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EUROPEAN SPACE AGENCY

NAVISP Element 1 Work Plan 2026 Addendum

Subject

This document presents the NAVISP Element 1 Work Plan 2026 Addendum activities.

Eligibility

AT, BE, CH, DE, ES, FI, FR, GR, HU, IE, IT, NL, NO, PL, PT, SE, UK

Note that there are Opt-Outs for specific activities contained in this Work Plan.

1. OVERVIEW

The Work Plan 2026 Addendum includes five (5) innovative activities, for a cumulative budget of **4.0 M€**.

The activities belong to the following classes:

- Assured PNT
- Low SWAP
- Complementary sensors
- Disruptive PNT Technology

Table 1 gives an overview of the activities.

ID	Area	Name	Duration (months)	Funding Required (k€)
EL1-130	Assured PNT	Robust GNSS Tracker for Sensitive Applications	18	800
EL1-131	Low SWAP	Chip Scale Optical Atomic Clock for PNT applications	24	900
EL1-132	Complementary sensors	Development and Validation of Flexible eLoran/GNSS signal simulator	24	800
EL1-133	Complementary sensors	Resilient PNT by a combined GNSS/eLoran/INS approach for U-space applications	24	800
EL1-134	Disruptive PNT Technology	All-weather Laser Communication Links for Optical PNT Systems	24	700
		Total		4000

Table 1 – Classes of proposed activities and their budget allocations

2. Activities descriptions

2.1. EL1-130: Robust GNSS Tracker for Sensitive Applications

The International Atomic Energy Agency (IAEA) safeguards system is designed to verifying States' legal undertakings to use nuclear material for exclusively peaceful purposes. States declare their nuclear material and activities to the IAEA, and the IAEA verifies the correctness and completeness of these declarations.

This requires robust and resilient GNSS trackers which can withstand sophisticated attacks (jamming, spoofing, and especially treacherous meaconing) and tampering attempts by State-level actors, providing Assured PNT (Trusted positioning data).

The GNSS tracker shall be battery powered and capable of unsupervised operations.

In previous projects (in particular, EL1-077) building blocks for this technology have been developed. The IAEA has expressed interest in a joint project to increase the protection against additional attacks identified and to raise the TRL level and to make the tracker ready for commercialization.

The IAEA will participate in the preparation of the ITT.

The objective of the activity is to study, design, implement and demonstrate a resilient and robust GNSS tracker to support IAEA safeguards activities, and other similar activities requiring Assured PNT

The tasks to be performed shall include:

- Based on EL1-077, the activity will study, design, implement and demonstrate the technologies required for the GNSS tracker, capable of detecting and mitigating jamming, meaconing and spoofing attacks, with focus on concrete uses cases and attacks scenarios identified by IAEA.
- Additional technologies (for example tightly coupled INS and CRPAs) will be integrated into a functional prototype. As part of the demonstration, the prototype will be subject to thorough tests representative of challenging jamming, meaconing and spoofing scenarios mounted by capable attackers.

The activity is part of a roadmap to make available to customers GNSS trackers with Assured PNT and will bring the technology to a TRL which will allow industry to make confident proposals for an Element 2. The activity will not include any Galileo PRS technology, as per NAVISP Declaration.

The main outputs of the activity will consist of:

- Design of jamming/meaconing/spoofing resistant GNSS tracker
- Prototype GNSS tracker, including test bed for evaluation in both nominal and attack scenarios, performance test report and user manual
- Expected RAMS, operations engineering, maintenance and recurrent unit costs
- Roadmap for commercialization, including potential Navisp EL2 activities

It is noted that no Participating State expressed their opt-out for this activity (EL1-130).

<i>Funding required: 800k€</i>	<i>Duration: 24 months</i>	<i>ITT issue: Jun-2026</i>
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2.2. EL1-131: Chip Scale Optical Atomic Clock for PNT applications

As for ground-based high-performance clocks, the exploitation of atomic optical transitions represents a promising approach to improving the accuracy and stability of very compact atomic clocks, down to 10 ns per day, with short- to medium-term stability ten times better (or more) than existing products.

While the main bottleneck of this technology lies in the availability of compact Photonics Integrated Circuit (PIC)-based optical combs, the engineering of the atomic reference module remains a key building block. Furthermore, the ongoing shift toward optical payloads makes the availability of a stabilised optical source a valuable opportunity, readily implementable in the microwave domain once PIC optical combs become available.

The objective of this activity is to study, design, and manufacture a compact optical clock module capable of generating a stabilised optical signal with stability performance at least one order of magnitude better than that of commercial compact microwave clocks (e.g. MAC SA-5x), and with timing performance of a few tens of nanoseconds per day. The clock shall provide an optical output within a compact architecture and with low power consumption (<5W).

The tasks to be performed shall include:

- Detailed design of the compact optical clock module, limited to the physics package. This shall include thermo-mechanical simulations to properly dimension the design and ensure its ability to withstand mechanical loads and thermal environments compatible with harsh applications.
- Specification of requirements for low power electronics to drive and control the optical clock module. This shall include the definition of algorithms for autonomous operation.
- Procurement, manufacturing, and assembly of the compact optical clock module.
- Procurement and assembly of an Electronic Ground Support Equipment (EGSE) capable of mimicking the functionalities of the low power electronics.
- Verification of performance under ambient and thermal conditions.

The activity is targeting ultimately a space clock, but its technology developments could be re-used also for ground applications.

The main outputs of the activity will consist of:

- Engineering Model (EM) of an optical clock module (mainly limited to the physics package).
- EM Test equipment and Data Package.

It is noted that no Participating State expressed their opt-out for this activity (EL1-131).

<i>Funding required: 900k€</i>	<i>Duration: 24 months</i>	<i>ITT issue: Jun-2026</i>
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2.3. EL1-132: Development and Validation of Flexible eLoran/GNSS signal simulator

Global dependence on GNSS for PNT has exposed threats from jamming, spoofing, interference, and space-weather effects. These threats are now widely recognised by defence, maritime, aviation, and critical infrastructure stakeholders as a systemic risk to safety and national resilience.

In response, eLoran has re-emerged internationally as a terrestrial, high-power, low-frequency complementary PNT system, offering fundamentally different propagation characteristics and robustness against GNSS-specific threats. Recent international initiatives, including strong leadership by the Republic of Korea, UK and France demonstrate renewed momentum towards operational eLoran deployment and multinational interoperability, particularly as part of a resilient PNT architecture combining GNSS plus terrestrial backups.

A critical enabler for eLoran adoption is the availability of high-fidelity, flexible signal simulators.

Previous work¹ has demonstrated the feasibility and value of integrated GNSS–eLoran simulators. However, these solutions were hardware centric and monolithic, region-specific (e.g. CONUS-focused), limited test scenarios (e.g. only static mode), not easily adaptable to evolving eLoran standards, modern digital architectures, or modular GNSS simulator coupling.

There is therefore a need for a next generation of flexible eLoran signal simulators, designed from the outset to:

- Be easily synchronised and coupled with existing GNSS simulators,
- Support complex and diversified test scenarios, including modelling of eLoran propagation (e.g. terrain type, urban effects, groundwave/skywave interaction, coastal boundaries, time of day variability),
- Enable future evolutions of eLoran specifications and multinational deployment concepts.

This activity offers a natural synergy with the NAVISP EL3-036bis activity “UK PNT Digital Twin Environment Development – Update Phase 2”. The datasets generated by the proposed eLoran simulator, especially from the record & replay unit, could support future validation steps within the PNT Digital Twin, enhancing the modelling of hybrid PNT architectures and terrestrial resilience layers

The objective of this activity is to design, implement, and validate an eLoran Signal Simulator synchronised with GNSS simulators, enabling the end-to-end testing and validation of hybrid

¹ Johnson, Gregory & Swaszek, Peter & Shalaev, Ruslan. (2009). Development of an Integrated GNSS-eLoran Signal Simulator and NAVISP EL1-o8o

GNSS–eLoran PNT solutions under realistic operational conditions, future-proof system evolution, and resilient PNT testing for manufacturers, integrators, and service providers.

The proposed activity introduces a modular, synchronisation centric eLoran signal simulator in which eLoran operates as a signal source tightly aligned with GNSS simulators.

The tasks to be performed shall include:

- Review of eLoran Signal Definitions: a review of the current status and evolution of eLoran signal definitions. This task will identify the different signal formats currently under consideration and define the requirements for a flexible signal generation framework capable of supporting present and future eLoran signal structures.
- System Architecture and Signal Generation Core: design and implementation of a software-defined signal generation core and overall HW simulator architecture, enabling flexible scenario configuration and synchronisation with GNSS simulators through standard timing interfaces (e.g., 1 PPS and frequency references).
- High-Fidelity Propagation Modelling: Development of a configurable propagation model, including ground-wave propagation, skywave effects and ground/skywave interference, with particular attention to urban environments and terrain-dependent conditions (urban, rural, maritime, mountainous, desert, Arctic).
- Multi-Chain and Multi-Time base Simulation: implementation of support for multiple chains, each synchronised to its respective UTC(k) national timing standard, and simulation of multiple GNSS time bases corresponding to different GNSS constellations.
- End-to-End Validation Capabilities: development of an eLoran/GNSS Receiver Analysis Tool and a record and replay unit, enabling end-to-end validation of the simulator and testing of hybrid PNT algorithms.
- Simulator Fidelity Validation: validation of the simulator by comparing simulated signals with live signals collected in representative environments.

The main outputs of the activity will consist of:

- A functional Signal Simulator prototype, a unit for record and replay of eLoran and GNSS signals, an eLoran/GNSS Rx Analysis Tool enabling end-to-end validation
- A configurable eLoran propagation modelling framework, including urban and ground/skywave interaction models
- A report on current and emerging eLoran signal definitions
- Validated integrated GNSS–eLoran test scenarios
- A EL1 → EL2 roadmap, identifying steps toward higher TRL equipment

It is noted that Italy expressed their opt-out for this activity (EL1-132).

<i>Funding required: 800k€</i>	<i>Duration: 24 months</i>	<i>ITT issue: Jul-2026</i>
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EL1-133: Resilient PNT by a combined GNSS/eLoran/INS approach for U-space applications

EC Regulation 2021/664 defines a minimum set of requirements for the Unmanned Aircraft Systems (UAS) operations in certain geographical zones, which is called U-space. U-space defines new services relying on a high level of digitalisation and automation, designed to provide access to airspace for large numbers of unmanned aircraft.

Emerging U-space Beyond Visual Line of Sight (BVLOS) operations, e.g., infrastructure inspection, delivery services, search and rescue operations, etc. increasingly depend on trusted, high-accuracy and resilient PNT, but GNSS-centric solutions remain vulnerable to interference, spoofing, jamming, multipath effects and PPP-convergence limitations. Galileo OSNMA provides authenticated navigation messages, Galileo HAS enables high-accuracy positioning and eLoran offers a robust terrestrial timing layer, however, no integrated concept currently combines these elements into a unified architecture meeting U-space integrity, continuity and availability requirements.

Note that NAVISP has funded projects for the development of compact H-field eLoran antennas and GNSS/eLoran integrated receivers, whose concept could be useful for this activity.

The objective of this activity is to define a hybrid PNT concept that leverages Galileo signals authenticated by OSNMA, high-accuracy corrections provided by HAS, a terrestrial timing layer from eLoran, a barometer for altitude estimation and Inertial Navigation Sensors (INS) to enhance PNT resilience for future U-space applications.

The tasks to be performed shall include:

- The concept aims to illustrate how timing-aided hybridisation could accelerate PPP convergence, improve resilience to GNSS interference and spoofing, support GNSS-fault detection, and provide PNT-health indicators suitable for U-space functions such as Remote ID, Flight Authorisation and Geo-awareness. The focus is on outlining feasibility, potential performance benefits and operational relevance. The concept investigates a loosely coupled, timing-aided hybrid PNT stack integrating OSNMA, HAS, eLoran timing and INS to support resilient navigation in future U-space environments.
- The concept also considers the research needs including authentication-aware integrity, GNSS/eLoran timing coherency validation, PPP convergence and re-convergence behaviour, data-driven eLoran analysis and the definition of KPIs and test methods for a hybrid-PNT performance assessment. An UAV-based hybrid-PNT demonstrator at conceptual level will serve as an illustrative TRL 4 pathway to explore feasibility and potential benefits.

The approach considers eLoran compact H-field antennas or similar, a horizontal accuracy of 10m (vertical accuracy not being very important for eLoran time transfer, even though the inclusion of a barometer or similar for the altitude estimation is considered necessary). The technology development activity will be defined in compliance with the EU Regulation 2021/664 on U-space.

The main outputs of the activity will consist of:

- a conceptual framework for timing-aided hybrid PNT, including architectural principles, integrity and timing coherency mechanisms, potential benefits for U-space services, and guidance for future research;

- outline of performance-relevant KPIs, identification of reference datasets and test methodologies needed for evaluating hybrid PNT, and definition how to support future Specific Operations Risk Assessment (SORA)-considerations and Remote ID records in evaluation contexts;
- considerations to inform future higher-TRL development of resilient hybrid-PNT solutions.

It is noted that Italy expressed their opt-out for this activity (EL1-133).

<i>Funding required: 800k€</i>	<i>Duration: 18 months</i>	<i>ITT issue: Sep-2026</i>
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2.4. EL1-134: All-weather Laser Timing and Ranging Links for Optical PNT Systems

Optical laser communication links from satellite to ground are affected by atmospheric conditions. When penetrating through clouds, optical signals suffer from power degradation up to complete loss of the satellite-to-ground link. As a result, optical ground stations (OGS) as used in the OpSTAR activity are not able to establish optical links continuously but will instead have data gaps. The availability of optical time synchronisation and ranging data is therefore dependent on the location of an OGS and the local weather conditions.

Solutions to enhance the performance of optical communication systems in cloudy conditions are proposed in current literature (see the Reference Documents paragraph below). These studies have successfully proven in laboratory environments that penetration through fog and clouds is possible using Femtosecond Laser Filaments. The filament creates an air waveguide that displaces water droplets in its immediate vicinity to create a cylindrical channel within which the laser signal beam can travel unobstructed.

The objective of the proposed activity is to study and demonstrate the use of innovative signal generation techniques for the transmission of optical timing and ranging signals in all-weather conditions.

The tasks to be performed shall include:

- suitability analysis for cloud/fog penetration techniques applied to laser communication in future PNT systems
- demonstration of selected cloud/fog penetration technique(s) in a laboratory environment with a focus on long-range experiments suitable for beam transmission at optical ground stations used for ground-satellite laser communication
- demonstration of the feasibility of applying the technique for transmission of timing and ranging signals in all-weather conditions in outdoor experiments, including consideration of high-power laser safety and security constraints (e.g. with aviation authorities)

The main output of the activity will consist of:

- Survey of current studies and suitability analysis of cloud-clearing laser signal generation techniques applied to future optical navigation systems such as OpSTAR
- Test reports comparing the performance of optical signal transmission using laser signals with and without cloud clearing in different atmospheric conditions, including experimentations in real-world scenarios (e.g. using drones as laser reception terminals)
- Roadmap for TRL increase of the new techniques for usage in future PNT systems, including potential NAVISP EL2 activities.

Reference Documents for this activity are:

- RD1: Schimmel et al. 2018: Free space laser telecommunication through fog, *Optica* 5, 1338-1341, <https://doi.org/10.1364/OPTICA.5.001338>.
- RD2: Wang et al. 2023: Structured light signal transmission through clouds, *J. Appl. Phys.* 133 (4): 043102, <https://doi.org/10.1063/5.0129902>.

- RD3: Li et al. 2024: Real-Time Demonstration of Multi-Gigabit/s Free- Space Optical Communications Employing Femtosecond Laser Filaments in Complex Environment, J. Lightwave Technol. 42, 4402-440, <https://opg.optica.org/jlt/abstract.cfm?uri=jlt-42-13-4402>.
- RD4: Moreno 2024: Long range filamentation for cloud clearing, Chapter 5 of Phd Thesis, <https://doi.org/10.13097/archive-ouverte/unige:180749>, using equipment and experiments conducted in the frame of H2020 ID 737033 "Laser Lightning Rod project (LLR)", see <https://llr-fet.eu/>

It is noted that Italy expressed their opt-out for this activity (EL1-134).

<i>Funding required: 700k€</i>	<i>Duration: 24 months</i>	<i>ITT issue: Oct-2026</i>
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3. Work Plan 2026 Addendum activities schedule

Table 2 summarizes the timeline for all the activities, including the Work Plan 2026 activities, considering the expected date for the Invitation-To-Tender (ITT) issue, the negotiation process and the Contract award and execution.

