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STANDARDIZATION AND MODULARITY IN SATELLITE DESIGN: THE ARGOTEC HAWK PLUS SPACECRAFT

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Abstract

The design of small satellites has traditionally relied on a one-off, mission-specific approach, leading to highly customized designs with limited adaptability. This methodology optimized individual missions but showed challenges in terms of rapid deployment, production efficiency, scalability and adaptability to multiple mission scenarios. Argotec's HAWK PLUS spacecraft represents a paradigm shift by transitioning to an incremental development model, enabled by a standardized and modular platform. This approach enhances industrialization, accelerates time-to-flight, and increases flexibility in addressing evolving mission needs.

Rather than designing the platform around the payload by tailoring the avionic bus accordingly, the development process is now centred on the avionic bus itself. This results in a fully standardized and payload-agnostic bus module, allowing for the integration of a wide range of payloads at the final stage of the assembly process. A clear separation between mission specific payload deck, the bus avionics, and spacecraft actuator (propulsion and attitude devices) is introduced, in terms of how the volume is allocated and how the related connections are designed. This establishes a unified standard and prevents the need for design adaptations in platform harnessing, reducing the non-recurrent engineering effort and ensuring repeatability when transitioning between different satellites of the same family.

The avionics module is internally partitioned into function-specific sub-modules, each constituting a self-contained assembly dedicated to a high-level function within the satellite bus. This structured modularity enhances system and performance scalability, simplifies qualification, test and integration processes, and ensures adaptability across different mission profiles. As each sub-module is assigned a specific high-level function, it houses a segment of the onboard avionics. In addition, it accommodates the harnessing to link its avionics portion to standardized perimeter connectors for electrical and data interfaces. The structural component is also standardized and designed to optimize space utilization while increasing the available volume for housing the internal components. The specific form factor also facilitates accessibility to the modules, both during integration and in the perspective of a future transition to in-orbit servicing operations. The modularity is reinforced by a specific layout, allowing independent access to each sub-module without impacting the integrity of the overall assembly. All these features are meant to streamline the integration phases of each sub-module and the entire satellite. Each sub-module can be designed separately as a plug-and-play unit, which can be tested and qualified independently, and then integrated at a later stage.

In this platform, standardization reaches a significant level, spanning multiple domains. On the structural side, it enforces an identical component for each sub-module, bringing advantages in design, industrialization, and production. On the harnessing side, it reduces complexity and potential points of failure. On the architectural side, it offers the possibility to scale down or up the performances of the entire platform without impacting the entire system design. Coupled with functional segmentation, this approach also enables incremental upgrades to the platform between generations, allowing modifications or enhancements to be applied only to the affected subsystem without disrupting the overall avionic design architecture.

This paper will provide a general overview of the approach followed during the design phase, including a detailed analysis of the platform architecture and the key concept of modularity. Concluding, the major advantages in terms of satellite development, integration and flexibility with respect to typical user cases will be presented.

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1 Program Overview

HAWK PLUS is the Argotec standardized and industrialized microsatellite platform with a wet mass of up to 170 kg (including payload). It combines key attributes such as high performance and flexibility to support a wide range of mission scenarios. Indeed, it can be equipped with different payloads to suit various mission types without requiring delta modifications to the core platform. The set of target applications upon which the platform is designed is optical and Synthetic Aperture Radar (SAR) Earth Observation, 5G satcom, space-based ISR, distributed edge computing, and CubeSat dispenser missions. Furthermore, it is designed for series production in the new Argotec SpacePark facility, through a streamlined industrial process.

1.1 Standard lifecycle approach vs the new paradigm

The standard lifecycle approach for space missions, as defined in [1][2], has been successfully applied to hundreds of space missions over the past 30 years. This approach follows a linear path to achieve complex space missions with a single spacecraft, typically developed over the course of several years, or even decades. These missions are usually characterized by medium to high budgets (> $50M) with low-risk profiles.

The process begins with the mission formulation, where stakeholders' needs are gathered and translated into a formal set of requirements. The spacecraft is then designed to satisfy these requirements, often incorporating custom technological innovations. Following the design phase, the spacecraft is manufactured, integrated, and subjected to an extensive testing campaign before launch.

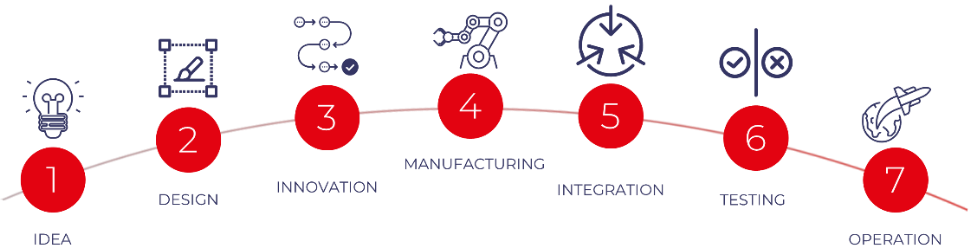

Figure 1: Standard lifecycle approach for space missions

The classical product lifecycle approach is highly effective for flagship missions with consolidated budgets and multi-year schedules, as it enables a high level of design detail and mission assurance.

However, over the past decade, there has been a trend in the space sector to contain both budget and lead time by focusing on mission lifetime and scope. This concept, often referred to as quick response or responsive space, is fundamentally at odds with the traditional approach, where each new mission requires a completely new design process, resulting in significant engineering effort and high non-recurring expenses (NREs), leading to an increase in costs and lead time. The growing demand for cost-contained missions (in the range of a few million dollars) with drastically reduced timelines (from years to months) calls for a different development model.

The key differenciator in Argotec's HAWK PLUS vision, compared to the classical approach, lies in the way stakeholder requirements are addressed. This paradigm shift focuses on the concept of adaptability of the platform rather than tailoring the design to a single, specific mission. The goal is to eliminate the need of redesigning the spacecraft from scratch for each mission. The platform is designed to accommodate a broad spectrum of payload types and sizes, ensuring compatibility within a defined design envelope without requiring structural or architectural changes. This concept does not imply that the platform will remain static throughout its product lifetime; rather, it will **evolve instead of restarting**. The core of the platform is designed to be easily upgradable, with placeholders for future developments already considered in the current configuration. Furthermore, **functional segregation** enables flexible configurations and targeted upgrades without impacting the rest of the platform and requiring additional design. This functional segregation concept enables a "plug and play" philosophy, allowing modules to be pre-integrated, validated and stocked for rapid assembly when needed.

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1.2 The HAWK PLUS concept

The HAWK PLUS platform represents Argotec's response to the growing demand for scalable and rapidly deployable microsatellite solutions. Moving away from traditional one-off mission architectures, the program embraces a product-based model grounded in standardization, modularity, and industrialization. At its core is a newly developed (patent pending) configuration that decouples the payload definition from the satellite bus development, enabling streamlined assembly, integration, and testing processes alongside optimized supply chain activities.

Unlike conventional spacecraft platforms designed around single-mission payloads, HAWK PLUS supports serial production with high annual throughput. The platform is optimized for stock-based manufacturing, allowing multiple units to be produced in parallel and stored in standard configurations. Once the payload is defined, these pre-integrated cores can be rapidly finalized, reducing mission lead time and enabling just-in-time customization. Argotec targets an industrial production rate exceeding 50 platforms per year, marking a strategic shift from bespoke mission engineering to scalable spacecraft manufacturing.

To realize this vision, the platform architecture incorporates standardized mechanical, electrical, and data interfaces. A key feature is the bay-based avionics deck design, where avionics and subsystem modules reside in functionally independent bays with uniform power and data interfaces. This enables true plug-and-play interchangeability across suppliers and hardware generations. Although the initial tranche of development (tranche-I) does not yet implement all these capabilities, the platform roadmap envisages evolving toward self-configuring “smart bays” that can identify connected subsystems, manage power and data negotiation, and support autonomous diagnostics and reconfiguration.

This approach requires a fundamental rethinking of the supply chain. Moving beyond per-mission sourcing, HAWK PLUS fosters strategic long-term partnerships with suppliers capable of delivering components and subsystems according to batch production logics, repeatable performance, and predictable lead times. The modular avionics deck and payload interfaces support a configurable supply chain, accommodating multiple vendor solutions within a common mechanical and electrical framework. To facilitate this, Argotec is developing a supplier ecosystem centered on a compatibility matrix that qualifies avionics and payload modules from various vendors.

Currently, development efforts focus on the platform definition, with tranche-I preparation underway. The roadmap follows a conventional engineering flow, progressing through SRR, PDR, and CDR, while advancing manufacturing readiness via dedicated industrialization activities (e.g., MRR) focused on the platform. When mission requirements are established, delta design activities tailor interfaces, perform mission-specific verification, and complete system integration. This dual-track approach enables early qualification of the standard platform architecture independently from specific missions. The first missions leveraging HAWK PLUS are anticipated to launch starting next year, validating both the modular architecture and scalable production framework.

While this section presents the strategic and architectural vision of HAWK PLUS, subsequent sections will provide a detailed technical breakdown of the platform's internal configuration, focusing on modular architecture and subsystem-level implementation.

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1.3 Heritage

The HAWK Plus platform is designed to retain the company heritage that has been achieved by Argotec over the years, both in challenging deep space missions such as LICIACube and ArgoMoon, and in Low Earth Orbit (LEO) constellations such as the IRIDE constellation with the HAWK for Earth Observation - HEO spacecraft class.

Deep Space CubeSats: LICIACube and ArgoMoon

In 2022, Argotec successfully operated two spacecraft in deep space, both based on the HAWK Lite class platform: the LICIACube and ArgoMoon.

ArgoMoon [3] is a 6U spacecraft that has been embarked on the first Space Launch System (SLS) rocket, as part of NASA's Artemis I mission, while LICIACube [4] took part in the first planetary defence mission in history: NASA's DART.

Both missions provided an extensive experience on the design of miniaturized spacecraft with constrains on volume, mass and power. Furthermore, due to the harsh environment of deep space, they also paved the way for high-reliability design within Argotec.

The platform is also equipped with complex attitude algorithms for autonomous pointing operations and with chemical propulsion solutions capable of performing maneuvers as well as Reaction Control System functionalities.

The core of the platform consists of a deep-space On-Board Computer (OBC) with an extreme level of radiation tolerance, developed by Argotec. This OBC is employed in the HAWK Plus platform whenever radiation tolerance or reliability plays an important role in the mission.

HAWK for Earth Observation: the IRIDE constellation

Argotec has designed and developed the Hawk for Earth Observation (HEO) constellation [5], under the IRIDE Program, from the EU-funded Recovery and Resilience Plan for Italy (PNRR) and managed by the European Space Agency (ESA).

This constellation, designed for multispectral Earth Observation (EO) from an altitude of 590 km LEO, is currently undergoing deployment. The first satellite of the IRIDE constellation, HEO Pathfinder (IRIDE-MS2-HEO-1, NORAD ID: 62697), has been successfully placed into a Sun-Synchronous Orbit (SSO) on January 16th, 2025 [6] by a Falcon9 rocket by SpaceX.

The HEO satellites rely on a complex architecture achieving high performances, especially in terms of processing power and pointing accuracy. Indeed, the hyperspectral payload produces a high volume of raw data that is pre-processed on-board and then transmitted to ground through a dedicated high speed X-band radio.

The majority of HEO constellation features and key subsystems are included in the first tranche of the HAWK Plus platform.

Figure 2: HAWK Lite and HAWK for Earth Observation comparison

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2 Platform description

The present section provides the reader with an overview of the platform in terms of its main concepts that results in the modularity and adaptability of the platform, namely:

- The **deck** concept
- The **bays** concept
- The **modular on-board software**

2.1 The system level deck concept

The concept defined at product level has been used as design driver for HAWK Plus platform definition. Indeed, an innovative deck and bay approach is used. This allows for easier integration and testing activities but also to upgrade single sections of the spacecraft without affecting the rest of the spacecraft.

The first system-level partitioning is obtained through the definition of three decks. Each deck is dedicated to a different functional aspect of the spacecraft:

- **Payload Deck**, designed to provide the mounting interface for the payloads and additional equipment requested for mission specific activities like a dedicated payload computer.
- **Avionic Deck**, composed of bays, dedicated to the core avionics of the satellite, responsible for platform management, downlink of platform and payload data, attitude determination, power generation and distribution.
- **Propulsion Deck**, containing to the propulsion capabilities as well as attitude actuators.

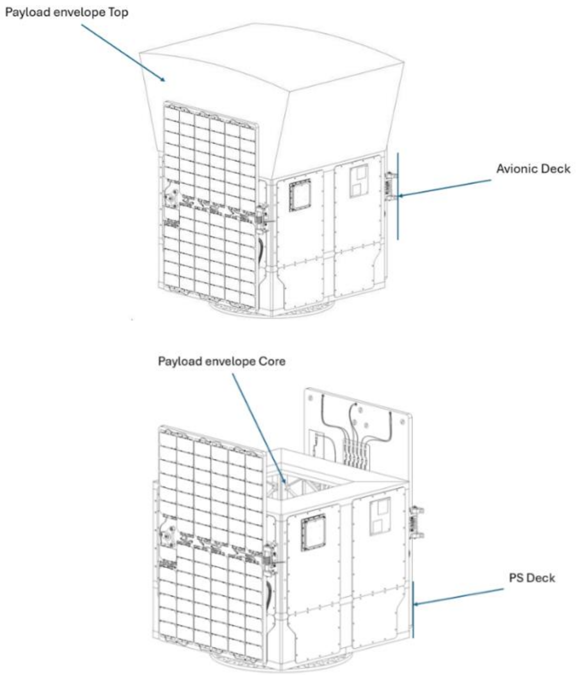

Figure 3: HAWK PLUS decks configuration

The **Payload deck** comprises two main volumes, the first one located on top of the platform and the second composed of a central (multi-purpose) core in the middle of the avionic deck. All the mechanical interfaces present a fixed hole pattern to mount payloads and secondary structures. The defined envelope can host different typologies of payload from SAR to optical payloads as well as enabler equipment like dedicated payload computers.

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The **Avionic Deck** contains all the Bus avionics, including the EPS suite, the ADCS electronics, the OBC, and the telecom suite. The avionic deck is based on the "bays" concept guaranteeing modularity and adaptability to different mission scenarios. The avionic deck can be configured with different architectures, for example scaling the number of the batteries or number and type of radios. In the middle of the central avionic deck there is a multi-purpose space (named central core) where it is possible to host additional part of the payload or other avionic components of the platform.

The **PS Deck** houses the propulsion system, RWs, and all GSE connectors. It also interfaces with the launcher via a standard 15" ring adapter. The propulsion system allows customization with three PS tank versions to meet various delta-V needs. Additionally, the thruster configuration can be adjusted for mission-specific requirements, such as tilting the thruster for RCS functionality. Both electrical (ion or hall-effect thrusters) and chemical (monopropellant) options are possible to be installed in the propulsion deck.

2.2 The Avionic Deck - the bays concept

Each mission has its own characteristic, payload and mission profile, this often implies challenging and different requirements in terms of power, pointing capabilities and downlink rate for the space platforms.

Table 1: Use cases

	Optical EO Payload	**SAR EO Payload**	**RF Payload**
Power Required	low	high	high
Service duration	med	low	high
Pointing accuracy	high	high	med
Data volume storage	high	high	low

To satisfy a broad range of requirements, the avionic core is designed based on a modular bay approach, as shown in Figure 4. This bay configuration has several purposes, to ensure upgradability based on mission needs by selecting the appropriate configuration, to simplify the assembly procedure and to ensure the presence of a central core to guarantee structural integrity and load transfer. Multiple types of bays are used to provide all the platform functionalities.

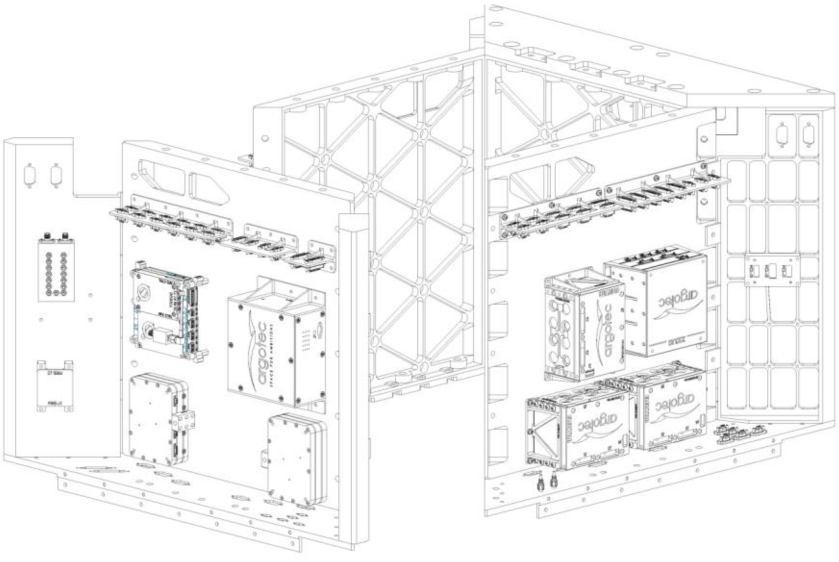

Figure 4: Bays concept

The **Avionic bay** is designed to host the main OBC as well as the telecom suite. These subsystems are enclosed in a dedicated bay mainly for testability purposes and to simplify intra-bay harnesses. Furthermore, to ease the integration

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process, all the data interfaces directed to the payload deck are located on a dedicated connector bracket while another bracket is dedicated to inter-platform data exchange.
Indeed, after the bay assembly, it is possible to completely and independently test the RF suite with dedicated antenna hats. At this stage, also a generic OSW for the configured bus is uploaded to the OBC while the final release is deployed once the bay is allocated to a specific mission.
Different configurations of avionic bay are present; all plug and play in the platform without any modifications.

Table 2: Avionic Bay possible configurations

	OBC	**TMTC Radio S-Band**	**Redundant Radio S-Band**	**Payload Radio X-Band**	**L-Band radio for GEO relay**
Minimal	X	X			
Baseline	X	X		X	
Increased reliability	X	X	X		
Extended	X	X	X	X	
Extended with GEO relay	X	X		X	X

The **ADCS bay** hosts the ADCS core electronics as well as the GNSS suite and the star trackers. Concerning this bay, the modularity is focused on the star tracker performances with different mounting options. This functional segregation of the ADCS core components, allows for easy integration but also for streamlined testing procedures.

The tranche-I **EPS bay** is available in 3 possible configurations based on payload power needs, solar power generation and energy storage capabilities. The modularity of such bay is obtained with two Argotec's products: the ZEUS PCDU and the ELEKTRA battery system.
The ZEUS PCDU is designed to work in with multiple units in parallel thus increasing the power handling capabilities and robustness of the suite. The ELEKTRA battery system is capable of being daisy chained to enhance the energy storage capacity of the whole system. This is especially useful to handle peak loads as well as demanding conditions like performing service during the eclipses.

To keep the other bays unaffected by the EPS bay configuration selected, an innovative bracket approach is used. The upper portion of the bay is dedicated to intra-bay harness. In this section three discrete connectors are present. One is entirely dedicated to the power input from the Solar Panel Arrays (SPA), one is allocated to the power supply of the platform while the last one is allocated to the mission specific payloads.
For each bay, the number and location of the connectors is sized upon the worst case in terms of configuration so that changing the configuration of the bays does not imply delta designs.

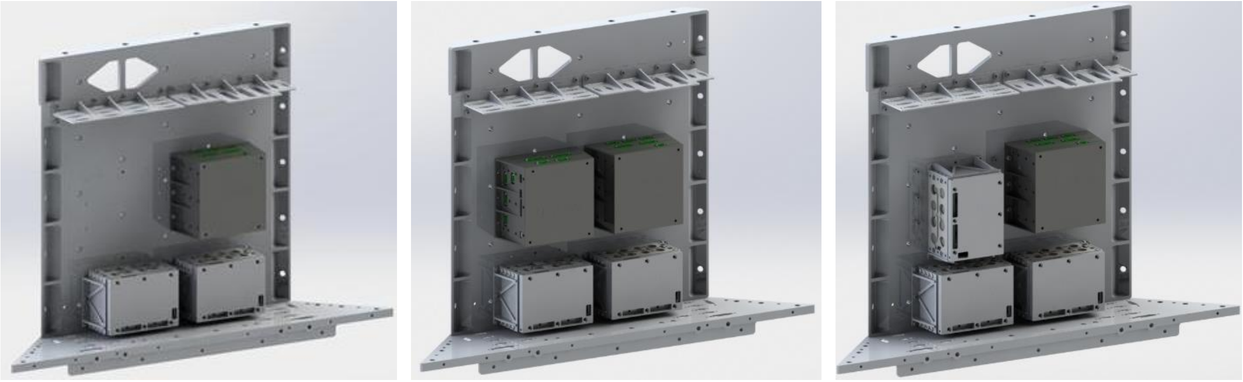

Figure 5: Different EPS bay configurations

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The deck and bays approach allows for a streamlined integration of the platform. As shown in Figure 6, the integration flow starts from the avionic deck, assembled through the integration of the bays. Each bay undergoes acceptance tests at bay level before integration to detect eventual issues early in the procedure. Then, the propulsion deck is assembled in the bottom section of the spacecraft. Finally, the payload is integrated in the dedicated sections at the latest possible step of integration. Therefore, the production line is optimized for the integration of the platform and only in the last step the customization of the process takes place.

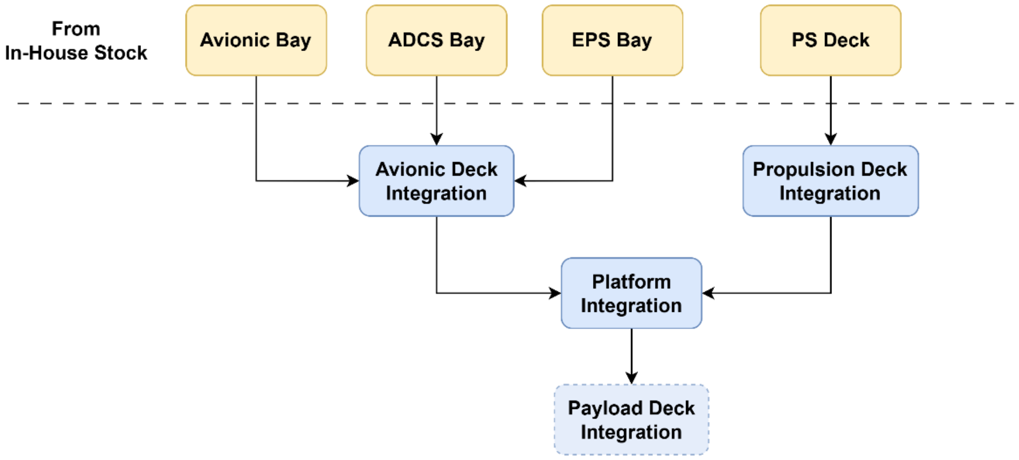

Figure 6: HAWK PLUS Integration Flow

2.3 The platform On-board Software: NEOS

The modularity and the standardization of the HAWK PLUS platform is complemented by the NEOS On-board Software. This software framework is designed to be reused across different missions and different satellite buses, reworking and extending what was developed for the HEO spacecraft and use it as a base to build new missions, reaching a high level of configurability, in order to accommodate different missions.

Software Architecture

The main architecture design driver is the idea of having a modular structure, in which applications are not coupled. This requirement is fulfilled by thinking about applications as isolated tasks that expose services through a communication middleware (i.e. messaging system). Intrinsically, it leads to an asynchronous and event-driven architecture. The NEOS software architecture is organized into layers, to which different functionalities are allocated. The architecture is depicted in the following figure:

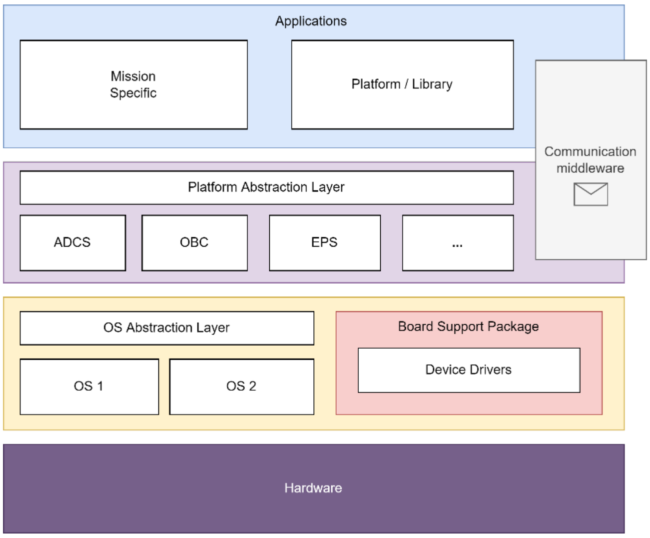

Figure 7: NEOS high-level architecture

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- **Application Layer:** the highest layer includes all those tasks that embed the software logic. This layer implements both mission specific applications and platform applications or libraries, i.e. those applications that are needed for all missions, such as the housekeeping management, FDIR mechanisms, software update, etc. Applications shall expose services that can be accessed through inter-task messages, leading to high decoupling between them.
- **Platform Abstraction Layer:** it contains the components, that may be tasks themselves, which can access the resources belonging to the subsystem they manage. They implement the specific logics of their related subsystem providing its services to the Application Layer through the Platform Abstraction Layer (PAL). It provides an abstraction for the entire platform, allowing applications to access the existing subsystems through generic interfaces.
- **OS Abstraction & BSP:** it abstracts the access to multiple operating systems (e.g. RTEMS and Linux) making it transparent to the upper layers. This layer also provides an abstraction of the underlying hardware, including the necessary drivers, enabling execution in a simulation environment too.
- **Communication Middleware:** this is a transverse layer which provides an inter-task communication service, based on a publish/subscribe paradigm.

Framework Goals

NEOS minimizes the platform adaptation effort, lowering new missions' development time, with lower overall cost and engineering hours requested, but also lowering the effort required to develop ground tools (e.g., GSEs, test suites or FOS software). Indeed, NEOS aims at standardizing both the space to ground interface and the OBC interface with the other subsystems: it limits the overhead for spacecraft users to learn how a new spacecraft works, through standardized behaviours and interfaces across different Argotec missions, which are deeply heterogeneous, ranging from LEO to deep space scenarios.

2.4 Platform Architecture and performances

The HAWK PLUS platform is designed to provide a solution to different mission needs and payload requirements. As such, it has an extended range of performances based on its configuration, while maintaining the same platform architecture and structural design. The platform modular design allows each bay to be tailored to a specific mission scenario, choosing among the possible configurations of each bay, characterised by scalable components within the avionic and propulsion decks.

In particular, the two extreme configurations in terms of platform performances are the following:

- The Baseline configuration envisages the same avionic bus as the HEO IRIDE constellation with the possibility of having a scalable propulsion system.
- The Extended configuration foresees a scaled configuration with respect to HEO, indeed in the avionic deck are included up to 3 PCDU and 5 batteries. The PS deck is also enhanced to accommodate larger tanks compared to the baseline configuration.

Transitioning between these configurations has minimal impact (and limited NRE effort) on the overall system architecture and design. Indeed, only minor modifications on the architecture are required while no impact is foreseen on the mechanical, power, and data interfaces within the platform due to its standardization.

The key expected platform performances for both configurations – Baseline and Extended – are summarized in Table 3.

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Table 3: Performance spectrum of the HAWK PLUS platform

	Baseline	**Extended**
Payload mass	Nominal 30 kg, higher mass can be assessed	
Payload allocated volume*	L 540 x W 540 x H 300 L 302 x W 302 x H 340 mm	
Payload electrical interfaces	5V @ 20W 12V @ 48W Vbat @ 240W	5V @ 40W 12V @ 144W Vbat @ 400W
Payload OAP**	Up to 35 W	Up to 120 W
Total S/C wet mass	128 kg	155 kg
Bus Dry Mass	74 kg	86 kg
Solar Power generation BOL-AM0	240 W	440 W
Operative Battery Capacity	270 Wh	340 Wh
Comms data band	S-Band, X-Band	S-Band, X-Band, L-Band
Pointing Knowledge	Up to 6 arcsec (1-sigma)	
Pointing Accuracy	Up to 54 arcsec (3-sigma)	
Pointing Stability	Up to 30 arcsec/s (3-sigma)	
DV capabilities	Chemical 1 - 60 m/s Chemical 2 - 110 m/s	Chemical 3 - 170 m/s Electrical - 1.05 km/s
Design Lifetime	Baseline 5 years LEO, adaptation for deep space available	

* additional payload volume dependent from PS configuration
** CONOPS and orbit dependent

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3 Conclusions

The transition from customised, mission-specific satellite designs to an industrialized, modular architecture marks a significant evolution in small satellite development. The HAWK PLUS platform exemplifies this change by embracing a payload-agnostic design philosophy that emphasises repeatability, scalability, and adaptability. By clearly separating the payload, avionic, and propulsion decks, and adopting a modular plug-and-play architecture segmented by function, the platform achieves a high degree of standardization across structural, cabling, and architectural domains.

This approach not only streamlines the design and integration processes but also reduces non-recurring engineering efforts and increases production efficiency by prioritizing the industrialization process. The ability to independently develop, test, and qualify each bay and decks accelerates time-to-flight and facilitates incremental upgrades without disrupting the entire system. In addition, the standardized interfaces and optimized form factor support future advances in the availability of configurations for the next tranches of the platform.

In conclusion, the HAWK PLUS platform demonstrates how modularity and standardization can drive industrialization in the small satellite sector, enabling rapid deployment and flexible adaptation to diverse mission requirements. This paradigm shift lays the foundation for a new generation of small satellite that are not only more efficient to produce, but also more versatile and resilient in an increasingly dynamic space environment.

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