subsystems and finally down to Astrocore equipment. This section presents the key design, implementation choices, integration and verification methods that are adopted for the equipment. It also highlights how system-level considerations contribute to reducing integration complexity and support efficient assembly, integration and testing activities.

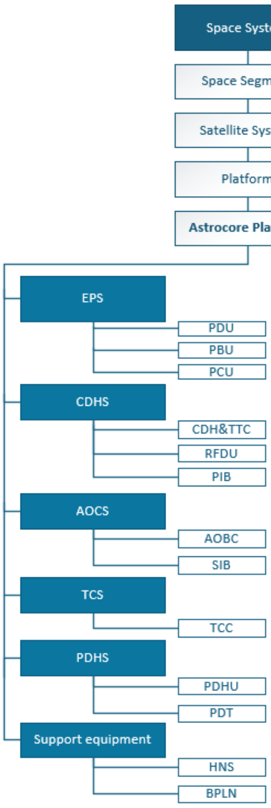

Figure 3. Astrocore platform overview

A. *Platform Design and Implementation Considerations*

All Astrocore equipment is enclosed in a mechanical housing that provides EMC protection as well as mechanical robustness. Each equipment is designed around the standard PC104-based mounting interface and has exposed common connectors to interface directly with the rest of the equipment via the backplane. The standardized mechanical layout and reduction in connector interfaces minimize complex harnessing and support faster integration and repeatability using common procedures.

The Astrocore platform supports both single string and redundant (fault-tolerant) configurations based on the mission requirements. In the single-string implementation, one of each equipment performs all nominal functions and in a redundant configuration, critical equipment is duplicated using either cold or hot redundancy schemes with fault isolation and recovery mechanisms, ensuring continued mission operation in the event of unit failure.

The stackable Astrocore platform built around the common connector interface eases production by supporting efficient assembly, integration and testing activities. Each equipment can be tested as a part of the fully integrated platform using the common connector Electrical Ground Support Equipment (EGSE) or unplugged from the stack and tested independently. This provides a low-risk path from unit-level testing to complete system validation, supporting a step-by-step integration and testing approach. This helps in improving fault isolation and verification at every stage.

B. *Verification and Qualification Activities*

Each of the Astrocore equipment is subjected to an end-to-end test campaign spanning from BB through EFM to FM, ensuring verification against functional, interface and environmental requirements at the relevant design maturity level. Early concept validation and derisking are achieved on BB level through functional and interface demonstration, followed by additional derisking activities like thermal testing on the EFM, environmental qualification on the QM and finally acceptance level testing on the FM. No equipment will proceed to the next program milestone without closure of all mandatory test activities at the preceding model level, hence building confidence in hardware maturity.

Environmental testing covers the represented mission conditions including vibration and shock, thermal vacuum, electromagnetic compatibility and radiation. Failure Modes, Effects and Criticality Analyses (FMECA) are performed both on equipment and platform level, informing the hardware and software design, with the distinct goal to eliminate any credible single point failures for platforms with redundant Astrocore avionics.

Furthermore, driven by an established *Radiation Hardness Assurance* (RHA) plan, critical components and equipment are identified for further verification. The radiation verification includes proton testing at EFM level and heavy ion testing at component level on BB hardware. Functional test sequences are performed between major test phases to continuously monitor the health of the equipment, enabling early detection of anomalies. All verification tests are executed as per the approved procedures.

C. *Astrocore Equipment Defination*

This section defines and elaborates on the different equipment per subsystem in the Astrocore platform –

1) Electrical Power Subsystem (EPS)- The Astrocore EPS is an improvement of the legacy ISISPACE's second-generation Modular Electrical Power System (iMEPS2). The different equipment making up the EPS are interconnected primarily using harnesses. Depending on mission requiremnets, it is posible to include multiple units of each EPS equipment in the platform. Each equipment provides a daisy chain connector that conveniently allows the creation of the EPS power rail backplane. This provides the flexibility to distribute the EPS equipment across the spacecraft in an organisation deemed optimal for the mission and platform. The Astrocore EPS consists of one or several of the following equipment:

- Power Conditioning Unit (PCU)
- Power Battery Unit (PBU)
- Power Distribution Unit (PDU)

2) Command and Data Handling Subsystem (CDHS) - The CDHS is responsible for controlling and monitoring spacecraft operations

The Command and Data Handling and Telemetry and Telecommand (CDH&TTC) - as represented in Figure 3, consists of a platform on-board computer and S-band RF daughter board. The TTC subsystem is based on the legacy ISISPACE radio implementation, while increasing the uplink performance and implementing CCSDS framing on both up- and downlink to increase compatibility with commercial ground stations.

Figure 4. CDH&TTC equipment

RF Distribution Unit (RFDU)- The RF distribution unit is a passive RF switching and routing network and connects the CDH&TTC core avionics equipment to Tx/Rx S-band patch antennas.

Platform Interface Board (PIB) – The platform interface board provides power, data and time interfaces with temperature sensors and Hold Down and Release Mechanism (HDRM) channels on the solar panels.

3) Attitude and Orbit Control Subsystem (AOCS) – The AOCS interfaces with the sensors and actuators to provide attitude knowledge, 3-axis control and orbit determination and control.

AOBC On-Board Computer (AOBC) – The AOBC is a successor to the high TRL legacy ISISPACE AOBC. The new design offers full redundancy support for the connected AOCS components. The AOBC also provides an interface to the internal GNSS receiver which is physically mounted on the RFDU.

Sensor Interface Board (SIB) – The SIB interfaces with attitude determination sensors such as the gyroscope and the Sun sensors. It implements configuration, power control and data collection functions.

4) Thermal Control Subsystem (TCS) – The TCS monitors and maintains the temeperature of the various components throughout all mission phases.

Thermal Control Computer (TCC) – The TCC represented in figure 4 provides thermal monitoring and control capability. It has 16 channels for thermal monitoring and 5 controlled heater strings. The TCC heater controller can be programmed to provide several different control modes encompassing thermostat, PID, safety shutoffs and guard heater functionalities. Depending on the sensor and heater selection as well as the TCS layout, the TCC can achieve a thermal control accuracy better than ±0.5°C at a given payload interface.

Figure 5. TCC equipment

5) Payload and Data Handeling Subsystem (PDHS) – The PDHS manages and processes data from the onboard payload.

Payload and Data Handeling Unit (PDHU) – The PDHU uses the Xiphos Q8 as the on-board computer and its primary functions include collecting, processing and formatting data from the payload, temporary storage of the data before transmission and finally, transmitting data to the onboard Payload Data Transmitter for downlink. The PDHU also provides interface to a commercially available X-band transmitter such as CubeCom XTX-2 and antenna. It executes the payload operation commands from the ground station via the CDHS.

6) Support Equipment

Backplane (BPLN)- As mentioned in the previous sections, the flexible backplane provides a robust and volume-efficient interconnection between equipment through the common connectors.

V. CONCLUSION

As part of a significant R&D effort, ISISPACE is developing a new avionics suite based on a product management oriented development approach. Equipment PDRs were being held in Q1/2 2026, followed by CDRs in Q2/3. Equipment qualification is expected by end 2026 and TRL9 by Q3 2027.