18th International Conference on Space Operations, Montreal, Canada, 26 - 30 May 2025.

Amazonas Nexus leading-edge flight dynamics operations

David Mostaza (1), Manuel J. Sansegundo (1), Antonio Abad (1)
Felipe Jiménez (2), Javier Cuesta (2), Alberto Herrero (2)

(1) Hispasat, Arganda del Rey, Madrid, 28500, Spain
(2)GMV, Calle Isaac Newton 11, 28760 Tres Cantos, Spain

e-mail: dmostaza@hispasat.com, mjsansegundo@hispasat.com, aabad@hispasat.com, fjimenez@gmv.com, jcuesta@gmv.com, alherrero@gmv.com

Abstract

This paper presents the Flight Dynamics operations for Hispasat's Amazonas Nexus satellite, based on the Spacebus Neo platform developed by Thales Alenia Space (TAS). The Amazonas Nexus satellite leverages a combination of advanced technologies, including on-board GNSS receivers, Semi-Active Ranging (SAR) tracking measurements, and an electric propulsion system, to achieve precise orbital positioning and efficient station-keeping.

One of the core innovations in this mission is the implementation of automated Flight Dynamics operations procedures, which significantly reduces the need for ground-based interventions while ensuring high-precision orbital control throughout all mission phases, from LEOP to station-keeping. The integration of on-board GNSS receivers facilitates continuous real-time orbit determination, even in the presence of frequent electric propulsion manoeuvres. To further refine the orbit determination process, a manoeuvre grouping technique has been employed, which optimizes the estimation process by reducing the number of parameters to be estimated, thereby improving overall accuracy.

SAR measurements complement GNSS data by providing high-precision range measurements between multiple ground stations and the satellite with a single uplink, ensuring reliable orbit control. This technology minimizes reliance on traditional ground infrastructure, reducing both operational complexity and costs.

The Flight Dynamics operations are powered by GMV's Focussuite software, a comprehensive toolset designed to streamline and automate various aspects of satellite management, including manoeuvre planning and collision avoidance. Focussuite's user-friendly interface and high level of automation enable the seamless execution of complex orbital manoeuvres, while also providing flexibility in manoeuvre computations and robust angular momentum control during station-keeping.

The integration of these advanced technologies—automated Flight Dynamics, GNSS, SAR, and electric propulsion—within the Spacebus Neo platform marks a significant advancement in geostationary satellite operations. This approach not only enhances the robustness and longevity of the satellite's orbital management but also sets new benchmarks for operational efficiency and cost-effectiveness in the industry.

In conclusion, Hispasat's Amazonas Nexus satellite, supported by GMV's Focussuite FDS software, exemplifies the forefront of satellite technology. The comprehensive and automated approach to Flight Dynamics operations ensures reliable, efficient, and cost-effective service delivery, establishing a new standard for future geostationary satellite missions.

1. Introduction

The management of geostationary satellites requires sophisticated Flight Dynamics (FD) operations to ensure an accurate orbit determination, optimal station-keeping manoeuvre computation, and efficient angular momentum control, while enabling automation to minimize human errors and optimize ground control teams and assets. These capabilities are essential for extending the satellite's lifespan beyond 15 years while ensuring uninterrupted service provision to end users. Hispasat's Amazonas Nexus satellite, based on the Spacebus Neo platform by Thales Alenia Space, represents a significant advancement in the field. By integrating cutting-edge technologies both on-board and on-ground -such as on-board GNSS receivers, electric propulsion system and Semi-Active Ranging (SAR) localization campaigns- with a highly automated flight dynamics framework, the mission achieves exceptional levels of autonomy, accuracy, and cost-efficiency.

The Spacebus Neo platform, tailored for next-generation geostationary missions, provides a robust and flexible foundation for these advancements. The Amazonas Nexus, designed to deliver high-capacity communication services relies on this platform to maintain its orbital slot with minimal operator intervention, a feature made possible by the synergy of its technological components and automation tools. This paper aims at providing a comprehensive examination of the flight dynamics operations of the Amazonas Nexus, detailing the technological advancements, their implementation through GMV's Focussuite software, and their broader implications for the satellite industry. In doing so, it highlights how this mission establishes a new standard for operational excellence, offering a model that could shape the future of geostationary satellite management.

The significance of this work extends beyond the Amazonas Nexus itself. As the geostationary belt becomes increasingly congested, the demand for accurate, efficient, autonomous, and cost-effective flight dynamics solutions grow. Amazonas Nexus mission demonstrates how flexible commercial off-the-shelf (COTS) tool suites, such as Focussuite, can be adapted to meet the highly demanding requirements of modern space missions, paving the way for scalable and sustainable satellite operations.

2. Overview of Amazonas Nexus Satellite

The Amazonas Nexus is a geostationary communications satellite operated by Hispasat, designed to deliver advanced broadband and mobility services to wide spectrum of users across the Americas, Greenland, and key Atlantic corridors. Its portfolio includes in-flight and maritime connectivity, rural broadband internet access, secure government and corporate communications, and cellular backhaul for 4G and 5G networks.

Developed on the Spacebus Neo platform by Thales Alenia Space, the satellite incorporates a suite of modern technologies intended to enhance efficiency, adaptability, and operational autonomy. Notably, it is equipped with a Digital Transparent Processor (DTP), enabling dynamic and efficient bandwidth allocation tailored to evolving market demands.

Launched in 2023 aboard a SpaceX Falcon 9 launch vehicle, Amazonas Nexus performed a four-month electric orbit-raising phase before reaching its final geostationary position. The satellite is co-located at 61°W with three other Hispasat satellites, operating within a tightly controlled orbital slot, in both longitude and latitude, This requirement calls for precise and frequent adjustments to counteract natural perturbations. Thanks to its all-electric propulsion system based on Hall Effect Thrusters (HET), the satellite is capable of delivering low-thrust, high-precision manoeuvres that are ideal for station-keeping. This combination of propulsion, advanced navigation and ranging capabilities, makes Amazonas Nexus particularly well-suited for advancing automated flight dynamics operations, as detailed in subsequent sections.

3. Advanced Technologies and Techniques in Flight Dynamics Operations

The flight dynamics operations of the Amazonas Nexus are driven by a suite of innovative technologies and techniques that collectively enhance orbital control, operational efficiency, and mission reliability. This section provides an in-depth analysis of each component, drawing on their technical foundations and operational impact.

3.1 On-Board GNSS Receivers

The inclusion of GNSS receivers on the Amazonas Nexus marks a significant departure from traditional orbit determination methods. By processing signals from multiple GNSS constellations, such as GPS and Galileo, the system provides continuous, real-time position and velocity estimates. This uninterrupted data stream complements the traditional ground-based localization campaigns. First, it offers an independent and consistent source for calibrating ground-based measurements, such as ranging and Doppler. Second, when merged with other ranging techniques (e.g., SAR), it improves the overall accuracy and robustness of orbit determination. Third, the real-time availability of orbital states enables rapid and precise orbit estimation, especially valuable during dynamic mission phases involving frequent electric propulsion manoeuvres. Lastly, the continuous flow of GNSS data significantly aids in the planning and estimation of such manoeuvres, both during LEOP and routine station-keeping. .

In the presence of unexpected events, the GNSS system delivers near-instantaneous orbital states, feeding directly into the flight dynamics system to reduce latency in manoeuvre planning.

3.2 Semi-Active Ranging (SAR) Measurements

SAR localization campaigns optimize ground-based tracking operations by streamlining the use of ground resources and reducing operational costs. Unlike conventional ranging, which requires an uplink ground station for each desired measurement retrieval point, SAR technology simplifies this to a single uplink signal sent from a unique master station. The signal is reflected back by the satellite's TC&R transponder to multiple secondary stations. These secondary stations are passive, eliminating the need for them to transmit the uplink signal, thereby reducing the equipment and infrastructure costs.

This technique provides multiple range measurements from every station (master and secondary) with a single uplink signal, equating to simultaneous traditional ranging campaigns. This results in lower ground infrastructure demands and operational overhead.

The SAR system enhances the robustness of flight dynamics operations by complementing GNSS measurements or even substituting them in scenarios where GNSS signals may be degraded, such as during solar flares or geomagnetic storms. Its integration with GNSS creates a hybrid orbit determination strategy that balances accuracy, redundancy, and cost-efficiency. For the Amazonas Nexus, this dual approach ensures reliable orbital control, even under challenging conditions, while minimizing the need for extensive ground station networks—a significant cost-saving measure.

3.3 Electric Propulsion System

The electric propulsion system, a defining feature of the Spacebus Neo platform, employs Hall Effect Thrusters to deliver low-thrust, high-efficiency manoeuvres. With a thrust level on the order of millinewtons—compared to the newtons provided by chemical thrusters—this system enables gradual orbital corrections over hours or days, rather than minutes. This approach is ideally suited for station-keeping, where small, frequent adjustments are needed to counteract perturbations such as solar radiation pressure, lunar-solar gravitational effects, and Earth's oblateness. However, it requires more advanced algorithms than those used for classical high-thrust manoeuvres, as it simultaneously couples multiple corrections in the north-south and east-west planes with angular momentum management.

The continuous operation of electric propulsion introduces unique challenges for orbit determination as well, as it generates low but persistent dynamic effects. To address this, the flight dynamics system incorporates advanced algorithms that process multiple types of measurements and manoeuvre estimation models. Furthermore, due to the low impact of a single thrust and the need of continuous manoeuvring, the flight dynamics system must include algorithms capable of optimizing the full-cycle manoeuvre plan to meet the station-keeping requirements, while keeping the evolution of the angular momentum within a defined limit to meet the mission objectives. This optimization allows for the optimal evolution of orbital control parameters, such as orbit inclination, eccentricity and drift, over the long term, maximizing the fuel availability throughout the mission.

This orbital control ensures that the satellite remains within its designated station-keeping window while maximizing lifetime, maintaining operational integrity throughout its mission.

3.4 Manoeuvre Grouping Technique

To optimize orbit determination during frequent electric propulsion manoeuvres, the Amazonas Nexus flight dynamics system employs a manoeuvre grouping technique. This method consolidates multiple low-thrust manoeuvres —— into single estimation parameters for the entire cycle. By grouping thruster firings by configuration, the technique not only reduces the number of independent estimation parameters (e.g., thrust magnitude, duration, and timing) but also enables better identification of individual thruster performance trends over time. This allows operators to monitor and anticipate changes in thruster efficiency, facilitating proactive adjustments in manoeuvre planning.

This approach mitigates errors introduced by noise in tracking data, such as minor discrepancies in GNSS or SAR measurements. The resulting orbital solution is more robust, ensuring that the satellite remains within its tight positional tolerances. The manoeuvre grouping technique exemplifies how innovative data processing can enhance flight dynamics performance setting a benchmark for missions with similar operational profiles.

4. Automation of Flight Dynamics Operations

Automation is a cornerstone of the Amazonas Nexus mission. This section explores the automation strategy, its implementation, and its integration with additional GMV tools like Focusoc.

4.1 Focussuite Software Overview

Focussuite, developed by GMV, is a state-of-the-art flight dynamics solution designed to support full lifecycle operations for any mission type, from geostationary (GEO) to low Earth orbit (LEO), medium Earth orbit (MEO), and beyond. Focussuite Flight Dynamics System covers all mission phases: mission preparation, LEOP, on-orbit operations, and end-of-life de-orbiting.

The flight dynamics software automates critical tasks such as orbit determination and propagation, manoeuvre planning and optimisation, station-keeping (both absolute and relative), mass bookkeeping, manoeuvre reconstruction, platform constraint management and flight dynamics products to be exchanged with external space actors. Its modular architecture integrates seamlessly with other ground segment components—mission control, planning, data archiving,

and monitoring—via REST-API interfaces and industry standards. The human-machine interface (HMI), available as a web application, offers advanced visualization tools, including 3D orbit displays, Gantt charts, and event logs, alongside a user-friendly control panel and report generation functions. These features enable operators to execute complex operations with minimal manual input, while its manoeuvre optimization module enhances efficiency, proving cost-effective manoeuvre solutions that fulfil every operational constraint applicable to the mission.
For the Amazonas Nexus, the implementation of robust algorithms and flexible configuration ensure compatibility with the Spacebus Neo's electric propulsion and navigation systems, making it an ideal tool for automating flight dynamics operations.

4.2 Automation in LEOP and Station-Keeping

During LEOP, Focussuite automates the transition from the transfer orbit to the geostationary slot, a process that requires precise manoeuvre sequences to achieve the target orbit efficiently. It integrates real-time GNSS and ranging data, enabling rapid adjustments based on the satellite's evolving state. The software calculates optimal thrust profiles, accounting for the low-thrust nature of electric propulsion, and executes these plans with minimal operator intervention, ensuring a smooth and timely ascent. Amazonas Nexus LEOP operations have been performed under Thales ALENIA Space responsibility, and GMV's Focussuite FDS for LEOP Electric Orbit Raising (EOR) operations, has been used for shadowing and mission analysis purposes, ensuring in this way the highest level of security and accuracy of the LEOP operations.

In routine station-keeping, Autofocus, the Focussuite's automation tool, schedules and executes electric propulsion manoeuvres to maintain the satellite's position within its slot. It determines optimal firing windows—typically aligned with orbital perturbation cycles—and controls angular momentum to prevent attitude disturbances caused by thruster firings. This automation reduces the need for constant oversight, allowing operators to focus on strategic mission planning rather than tactical adjustments. GMV highlights that Focussuite supports state-of-the-art orbital control strategies, including eccentricity, inclination, and semi-major axis control, individually or combined, further enhancing its effectiveness for the Amazonas Nexus.

4.3 Collocation, Collision Avoidance and Robustness

As the number of objects in the geostationary belt increases and the demand for coverage of specific areas on Earth grows, the need for precise positioning at certain longitudes becomes critical. To address this challenge, operations have implemented a solution by collocating multiple satellites at the same longitude. This technique involves adjusting and controlling orbital parameters according to specific strategies to ensure the safe coexistence of satellites within a collocation cluster. The flight dynamics system provides the necessary tools for long-term analysis and assessment during station-keeping manoeuvres, ensuring the integrity of satellite operations.

The flight dynamics system also includes a collision avoidance module that monitors conjunction risks using data from external catalogues, such as Space-Track. When a potential collision is detected, it generates avoidance manoeuvre options, which operators can review and approve. This capability is complemented by GMV's Focusoc, a dedicated conjunction analysis and collision avoidance (CA/COLA) service that enhances mission safety.
For Amazonas Nexus, and the rest of the Hispasat's satellite fleet, it provides fully automated CA/COLA services for GEO. It leverages operational data and an augmented 19th Space Defense Squadron (19SDS) catalogue, updated daily with over 20,000 objects, to predict conjunctions up to 15 days in advance for GEO missions. With latencies as low as 5 minutes, Focusoc computes miss distances, collision probabilities, and detailed reports in CCSDS-compliant formats, accounting for operational manoeuvres and covariance uncertainties. For the Amazonas Nexus, the integration of Focusoc with Focussuite platform ensures proactive risk management in the increasingly congested geostationary belt, where debris and satellite density pose increasing threats. A key advantage of this integration is its ability to detect potential close approaches well in advance, allowing these events to be incorporated into routine planning cycles rather than treated as last-minute contingencies. This not only enhances mission safety but also reduces the need for unscheduled collision avoidance manoeuvres, ultimately conserving fuel and preserving mission longevity.
The automation framework's robustness is evident in its handling of off-nominal scenarios, such as propulsion anomalies or data outages. Focussuite's built-in contingency protocols, combined with Focusoc's real-time monitoring, maintain operational stability, ensuring the satellite's integrity under adverse conditions.

5. Operational Results and Benefits

Following its entry into service, Amazonas Nexus has achieved stable, highly autonomous operations, fully validating its integrated flight dynamics and automation framework. Orbit determination accuracy consistently meets mission requirements, and station-keeping manoeuvres are executed with precision, minimizing operator input and optimizing fuel use—crucial for extending mission lifespan.

Reliance on onboard GNSS navigation could reduce ground station usage, lowering operational costs and simplifying logistics. The proactive conjunction analysis integrated into routine planning has so far eliminated reactive avoidance manoeuvres, enhancing safety and resource efficiency. Additionally, the manoeuvre grouping technique enables a more consistent monitoring of thruster performances, allowing early detection of potential degradation trends and supporting predictive maintenance strategies.

Together, these advancements highlight a shift toward more efficient, resilient, and cost-effective geostationary satellite operations.

6. Implications for Future Geostationary Missions

The Amazonas Nexus mission sets a compelling precedent for future geostationary satellites, demonstrating the viability of automated, technology-driven flight dynamics operations. Its hybrid GNSS-SAR approach could be adapted to smaller satellites or constellations, while the manoeuvre grouping technique offers a scalable solution for missions requiring frequent adjustments. Focussuite's success, bolstered by Focusoc's collision avoidance capabilities, suggests that similar software suites will play a pivotal role in next-generation satellite management, potentially incorporating AI for predictive analytics and greater autonomy.

Challenges persist, including standardising these technologies across diverse platforms and ensuring resilience against emerging threats like space debris. GMV's ongoing development of Focussuite, with upgradable flight dynamics models and ML/AI optimisation, positions it to address these issues. The Amazonas Nexus thus provides a blueprint for efficient, reliable, and cost-effective operations, influencing the design and management of future missions in an increasingly complex orbital environment.

7. Conclusion

Hispasat's Amazonas Nexus, supported by the Spacebus Neo platform and GMV's Focussuite software, represents a leap forward in geostationary satellite technology. Its use of on-board GNSS, SAR measurements, electric propulsion, and automated flight dynamics operations—augmented by Focusoc's collision avoidance tools—delivers unparalleled precision, efficiency, and cost savings. By minimising ground intervention and optimising resources, the mission not only achieves its operational objectives but also establishes a new industry standard. As the satellite sector evolves, the lessons from Amazonas Nexus will guide the development of more autonomous, resilient, and economical missions, ensuring the continued advancement of space-based services in a competitive and crowded domain.