GNSS receivers onboard Space Assets session MoM's

<table>
<tr><td>Meeting Date</td><td>04.12.2025</td><td rowspan="2">Location</td><td rowspan="2">Prague
Vienna House by Wyndham Diplomat Hotel</td></tr>
<tr><td>Meeting Called By</td><td>EUSPA</td></tr>
<tr><td>Minutes Taken By</td><td colspan="3">Name: Xabier Mendaza, Karen Boniface FDC, Riccardo Nicole, GSOp - GSC</td></tr>
<tr><td>Representatives & Speakers</td><td colspan="3">EUSPA Representatives
Giovanni Lucchi, EUSPA MDI Officer

Speakers / Moderators
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Milena Nicole Veliz Amaya, EUSPA
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Samuele Fantinato, Qascom
Giancarlo Varacalli, ASI
Harald Hofmann, DLR-GK
Francesco Menzione, JRC
Salvatore Guzzi, Qascom
Pedro Pintor, Spaceopal
Stefan Schlüter, DLR-GK</td></tr>
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AGENDA

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10. New user needs and requirements (Presentation and Q&A)	Xabier Mendaza, FDC
11. Galileo differentiators space market trends (Roundtable and Q&A)	*Panel discussion moderated by* Giovanni Lucchi, EUSPA Xabier Mendaza, FDC *Space market trends by* Pedro Pintor, Spaceopal Stefan Schlüter, DLR Galileo Competence Center Samuele Fantinato, Qascom Francesco Menzione, JRC

SUMMARY

Summary

The "GNSS receivers onboard Space Assets and Space Surveillance and Tracking" session of the User Consultation Platform (UCP) 2025 took place on 4th December 2025 as a hybrid event, with in-person venue in Prague, Czech Republic. The event was divided into two distinct themes: "GNSS receivers onboard Space Assets" comprised of morning and afternoon sessions, with the latter being shorter to accommodate the "Space Surveillance and Tracking" session in the afternoon.

The panellists gave in depth presentations of their applications, how they use or contribute to GNSS space-borne receivers, and related needs and requirements. Participation and engagement in this UCP session were outstanding, and attendance remained high for the entire duration. Attendees on site congratulated EUSPA for the fruitful presentations and discussions that were provided during the day, where a collaborative framework was promoted and achieved by the participants, as well as the attendees appreciated the opportunities offered for networking alongside the event.

The session highlighted:

- Strong interest in GNSS applications, with session' requirements discussion focusing particularly in validating the following use cases:
  - GNSS-Reflectometry: expected accuracy of 2-5 cm (mainly for altimetry applications), 99.9% availability with necessary multi-frequency multi-constellation capabilities.
  - Space-Based monitoring: accuracy <1 m, 99% availability, multi-frequency multi-constellation capabilities, and less stringent timing accuracy (milliseconds) which is by the fact a new application for the market segment.
  - Launcher-related phases: accuracies of <10m for Ascent and ~1 m for stage recovery/orbit injection, with full integration with inertial systems. New trends of First Stage Recovery and Autonomous Termination Systems will consider GNSS an enabler, whilst Robustness and integrity parameters may need further definition work.
- The recent lunar mission GNSS test results were also particularly of interest for the audience, supporting the use of GNSS in future deep space missions.
- Presentations drew attention to new research funded opportunities and the potential for space-developed GNSS solutions to benefit other sectors, whilst also supporting testing of Galileo's new/evolution services on ground and in space.
- Galileo differentiators are enabling the use of GNSS in Space: whereas HAS contributes supporting demanding applications (e.g. Precise Orbit Determination) and with high expectations for the upcoming Service Level 2 as it can further improve performance not only because of improved quality of existing corrections but due to the addition of new elements like SAGA and ERP which are key for space applications, OSNMA is targeted as an important asset for resilience, as interference cases are raising especially in LEO, and should be further subjected to study. On top, EWSS test demonstrates it can be used to support deep space missions.
- Participants also emphasized other topics:
  - The need to address in the near future standardisation aspects for future GNSS space applications, as well as the importance of sharing and codifying best practices.
  - The importance of having a reliable manufacturing application-specific GNSS hardware industry supported by rising market production volumes. The discussion underscored the urgency of strengthening EU-based manufacturing to fulfil European needs.
  - The needed support (financial, partnering) to equipment development, with particular focus on antennas (as it is becoming a limiting factor to improve GNSS performance), specific-application receivers (e.g. GNSS-R dedicated receivers) and inclusion of new Galileo services.
  - To continue the cooperation between the different actors to support the adoption of GNSS in space, such as evolution roadmaps, requirements analysis, guidelines for manufacturers and expanded access to observable databases.
- Overall, the space market is seen as rapidly expanding, propelled by increasing private-sector involvement that is reshaping both industry dynamics and regulatory perspectives.
- EUSPA proposed to establish bilateral meetings with ASI, DLR and JRC starting January 2026, to find ways of mutual cooperation to support Space users.
- EUSPA also takes the action to further promote the opportunity for users/companies in participating to

the review of technical information (e.g. SDDs), if the proper framework is set beforehand (not-disclosure of information, etc.).

Minutes of Meeting

Agenda Item 1 - Welcome and introduction to the Space session. Giovanni Lucchi, EUSPA MDI Officer.

Giovanni Lucchi, Market Developer Officer from EUSPA, introduces the session 'GNSS receivers onboard Space Assets and Space Surveillance and Tracking Session', detailing the agenda, which will be focused on examining success stories and initiatives, together with describing new needs and specifications starting from the heritage of EUSPA market reports (technological, market report). The session is hybrid, albeit the online audience will only be able to Q&A with the online form.

The output of the session will be collected via Minutes of Meeting and made public, which will originate actions for the future activities, as one of the main goals of the UCP process. This process is described in detail, along with all the preparation work (desk research, stakeholders' involvement, review of needs and applications) all leading to this final collecting and validating session.

It is also noted that reports alone are not sufficient and further synchronisation between EUSPA and users is required, especially when new services and applications have arisen that require analysis and actions definition. One of the EUSPA goals is to raise support, but it is key to identify the opportunities in order to speed up process to get initiatives done in a productive way, respecting the set of rules and procedures required as a public institution.

It is explained to participants that the findings of the UCP can be reviewed and complemented. The link to the RUR as an on-going publication will be provided so the users can take opportunity to suggest new user needs and requirements promoting novelties for space and new Galileo services. In this regard, the latest edition of the Report on Space User needs and requirements (RUR) was advertised.

It is also presented the status of the new launched Galileo services over the past two years and several EUSPA-funded projects have been completed. OSNMA has become operational in July and HAS is entering its second phase. This is creating opportunities for new concepts and applications, as new HAS receivers for space applications have been launched within EUSPA calls projects, now followed by a new €2M call just launched for to develop a HAS receiver for space (max 2 projects, 24-month duration, deadline 30/01/2026). Development efforts will also focus on receivers for LEO satellite, complemented by success stories such as the Qascom product developed under Fundamental Elements, showing the value of sponsored innovation.

Closing the item, the EUSPA officer emphasized the importance of direct user involvement and active participation in expressing their needs and ideas requiring support. He also highlighted the value of connecting with other users and companies, noting that such collaboration is essential for addressing shared needs and creating new opportunities—core objectives of the UCP.

Agenda Item 2 - The EU Space Programme update – HAS and OSNMA. Giovanni Lucchi, EUSPA MDI Officer.

Giovanni Lucchi details the status of Galileo services portfolio, namely the Galileo OS, PRS, HAS, OSNMA and SAR services, with updated OS SDD and OSNMA newly released SDD information available online.

Then the upcoming services evolution is presented. As the system moves from initial services toward Full Operational Capability, new services such as EWSS, Galileo Signal Authentication Service and the

Galileo second Generation (G2G) service portfolio are under preparation. Service evolution for G2G is increasingly service and exploitation driven, making it essential to gather user needs to guide future developments and upgrades, including interest in HAS Service Level 2 which is expected for 2027.

Upon a request, it is reminded that the presentation slides will become available once integrated with the feedback to be collected within the UCP.

Agenda Item 3 - New User Needs and Requirements for Galileo-enabled receivers for Space assets (with a focus on Reflectometry and Launchers). Xabier Mendaza, FDC

Xabier Mendaza from FDC first explains that the presentation is divided into two splits, one in the morning focusing on presenting the findings, and the second split in the afternoon focused on answering gathered questions from participants and fostering requirement discussions.

Xabier Mendaza continues by briefly introducing his company's profile and describes the role in the UCP supporting EUSPA tasks, mainly focused on user needs and requirements identification and analysis. A first analysis was performed for UCP 2023's Space session, primarily focused on Real-Time Navigation, POD, Timing and Synchronization and GNSS Radio-Occultation (RO). The UCP 2025 goals aims at completing the analysis going deeper into the topics of GNSS-Reflectometry, Space objects monitoring or the development of GNSS use in launchers phases. This day's feedback will contribute to a new version of the RUR.

The three main topics of interest are presented:

- GNSS-Reflectometry: the principles of the remote sensing technique are described, as well as relevant project. It is highlighted multiple initiatives requiring dedicated GNSS receivers to this purpose, accuracy requirements of 2-5 cm in more demanding cases, stringent MC/MF performance, and low latency.
- Space-based monitoring: an emerging activity that uses space assets to identify, monitor and track space objects, instead of relaying in ground trackers. Accuracy requirements of meter level, complemented with a high need of availability and robustness Timing is not demanding in terms of accuracy (ms), but reliability is the key.
- GNSS in launchers: GNSS is a becoming a key source of positioning and timing in different phases such as Ascent, Flight Termination systems or First Stage recovery. Nowadays working jointly with other technologies (inertial units), it is a field of application requiring exceptionally high robustness due to the high-dynamics experienced. Although the requirements vary at different phases, accuracies of ~10m level are required in Ascent whilst 0.2-1m are demanded in stage recovery.

Finally, contributions from Galileo HAS, OSNMA and EWSS are presented in order to be also discussed in the afternoon, focusing in the benefits and opportunities that the services bring specifically to Space users, such as testing of EWSS in the Moon.

Agenda Item 4 - In flight GEYSER technology experimentation for future user needs. Samuele Fantinato, Qascom

Samuele Fantinato from Qascom introduces the EUSPA's GEYSER initiative that the company has primed: the project spanned from 2021 to 2023 and generated a solution that is now marketed as a product. Its core consists of a Software Defined Radio (SDR), modular and highly configurable for emerging GNSS applications in space. This technology has allowed to start the development of a customised receiver version to be deployed for lunar navigation testing (Moonlight initiative) and to allow future upgrades to new Galileo services like HAS and SAS.

The presentation follows with several graphics, intended use, type of orbit and type of satellite market trends overview is shown highlighting the commercial developments and the increase in smallsats launches. The LEO small-satellite market continues to accelerate, with a 32% increase in launch volumes and 99% of all small satellites deployed in LEO. Telecommunications remain the dominant application, while technology and Earth-observation missions are experiencing strong growth (+125%).

Across launchers, LEO, GEO, and lunar missions, users increasingly require robust, resilient GNSS, including multi-GNSS capability, spoofing/jamming mitigation, and OSNMA support during critical phases. LEO satellites demand meter-level positioning, tight velocity and timing accuracy, and enhanced POD performance, with Galileo HAS enabling ~5 cm accuracy by 2025. Meanwhile, jamming and spoofing activity is rising sharply, with over 430,000 events reported and up to 700 disturbances per day, globally, on LEO orbits.

Launchers Navigation, supported by the results of flight experiment are related to LEO Robust & High Accuracy Navigation, to be verified by the use of GEYSER receiver as a payload for future IOT Missions. Alternative LEO PVT was tested on the ISS, demonstrating the use of ground-based transmitters for PVT, a possibility for Lunar applications.

Strong emphasis is placed on Moon missions, especially after LuGRE successful experimentation. The LuGRE mission demonstrated the emerging potential of GNSS beyond Earth orbit on the Moon. Data were collected through the different phases of the mission, achieving the first GNSS positioning in lunar orbit, the first GNSS PVT solution on the Moon's surface with 3D POD achieved with less than a kilometer. Notably, Galileo navigation messages were successfully demodulated at the Moon without ground assistance, underscoring the system's value for future deep-space applications. Data are public through Zenodo platform.

Another major achievement is the successful demodulation of the Galileo navigation message on the Moon. Clock and ephemeris from SIS can also been received from ground without assistance. Dual frequency/dual constellation on L1/L5 allowed the fix, with Galileo performing better than GPS, demonstrating its capability to perform autonomously. OSNMA messages could be demodulated and EWSS testing was described, since hence during the LuGRE mission, dummy EWSS messages were transmitted by Galileo and acquired on the Moon surface in March.

Finally, the future LCNS Navigation is presented, highlighting the upcoming user needs and the different applications within this field. On the Moon there should be cooperation between different technologies and scientific reference models. Interoperability between LCNS and GNSS will be key, especially in the initial stages.

Questions were raised about:

- the challenges encountered in meeting the SDA requirements. In terms of size and power consumption, the constraints are comparable to those of other satellites.
- the existence of jamming events occurring on orbits. The number reported in LEO is of 700 events/day.
- the processing made for the LuGRE mission. LuGRE relies on ground-based post-processing, complemented by real-time onboard PVT computation, which is further explained in a dedicated presentation in the afternoon.
- The accuracy values given are related to 3D RMS accuracy.

Agenda Item 5 - ASI perspective on evolution of GNSS space receivers to cope user needs. Giancarlo Varacalli, ASI.

Giancarlo Varacalli, Head of ASI Tecom and Navigation Office, presents Italy's activities in the field of PNT services, covering both Earth orbit and Lunar applications. Italy is running several programmatic initiatives to operate and develop PNT infrastructure and provide a national competence center available to the wider national community. A series of programmatic lines are in place for operating/developing infrastructure to national operation toward operational national capabilities. Therefore, centres of competence are put at disposal of national community. Specific projects were mentioned focused on Radio-Occultation and reflectometry:

- GROOVE project (GNSS-RO capability), just passed its PDR and focuses on the use of GNSS for Radio-Occultation weather forecast applications. The test bed is currently running on test aircrafts, and the next step will be its qualification for use on LEO satellites, aiming at providing LEO-embarkable GNSS receivers to support future LEO constellations. In this regard, low-orbit components of IRIS² could be candidates for future LEO-based PNT services. The project ends in late 2026.
- GREAT project (GNSS-Reflectometry capability): the main applications being sea surface altimetry and biomass monitoring. The capability includes dual constellation, dual frequency exploitation with on-board processing. It is highlighted the variety of possible users, from institutional to research organisations. The initiative also foresees the use of AI for data process and analysis

The technical challenge to synchronize both projects lies on the antenna. GNSS-R requires nadir (straight down) and zenith (straight up) antenna views whereas RO requires limb-looking geometry (the signals are observed tangentially through the Earth's atmosphere, rather than straight down or straight up). These viewing requirements are difficult to combine on a single antenna system.

The presentation then focuses on the TAS-I manufactured and NAVISP- funded Marconi GNSS receivers, specifically designed for space applications in multiple fields. It is a cost-effective product, based on COTS components enhanced to grant durability in space. Two parallel product lines are existing with mid-end, high-grade receivers using space-qualified components and New-space receivers optimized for low mass, low power consumption and stream-lined quality processes (with 5 years, suitable for New Space satellites). First models will fly on LEO PNT missions to be launched in 2027.

A third use-case is also presented, referring to the LuGRE mission, from the Space Agency point of view. It was a bilateral cooperation where Italy developed the receiver whilst NASA provided for the launch opportunity. The mission exploitation was handled by NASA and Politecnico di Torino and it is part of a broader roadmap for progressive GNSS demonstrations in deep space. The approach to Lunar positioning is stepwise, starting from GNSS and switching gradually to lunar orbiting satellites and to local signals (pseudolites, differential corrections).

The mission relied on commercial LNA and antenna. It was the first acquisition in lunar orbit and lunar surface, whilst other nations attempted a similar mission few days after without being able to compute PVT. The mission produced continuous collection of data to improve analysis and requirements definitions. Main challenges to recall as lessons learnt from this mission are importance of the high-gain antenna, the low signal power and the limited GNSS satellites visibility leading to the need for multi-constellation operations.

Receiver sensitivity exceeded conventional thresholds by more than 20 dB, confirming high-sensitivity performance suitable for very weak lunar GNSS signals. Further enhancements are expected from hardware improvements and advanced processing algorithms, which will increase link margin and positioning reliability in cislunar and lunar environments. For sustained lunar operations, multi-constellation usage is essential to secure adequate satellite visibility and geometry, while dual-frequency capability (L1/L5 – E1/E5) is crucial for robustness, and high-accuracy PNT.

Finally, the mission also demonstrated successful reception of the Galileo EWSS test signal on the Moon, transmitted by three Galileo satellites, with the resulting datasets published on Zenodo for community use.

Future work will need long-duration missions, use of rad-hard components, improved receiver and antenna performance, and further lunar and cislunar signal reception campaigns. In parallel, it is mentioned the next call for proposals from ASI that is expected to feature around ten thematic areas, including a topic on 5G-PRS hybrid receivers capable of processing GNSS signals together with 5G-PRS (Positioning Reference Signal), enabling more reliable navigation solutions. Collaboration with EUSPA within this framework is welcome and encouraged.

Agenda Item 6 - DLR Galileo Competence Center overview and projects to support user needs. Harald Hofmann, DLR-GK.

Harald Hofmann presents the Center's purpose and role as a bridge between public institutions and private industry research, detailing activities and resources such as the demonstration mission for quantum optical technologies like optical clocks and quantum-based gyroscopes.

Additionally, there are outreach efforts aimed to make GNSS performance monitoring more accessible to the public, through the public GNSS performance monitoring website and the development of a mobile GNSS performance monitoring station (ULMOST). Other activities include the realisation of a Robust Precise Timing Facility and the System & Service Volume Simulator Environment (S2VSE). Then, an overview of operation concepts relying on AI support is outlined for future activities, along with their System Design & Verification methodology.

The presentation concludes with examples of consulting and knowledge transfer, and specific activities that support Space Users needs and requirements. These include among others the development and demonstration of new technologies demonstration from TRL 4 to 7 (e.g. COMPASSO, QYRO), the provision of expertise in robust time generation and comprehensive performance analysis, i.e. the monitoring and signal analysis of all GNSS systems, as well as simulation and laboratory capabilities to support Galileo users' needs

By questions from the audience, the information is complemented:

- Ultra Mobile GNSS Monitoring Stations can also be used to analyse the local performance of other services, such as HAS, OSNMA, or EGNOS in real-time and potentially forecasting capabilities.
- The simulation capabilities of the Centre include multiple simulators at different levels. Their QYRO product deployment is realised and managed by private industry. The GNSS performance monitoring platform could be used for near real-time monitoring, and even provide some limited forecasting capabilities to help plan activities or operations to optimize GNSS performance.
- Commercial opportunities toward LEO and collaborations with Earth Observation for topics such as urban heat islands were highlighted, together with benefits of space optical atomic clocks, larger constellations, and time provision when GNSS is unreliable.

Giovanni Lucchi closes the slot agreeing on this type of capabilities that increases industrial opportunities and the support given to making information public and shareable with users.

Agenda Item 7 - Galileo as an essential enabler for present and future lower and upper SSV applications. Francesco Menzione, JRC.

Francesco Menzione, Technical Officer from JRC E.2 –Space, Connectivity and Economic Security, starts with an overview of the JRC's Galileo related activities and the dedicated laboratory, with focus on their controlled-pattern antenna test bench, including one for timing and one for the GNSS Space Service Volume (SSV) for spaceborne applications.

The SSV was described as a 2nd age of the Galileo SSV, comprising two separate layers in terms of performance: an upper layer, mainly supporting space exploration missions such as lunar operations where robustness is prioritized over accuracy, and a lower layer below about 8 000 km, where crowded LEO environments require high-precision capabilities to support mega-constellation deployment.

For the upper SSV, JRC contributions include the calibrated Galileo Reference Antenna Pattern and associated test capabilities in anechoic chambers to derive meaningful C/N0 values (including testing of lunar receivers for an appropriate reception in lunar and deep space missions). For the lower SSV, the GASPER project (GAlileo SPace ReceivER) for onboard LEO-PNT applications to be launched by end-2026 aims to update Galileo performance by implementing state-of-the-art precise orbit determination using HAS corrections, fully characterizing antennas for PPP on the ground, and emphasizing proper antenna calibration and recalibration to achieve centimetre-level accuracy.

The presentation wraps with a recap of the main points, highlighting the key contribution from JRC to Galileo evolution of SSV and performances for space applications. When asked about LEO-PNT, Francesco Menzione states that it can support both ground and space, as Galileo and GNSS do. Thus, LEO PNT and SSV are highly synergistic, with precise orbit determination as a fundamental function, leading to integrity as a key requirement, and advanced, more complex antennas identified as a critical bottleneck that must not be overlooked. Finally, it is remarked that these resources are publicly (and freely) available to EU users and enterprises.

Agenda Item 8 - Technical aspects of the GEYSER receiver (Q&A). Salvatore Guzzi, Qascom.

Salvatore Guzzi, Qascom GNSS Rx engineer, presents GEYSER architecture and its performance analysis.

It is based on software defined radio technology. The architecture is highly configurable for different application scenarios. OSNMA is included as well as anti-jamming solutions. Test on launcher results are shown, where the receiver withstood launching conditions and able to track GAL/GPS signals, with PVT solutions aligned and consistent with radar measurements, obtaining 3D RMS of 5m accuracy.

LuGRE result were based on dual frequency GAL/GPS measurements, most results in real time. With the first PVT ever computed on the moon, the navigation solution was computed in ECEF reference frame with a position in the Moon PVT solution below 2 kilometres, while the POD solution was computed in ECI reference frame, with the position below 1 kilometre.

GEYSER results in LEO achieved a position error of 1m accuracy for POD while for the NAV solution was 3.6 metros, tracking more than 30 satellites at the same time. Anti jamming and anti-spoofing were activated, with very effective results.

In the future, the receiver will be adapted to the S-Band for LCNS (it is the designated operating band, instead of the Earth L-Band). A simulation has estimated a 3D error for the future LCNS position from 20 to 5m depending on the solution.

There is a question from the audience asking about the implementation approaching, and he states that a CDMA approach was implemented for both navigation and communication infrastructure

Agenda Item 9 - HAUT in space requirements for users (Presentation and Q&A). Pedro Pintor, SpaceOpal.

Pedro Pintor from Spaceopal presents the company and its role in Galileo and the contribution to technology evolution (HAUT 1 & 2, OpStar…), as Spaceopal manages the day-to-day operations of the Galileo system for EUSPA.

Hosting a GNSS receiver onboard is now a requirement for most satellites, with missions including the use of precise orbit determination and timing solutions based on GNSS to achieve enhanced operational autonomy and support in-orbit services, without continuous link to the ground segment.

Pedro Pintor provided a description of HAUT-S, a commercial Spaceopal product (a 3D printout is shown physically to the audience) consisting of a real-time Orbit Determination and Time Synchronization (ODTS) payload specifically designed for Low Earth Orbit (LEO) satellites that uses both HAS, which improves convergence besides accuracy in position and time, and OSNMA, to improve robustness. HAUT-S performance results indicate Galileo HAS is bringing significant improvements in 3D convergence time compared to the use of broadcast ephemeris only. This performance evolution opens new opportunities for space applications. The roadmap for HAUT-S includes achieving TRL 7 readiness in Q1-2026 with the qualification of the proto-flight model for space environment and advancing to TRL 9 in 2026 with commercial launch and in-orbit validation. HAUT-S has high relevance for various use cases, including LEO-PNT, In-Orbit Servicing & Formation Flying, Autonomous Station Keeping & Collision Avoidance, and Laser Communication Support.

Spaceopal is looking for innovating partners to exploit the receiver capabilities in their constellations.

It is also stated that a major bottleneck remains in access to space, which requires considerable resources and time. The European industry would be better positioned if access to orbit was easier. Several additional enabling elements would also accelerate adoption: earlier access to new services ICDs and test vectors, allowing better planning for future product lines, real Galileo observables, expanding existing databases for testing and modelling. Support to export controls assessment that will ease international commercialization.

Questioned about regarding commercial scalability, Pedro Pintor explains that component manufacturer is actively working to overcome challenges and accelerate development, and that for HAUT-S, based on COTS, some space grade component has long lead times (typically 5–6 months). Ultimately, orbit validation remains a key challenge for commercial growth.

Questioned also about upcoming activities for HAUT-S (Q1/Q2 2026), he mentions that space qualification is planned, including vibration and thermal vacuum testing in operational conditions (acceptance and qualification levels) and, although HAUT-S is non-antenna specific, a space antenna calibration campaign is undergoing. A Hardware in the Loop (HiL) performance campaign will also be conducted at varying orbit altitudes. Whereas some radiation testing was executed on the previous prototype, additional radiation testing is considered necessary (e.g. TID, heavy ions, proton). Finally, when it comes to evolution, the integration of Galileo HAS Service Level 2, solar geomagnetic activity parameters and earth rotation parameters been in the product roadmap as this information is very valuable for atmospheric drag modelling and for enabling fully independent performance from GPS (MT31), enhancing the product overall appeal.

Agenda Item 10 - New user needs and requirements (Presentation and Q&A). Xabier Mendaza, FDC.

Xabier Mendaza from FDC introduces the second of the two-split presentation, which is focused on the questions and discussions regarding the presented users and their needs. The discussions are organized below by theme:

GNSS-Reflectometry:

- Fast reactivity and on-board Processing needs: Participants highlighted the growing need for rapid reactivity, particularly for alert message generation in emergency applications where timely information can significantly impact response effectiveness. In many cases, data is already generated at the satellite level (as downloading unprocessed data is time consuming), but the speed at which it is transmitted to the ground and analysed remains a key limitation. To address these constraints, more on-board processing capabilities and advanced on-board features are required. These improvements would reduce latency and enable quicker decision-making. Constraints exist both at the receiver level and in the implementation of inter-satellite links, with antenna performance and geometry directly influencing achievable accuracy. A question of the audience inquiries about the potential use for real time applications, as it would be one of the main benefits regarding the potential overlaps with products already available through the Copernicus program, particularly for Earth observation-oriented services. It is conferred that there are ongoing tendencies to support this demand but it will depend on the evolution of the sector and receiver capabilities development.

- Antenna and production scalability challenges: It was noted that high-end space antennas require long lead times, creating difficulties in scaling production and meeting increasing mission demands. This affects not only navigation missions but also remote sensing applications where high-performance antennas are essential. The availability and manufacturing scalability of antennas remain a critical bottleneck for industry growth and timely mission deployment.
- Requirements for Remote sensing vs Navigation: Francesco Menzione notes that remote sensing missions require higher I/Q resolution, often far exceeding navigation needs, where only a few bits are typically used. Supporting higher bit-depth demands careful customization of GNSS signal processing, with different best practices for I/Q correlation depending on whether the receiver is used for navigation, remote sensing, or Radio-Occultation. When a GNSS receiver acts as a remote sensing sensor, design considerations differ substantially from those for a classical navigation receiver. Xabier Mendaza comments that high customisation is actually needed and that the market trend is addressing this customisation. Francesco Menzione adds that Radio-Occultation has more relaxed requirements (no reflected signal), but most components are common with Reflectometry. He suggests that the same receiver should be used to verify this harmonisation.
- Timing and Synchronization Constraints: the audience debates about the timing needs, and that applications such as GNSS-R and RO impose stringent requirements on the RF front end and on timing. Accurate synchronization between the incoming signal and its replica is essential for geolocating measurements and determining velocities. The time requirements are also very strict for RO on the ground, making timing accuracy a core performance driver for these advanced sensing applications.
- Signal Availability and Certification Needs: it is also commented by the audience that weak-power GNSS signals in space represent a significant challenge for coverage and usability, especially for missions extending beyond LEO. The audience also inquiries about the possible need for receivers' certification, since several application segments require specific certifications to ensure compliance with mission and safety standards, which it is acknowledged that it is a possible scenario in long term, depending on the sector evolution.

Space-Based Monitoring:

- The main and key requirement for this application is availability, to support needs and demands when the service is provided in quasi real-time.
- Standardisation: the audience inquiries about possible standardisation requests, as there is a need for clearer standardization of telemetry information, ensuring that operators receive consistent and interoperable data across missions. It is also commented that GNSS in this

application has a dual usability, as not only contributes to the monitoring aspect of the application but also to satellite manoeuvring, and it would be the former aspect that standardisation would be needed.

- As interest grows in PNT services beyond LEO, the audience asks about the limitations of the space-based monitoring capabilities, due to interest up to GEO and eventually into deeper space, as requirements for space monitoring and awareness may also become increasingly relevant and integrated into future capabilities. Xabier Mendaza comments that until today, the current situation offers these services up to GEO, and that the synergies are expected with current SST needs, since although the space-based monitoring not only covers current private demands in tracking and status monitoring of space assets but also can contribute to public programmes. It is also noted by the audience that for that purpose all constellations must be monitored, included GNSS constellations.

Launchers considerations:

- There are several phases supported by GNSS (e.g. Ascent, FTS, first stage recovery), having different requirements. GNSS is acknowledged as an enabler, working jointly with other systems (inertial, etc.). Generally, availability is essential with an extremely needed robustness, due to the extreme dynamics of the launching sequence.
- For launch vehicles, antennas are a fundamental necessity. Typically, two antennas must be placed within the vehicle structure, requiring thoughtful integration. While accuracy requirements for launchers are generally not stringent, the audience agrees that robustness, reliability, and resilience particularly against jamming are essential. Samuele Fantinato comments that Lessons learnt show that antenna placement is often a critical factor. Additionally, it is commented that multi-frequency antennas are difficult to procure, suggesting that application-specific design should be envisaged.
- Security and confidentiality aspects complicate the framework. Export-control constraints and the limited availability of launch facilities further complicate market access.
- Francesco Menzione takes the chance to highlight that robustness refers to the reliability and durability of equipment (resistance to generic disturbances or faults) and must be distinguished from resilience, which refers to the ability to withstand or mitigate interference (jamming, spoofing). Both aspects must be clearly defined in requirements to avoid ambiguity in system design, as robustness mostly pertains to reliability of signals, equipment, etc. depending on environmental and demanding use conditions.
- Stefan Schlüter brings up some other potentially requirements such as the aviation-like Integrity for this domain. Xabier Mendaza also adds that this specific requirement would need first a clear definition (as its scope changes from one market to other) and then an analysis of its specific applicability to launchers, since the focus is currently in other aspects of the application. Participants also ask whether any risks exist concerning continuity of service. This area remains under consideration, particularly as missions become more dependent on multi-frequency, multi-constellation solutions and as signal availability challenges increase with mission altitude.
- Navigation units for launchers must support autonomous operation, ensure synchronization with ground systems, and maintain redundancy for safety. It is asked how this situation works at the launching sequence. Xabier Mendaza comments that before lift-off the rocket relies on ground information, hence the accuracy of position is not lead by GNSS performances at that stage.

Finally, the split slides display the Galileo differentiators, which will be the topic of the next and last slot.

Agenda Item 11 - Roundtable on Galileo Differentiators. Pedro Pintor, SpaceOpal / Stefan Schlüter, DLR Galileo Competence Center / Samuele Fantinato, Qascom / Francesco Menzione, JRC.

Giovanni Lucchi introduces the Roundtable, asking the vision from the presenters in relation to the Galileo differentiators. The panellists reiterated that the quality of service is improving but has not yet reached its full potential. The overall technological trajectory is well defined in many use cases, but decision-makers need to ensure the necessary support and visibility for implementation.

Pedro Pintor expresses that the availability in advance of information for new evolutions and services would be welcomed, in order to anticipate development and new needs. He also addresses two additional expectations that could improve future services: the inclusion of Solar and Geomagnetic activity parameters (SAGA) and Earth Rotation Parameters, and the promotion of an easier access to Space for testing capabilities.

Then Stefan Schlüter takes the turn, building on the previously mentioned concepts, to state current needs for the European industry. One of the major needs is to have an enlarged industry landscape to facilitate user's access to high-end receivers with a cost reduction effect. In that respect it is considered relevant to have greater productive capacity with more or new manufacturers to support the availability of equipment on the market, and accordingly there is the need to foster the availability of materials and space proofed electronics, which are scarce.

Giovanni Lucchi acknowledges these needs to be considered in future funding opportunities, promoting technology that can be market ready. Funding instruments and pilot projects are already in place to encourage the emergence of competitive European products. With mega-constellations preparing for procurement, the market is mature and open for collaboration. Both public institutions and industry acknowledged that European-produced receivers and services are essential to meet user needs.

Next Samuele Fantinato takes the opportunity to mention how commercial operators (Firefly) contributes to access to Space, aligned with the identified need of having In-Orbit demo possibilities. He also states that Galileo is a differentiator in itself when concerning outer space, as it has better performance that other GNSS constellations. In this regard, clear roadmaps (such as the one presented for HAS SL2) are quite important in order to plan and schedule the development of new capabilities or operations (such as software updates).

Giovanni Lucchi suggests that this type of lessons learnt and issues to be addressed would support the creation of collaborative knowledge support for new players.

Francesco Menzione takes the floor, to encourage this last topic, suggesting that best practises could be shared openly so for the industry to benefit. He also raises the need for players to clearly assess and differentiate the requirements that should be demanded for each mission/application, as in many occasions stringent requirements are applied but not demanded for the purpose of the targeted application. In addition, he also states that I/NAV improvements should be considered as an additional benefit due to the faster convergence time that is allowed in degraded conditions, especially useful for GEO orbits or other situations where the conditions are met (e.g. user working in assisted GNSS (A-GNSS) mode).

Then as final notes, Stefan Schlüter states that this market is clearly differentiated from other markets, as Space industry more and more targets Space without necessarily bearing in mind any other ground segments, mentioning a clear military interest in the Moon, and Francesco Menzione reflects on the receivers market, which is clearly growing, and the expectations of the new services coming in the future, especially if hundreds of lunar missions are planned for the next 10-15 years.

Finally, Giovanni Lucchi takes the floor to close the “GNSS RECEIVERS ONBOARD SPACE ASSETS” session, and takes the occasion to thank the panellists, the rest of the presenters and the attendees (both on site and online) for the participation in this very fruitful collaborative session.

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