

navisp: Element 1 Work Plan 2024

January 2024



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→ THE EUROPEAN SPACE AGENCY

nausp Element 1 Objectives

Perform feasibility studies and viability analysis for the emergence of new concepts in the PNT world (both upstream and downstream)

Contribute to the formulation and implementation of PNT technology strategies and roadmaps

Prove concept of promising PNT-based services



- analysis of technical journals articles and worldwide patents
- other organisations' technical and market reports
- participation to conferences and ESA TECNET NAV
- interaction with Program's stakeholders
- review of the State of the Art in PNT technology/product/services
- analysis of the most important trends in PNT
- identification of PNT gaps that needs to be filled



- EL2: co-fund EOs activities when applicable/relevant
 - Thematic windows to steer gently EOs
- EL1: establishing a plan of activities to develop the PNT technology identified
- EL3: align with Participating States vision



Summary trends in PNT

- **Quantum technologies** (Photonics optical gyro, inertial [accel/ang vel] and magnetic sensors, optical clocks)
- **Precise positioning** (PPP-AR, PPP-RTK)
- **Sensor fusion** (GNSS/INS/Visual/LiDAR/Bluetooth/5G/UWB/Magnetic/Vibration) and its integrity - Role of **maps**
- **Autonomy**
- **Artificial Intelligence** (Machine Learning)
- Indoor navigation
- **Meta-signals**, DPE, VTL, **Factor Graphs**, Particle filters, super-resolution/synthetic aperture receiver
- **LEO satcom/5G Signals of Opportunity** - **5G/6G Positioning Reference Signal (PRS)** (NTN)
- Doppler processing
- **RFI** Detection/Characterisation/Mitigation/**Monitoring** for GNSSs: several initiatives ongoing, e.g. push for **antenna arrays** in US for GPS and for PRS in EU
- Pulsar



Work Plan 2024

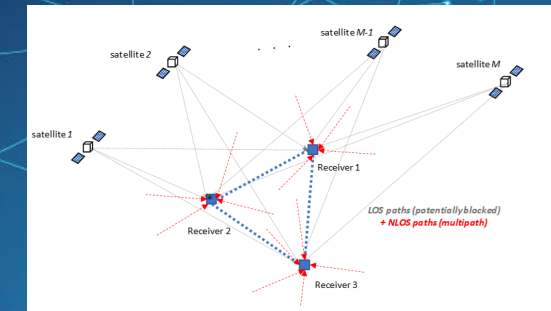
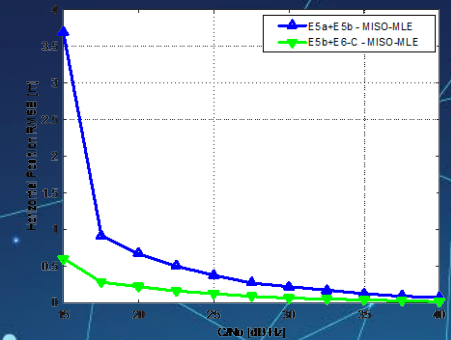
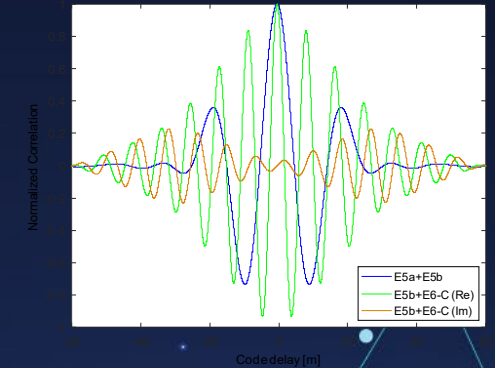


Activity Name	Budget (k€)	Rationale
Instantaneous High-Accuracy Positioning based on Hybrid-Meta-Signal Solutions	600	Advances understanding of meta-signal processing with real data
Verifiable AI/ML techniques for PNT applications	400	Supports usage of AI in PNT applications requiring high integrity
Proof-of-concept of advanced navigation algorithms based on factor graph optimization	600	Supports adoption of factor graph processing techniques
Modelling Quantum Sensors in a realistic navigation system context	400	Promotes Quantum technologies integration in PNT systems
Robust Navigation for Autonomous Driving with Low-Cost/SWaP Arrays of Antennas	500	Advances technologies underlying Autonomy for vehicle applications
Proof-of-concept of SOOP with broadband satcom signals in Ku/Ka-band	800	Advances LEO satcom Signals of Opportunity processing
Integrity in 5G Private Networks for Industry 4.0	750	Prove the concept of 5G Private Networks for PNT in industrial contexts
Enabling PPP ambiguity resolution in satellite and terrestrial frequency-varying carrier-phase signals	500	Advances understanding of PPP-AR with LEO satcom Signals of Opportunity
High-accuracy formation flying technologies for future distributed space instruments	600	Develops elements for Precise Positioning in satellite constellations
Exploitation of Geo-spatial Data for Automated Vehicles	600	Advances usage of geo-spatial information like Visual/Lidar datasets, maps (including height data), and building models to improve PNT for automated vehicles
Advanced visual INS for high-end handheld devices	450	Prove the concept of the integration of INS with Visual dataset
Use of ML techniques to optimize the adaptive beam-steering capabilities of CRPAs for GNSS user receivers	800	Applies Machine Learning techniques to the design of antenna arrays
Metrics to Assess the Performance of GNSS Authentication Schemes	400	Assess the performance of GNSSs against the threat of RFI
Location, Tracking and Salvage support of lost shipping containers at sea	500	Applies Sensor Fusion to the solution of an economic and environmental problem

Meta-signal processing has raised interest in order to enable the achievement of high-accuracy solutions based on the **joint exploitation of 2 or more signal components as a single composite signal**. The drawback of this approach is the appearance of multiple correlation peaks, inducing potential biases in the meta-signal pseudoranges when operating in harsh environments.

On the other hand, **collaborative positioning exploiting peer-to-peer ranges**, for example based on WiFi-Round Trip Time (RTT)/UWB, is a potential candidate to allow positioning in harsh conditions, including indoors.

In this context, **hybrid solutions exploiting both meta-signals and peer-to-peer ranges** are expected to enable the robust and unambiguous exploitation of meta-signals in urban-to-indoor scenarios.



Activity Description

Objective: To study, design, implement and demonstrate the achievement of instantaneous high-accuracy positioning based on hybrid solutions exploiting both meta-signals and peer-to-peer ranging.

Description of innovation/Tasks: The activity will study, design, implement and demonstrate hybrid solutions **exploiting meta-signals and peer-to-peer ranging for achieving instantaneous high-accuracy in urban-indoor conditions**. As part of this study, new WiFi technology (based on the IEEE 802.11az standard and exploiting bandwidths > 160 MHz) shall be benchmarked against UWB and 5G (optional) to serve as source for peer-to-peer ranging. Meta-signal exploiting existing legacy signal combinations and peer-to-peer ranges considering different mass-market technologies are to be considered. The potential benefits and applications of the proposed solutions are to be assessed in different user environments and use cases based on **test campaigns with real measurements**.

Expected output:

- Definition and design of innovative hybrid meta-signal solutions
- **Breadboard** and test report
- Roadmap for commercialization, including potential Navisp EL2 activities

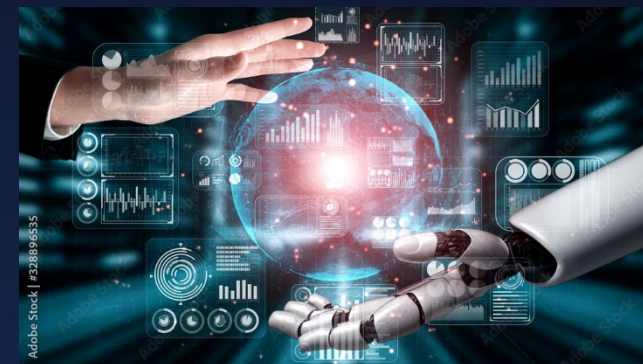
Duration: 18 months

Budget: 600 k€

Verifiable AI/ML techniques for PNT applications

Background and Rationale

Artificial intelligence (AI) is increasingly utilized in the PNT field, enhancing the performance and reliability of GNSS (Global Navigation Satellite Systems) systems, from RF interference detection and mitigation, to sensor fusion. The advancement and ever-increasing size of neural networks increase the complexity of applications supported by AI, and with the increasing complexity, verifiability decreases. Unreliable or biased AI systems can have serious consequences, risking both the environment and human lives, especially in domains like autonomous vehicles, Unmanned Aerial Vehicles (UAVs), and marine applications.



To overcome concerns about data biases, insufficient data, and lack of transparency, effective techniques such as data augmentation, transfer learning, and Explainable AI (XAI) methods can be employed. However, addressing issues like inaccurate specifications and algorithmic biases is even more crucial to avoid incorrect and undesirable outcomes. Therefore, it is essential to develop methods that can verify the behaviour of AI systems.

Verified AI, as defined by the Association for Computing Machinery (ACM), seeks to design AI systems that provide robust assurances, ideally with provable correctness based on mathematically specified requirements. This approach is crucial to ensure reliable and trustworthy operation of AI systems in PNT applications.

Verifiable AI/ML techniques for PNT applications

Activity Description



Objective: Study the viability of integrating verifiable artificial intelligence and machine learning (ML) techniques to enhance PNT applications.

Description of innovation/Tasks:

- Review of the state-of-the-art verifiable AI techniques and design processes for ML systems in PNT domain
- Develop verification algorithms based on formal specification and formal verification methods to enhance trust and verifiability in AI systems operating in the PNT field, where the human-AI interaction at design level is instrumental in ensuring reliable and transparent performance for the human agent.
- Develop a simulator to test few specific use cases in complex environments e.g. sensor fusion
- Design a demonstrator to evaluate the performance of the developed verified AI algorithms for PNT

Expected output:

- Design and development of verifiable AI/ML architectures and algorithms applicable in the PNT domain for autonomous systems applicable for e.g. maritime, road, railway or aviation
- Simulator and demonstrator to assess the verified AI algorithms in challenging environments
- Recommendations for best practices for testing AI for PNT applications

Duration: 18 months

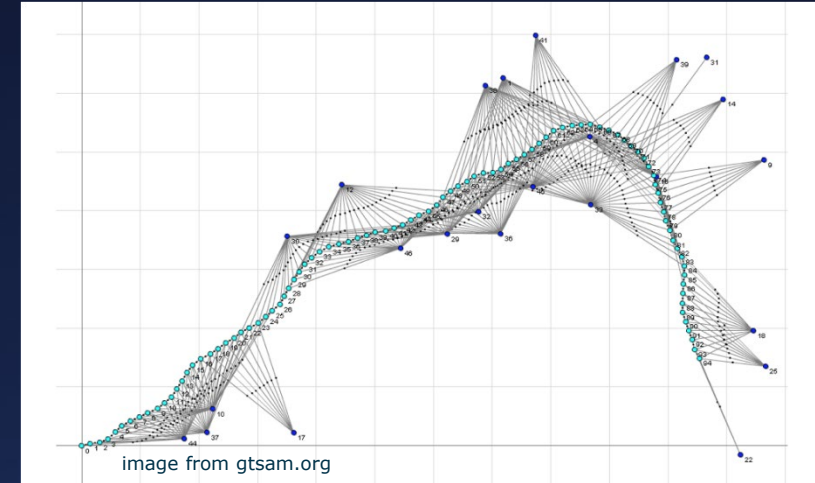
Budget: 400 k€



Factor graph optimization is gaining attentions from the community (**it has won the Google challenge**) as is outperforming traditional positioning algorithms.

Factor graph optimization may be used to **replace the traditional Weighted Least Square (WLS) or Kalman Filter (KF)-based solutions**, both in stand-alone and hybrid positioning solutions in combination with Sensors, as well as for ambiguity resolution.

Thus, its application may be **of interest for the derivation of improved positioning solutions for different receiver grades**, including low-end/quality mass-market receivers, and high-accuracy solutions requiring ambiguity resolution.



Activity Description

Objective: To investigate **innovative navigation algorithms exploiting factor graph optimization**, both standalone and in combination with other **sensors**, and for different receiver grades, including **low-quality observables** and **ambiguity resolution for high-accuracy**.

Description of innovation/Tasks: The activity will cover the application of factor graph optimization for improving the performance obtained with traditional KF-based solution and ambiguity resolutions in different user scenarios, in particular: a) when exploiting **GNSS observables from different receiver grades** (from high-end to low-quality / mass-market receivers for smartphone/IoT applications), and no data of other sensors; b) when applied for **integrating GNSS with other sensors** (different types and grades, including, but not limited, inertial sensors); and c) in the presence of different user conditions, including harsh propagation scenarios typical of urban and indoor environments. The benefits provided will be assessed based on **real field measurement campaigns and observables from commercial/mass-market receivers**.

Expected output:

- Design of innovative positioning solutions based on factor graph optimization for different receiver grades
- **Testbed** including commercial/mass-market receivers and test report
- Roadmap for commercialization, including potential Navisp EL2 activities

Duration: 18 months

Budget: 600 k€

As well as the potential next generation quantum time and frequency sources, the world of quantum systems offers the prospect of gyroscopes, accelerometers, gravitational sensors and magnetometers based on quantum effects. Predictions of the performance of these new quantum sensors offer the prospect of accurate navigation without GNSS for long periods of time with some predicting that GNSS will no longer be necessary.

However few models exist to be able to test and show the potential impacts of quantum-based technologies when integrated into a navigation system. Where modelling capabilities exist, they do not factor in realistic environments and dynamics and all potential sources of noise or error that might exist in a mobile system. Similarly, much of the experimentation with quantum sensors for navigation has been laboratory based and there is little experimental evidence of performance in the real world and the degradations that might occur when quantum sensors are integrated into a complete PNT solution.



Objective: To develop new models for end-to-end navigation solutions that incorporate quantum sensors and account for real world environments and dynamics.

Description of innovation/Tasks: The models for the quantum sensors in this context may need to be supported by laboratory or even field experiments. The state-of-the art in US Quantum PNT has to be considered as a starting point. The objective is to provide realistic estimates of the improvement or otherwise in performance of PNT systems that might be achieved by incorporating quantum sensors.

Expected output:

- Survey of state of the art on quantum sensors and their models
- New models development and their incorporation in PNT systems

Duration: 18 months

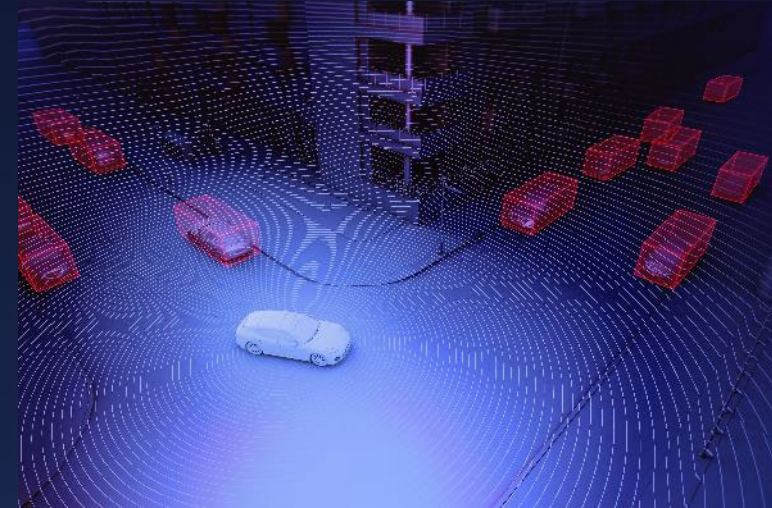
Budget: 400 k€

The derivation of **robust positioning solutions under harsh propagation conditions** typical of autonomous driving applications remains an open problem in GNSS.

The application of **MIMO-GNSS-like processing approaches for robust GNSS positioning with low-cost arrays of antenna platforms** has shown important benefits in the presence of obstruction, fading and multipath conditions, and can be exploited as well for the mitigation of interference and jamming. The introduction of a larger number of antenna elements, even if low-cost, allows to improve the PNT solution.

In this context, the signals received from **array antenna configurations** are proposed to be exploited in the position domain (via **Direct Position Estimation**), including the exploitation of **undesired spatially-correlated signal contributions** from different elements, and received from different satellites.

This is to be done exploiting **low-cost arrays of antennas in vehicular applications and targeting low-Size Weight and Power (SWaP) processing platforms**.



Activity Description

Objective: To study, design, implement and demonstrate the achievement of robust positioning solutions for autonomous driving with low-cost arrays of antennas in low-SWaP platforms, via the **exploitation in the position domain (via Direct Position Estimation) of undesired spatially-correlated signal contributions from different elements, and received from different satellites.**

Description of innovation/Tasks: The activity will study, design, implement and demonstrate **robust positioning solutions** for autonomous driving based on the exploitation in the position domain of spatially-correlated signal contributions from different elements, and received from different satellites, **with low-cost arrays of antennas in low-SWaP platforms.** The potential benefits in different vehicular user environments and dynamics is to be assessed for different array configurations (from few elements to above 10 elements) based on **test campaigns with real measurements.** A car manufacturer should be included in the consortium to discuss and facilitate adoption of the solution.

Expected output:

- Innovative **solutions in the position domain exploiting undesired spatially-correlated signal contributions**
- **Breadboard** and test report
- Roadmap for commercialization, including potential Navisp EL2 activities

Duration: 18 months

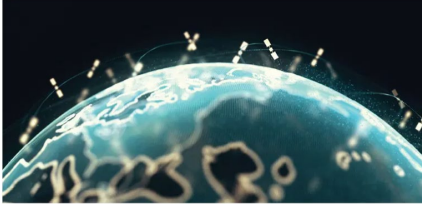
Budget: 500 k€

TRANSIT on Steroids: Doppler-Based GNSS Meets Large LEO Constellations

December 7, 2020

By Inside GNSS

[f](#) [t](#) [in](#)



The advent of large LEO constellations is a game-changer for navigation. A key feature of these constellations is their potential to allow simultaneous measurement of Doppler shifts from a large number of satellites.

It may be possible to exploit their downlink communication signals for navigation with little or no modification. The GDOP analysis and the batch filter results on simulated data both indicate absolute navigation performance similar to that of current pseudorange-based GNSS.

MARK L. PSIAKI AND BRIAN McLEMORE, VIRGINIA TECH

A white, rectangular device with rounded corners, featuring the Intelian logo in blue and the Red Hat logo in red. The device is shown from a slightly elevated angle, highlighting its sleek design.

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Objective: To develop and demonstrate User Technology for PNT with broadband signals of opportunities from LEO satcom, tailored to real world applications.

Expected output:

- Thorough survey of SOOP with broadband satellite signals
- Design of solutions tailored to representative use cases, resulting breadboard and test report
- Roadmap for follow-up (e.g., commercialization via potential Navisp EL2 activities), associated to lessons-learned useful for ESA's LEO PNT activities (e.g., FutureNAV, etc.)

Budget: 800 k€

Integrity with 5G Private Networks for Industry 4.0

Background and Rationale

5G private networks, also known as 5G non-public networks, have been of interest to industrial applications, such as smart manufacturing, process automation, or logistics, supporting the Industry 4.0 revolution across all verticals. Besides requiring ultra-reliable and low-latency communication, many emerging industrial use cases require high-accuracy and trustworthy positioning. These use cases include asset tracking, collaborative mobile robots, or autonomous machines.

The expansion and optimisation of 5G private networks to complement the accuracy and availability performance with integrity commitments will strengthen the position of 5G PNT and enable its use for new, more demanding use cases. Provision of integrity with 5G private networks will require detailed understanding of the contribution of network elements to the positioning performance (e.g., fault modes characterization) along with necessary commitments, adequate system architectures, and key performance indicators.



Integrity with 5G Private Networks for Industry 4.0

Activity Description



Objective: The objective of the activity is to study and demonstrate system architectures, solutions, error budgets, and fault modes within 5G private networks enabling integrity for Industry 4.0.

Description of innovation/Tasks: The activity will provide innovative system solutions, novel fault mode characterizations, and recommendations/guidelines for enabling integrity with 5G private networks for Industry 4.0.

Expected output: As the output, the activity will provide:

- Innovative system architectures and solutions of 5G private networks.
- Error budgets, fault mode characterization, and relevant key performance indicators.
- Technical means to allow demonstration of the developed solutions.

The activity will also foster the adoption of 5G private networks for integrity-related applications within Industry 4.0 and will prepare industry to the use of 5G/6G also in other network, like Non Terrestrial Network (NTN).

Duration: 24 months

Budget: 750 k€



Enabling PPP ambiguity resolution in satellite and terrestrial frequency-varying carrier-phase signals

Background and Rationale

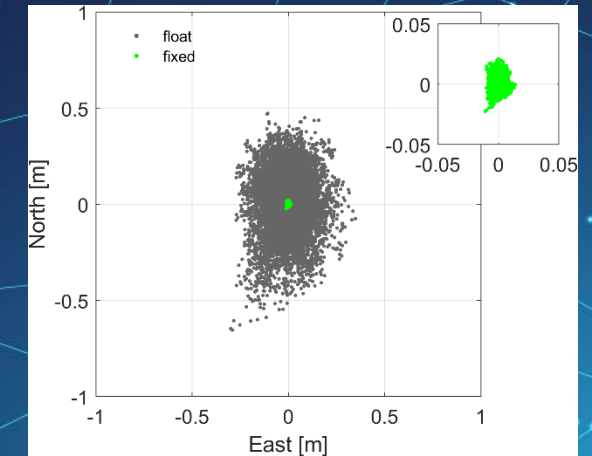
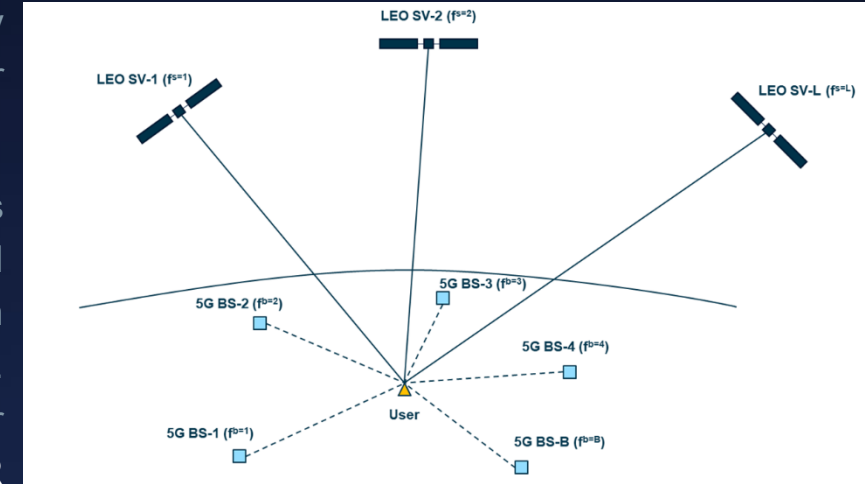
The Integer Ambiguity Resolution (IAR) enabled Precise Point Positioning (PPP) concept, namely PPP-AR, has proven to be capable of delivering centimetre-level positioning for CDMA-based GNSSs, i.e., when the satellites transmit signals on identical frequencies.

The recent developments of Low Earth Orbit (LEO) constellations for communication purposes (e.g., Iridium, Starlink) have raised an interest in the navigation domain. The stronger signal reception levels on the ground and the fast geometry change offered by the LEO satellites can strengthen the user model and lead to **ultra-rapid PPP convergence times** to the cm-level. Furthermore, the pivotal advantages of 5G signals in terms of their larger bandwidth and higher frequencies can serve in **realizing non-GNSS PPP-AR** and in **augmenting GNSS PPP-AR** positioning, thereby providing new navigation opportunities.

This comes at the cost of processing **carrier-phase signals with frequency diversity among terrestrial and satellite transmitters** (LEO, 5G, etc.), which prevents the users from forming the conventional double-difference ambiguities and, therefore, from fixing them to their integers.

Therefore, there is the need to tackle this challenge in order to achieve rapid and ubiquitous centimetre-level positioning with:

- non-GNSS frequency-varying carrier-phase signals for **alternative PPP-AR**, and
- GNSS/LEO/5G frequency-varying carrier-phase signals for **augmented PPP-AR in challenging user environments**.



Enabling PPP ambiguity resolution in satellite and terrestrial frequency-varying carrier-phase signals

Activity Description

Objective:

- Definition, implementation and test of algorithms for enabling **high-accuracy positioning with IAR in frequency-varying carrier-phase signals**
- Development of a proof-of-concept demonstrator for a **GNSS/LEO/5G PPP-AR user positioning setup**

Description of innovation/Tasks:

- State-of-the-art review on the integer-estimability concept in transmitter-dependent carrier-phase measurement systems (checking in particular Ku/Ka-Band signals link budget, phase offset for array antennas, potential PPP correction network)
- Investigation, definition, design and trade-off analysis of the network and user algorithms to support the full exploitation of frequency-varying carrier-phase signals for IAR-enabled positioning targeting the GNSS/LEO/5G user applications in challenging environments
- Development of a measurement generator for GNSS, LEO and 5G signals suitable for positioning applications
- Development of a software prototype for a) network correction generation and b) PPP-AR positioning using integrated GNSS, LEO, 5G carrier-phase signals with frequency diversity
- Prototype verification and performance assessment with representative synthetic measurements for various network configurations and challenging user environments
- Definition, realization, and assessment of 5G and/or LEO test cases with real-world carrier-phase measurements

Expected output:

- Data package (reports, algorithms, results, etc.) providing a complete understanding of the achievable capabilities of **IAR-enabled positioning based on frequency-varying carrier-phase signals**
- **Emulated real-time PPP-AR post-processing software** and user manual

Duration: 18 months

Budget: 500 k€

Distributed Instrumentation in space = Opportunity for most space domain: Science, Earth Observation, Exploration, and also Telecom (array of satellites). Many concrete examples :

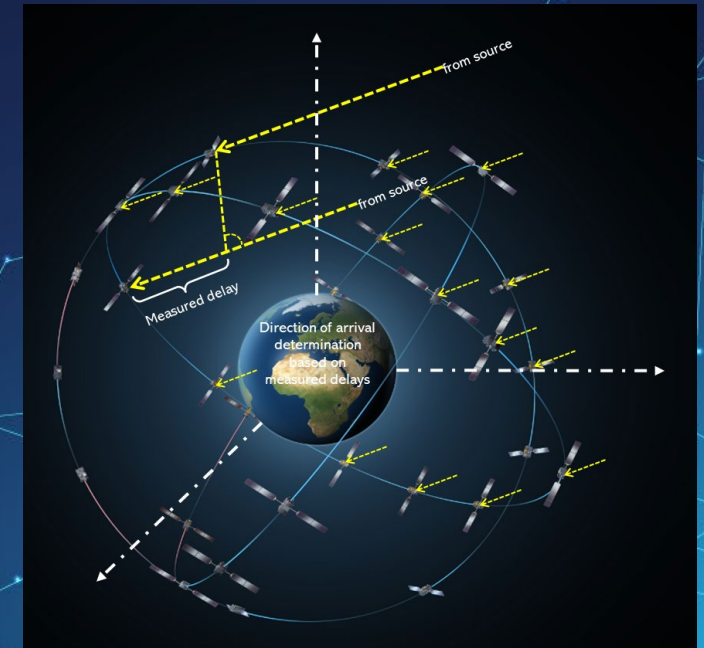
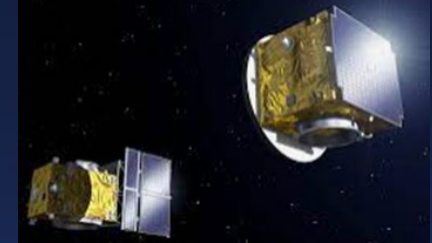
- Science = SKA, ALMA, seismology, etc.
- Telecommunication: 5G/6G massive MIMO concept
- Grace / Grace-FO and Proba-3 missions

Expected acceleration of opportunities and demands for distributed instruments in space, attracted by large volume of cheap small satellites (New Space paradigm)

Key drivers: accurate knowledge on satellite relative positions, clocks and attitude

- Need to update and expand state-of-the-art beyond Proba-3 for very long baseline, beyond 100 km. Challenges : technology trade-offs (RF or optical), 3D formations (so far, most demonstration related to 1D)

Opportunity for Europe and DNAV: development of enabling technologies for next generation formation flying solutions and inspire new missions relying on distributed instruments.



Activity Description

Objective: To investigate most promising concepts for ultra-accurate formation flying systems with long baseline in support of distributed instruments in clusters of satellites, and initiate the proof of concept with the most critical key technological enablers

Description of innovation/Tasks: The activity will study and design concepts aiming to enable one order of magnitude improvement in terms of satellite formation flying technologies in Europe and establish new frontiers in terms of state-of-the-art (e.g., beyond Proba-3 demonstration, for very long baseline up to and beyond 100 km still with mm-level or better accuracies). The concept will be validated with the demonstration of the critical enabling technologies such as ranging with RF or optical links. The analysis will trade the nature of the link between RF and optical, for different ranges of accuracies mapped to representative use cases, and depending on the trade-offs, critical elements of that relevant link will be demonstrated (RF or optical). Frequency combs might be considered in optical systems.

Expected output:

- Survey of state of the art, study of the possible concepts, enabling technologies and associated trade-offs
- Breadboards of the critical elements and technologies
- Roadmap for technology maturation up to in-orbit demonstration, for instance in the context of future DNAV programmes (e.g FutureNAV)

Duration: 24 months

Budget: 600 k€

The provision of ubiquitous, high-quality, positioning, navigation, and timing information, and the full situation awareness of the environment, belong to the main challenges for Connected, Cooperative and Automated Vehicles, that need to be countered in the future. **Geo-spatial datasets capturing the topographic surface of the Earth and its overlying features, such as building and roads**, can provide information not only for the static environment surrounding a moving agent, but also to **assist the navigation engine** into providing accurate and trust-worthy position fixes.

Several research works have demonstrated the value of incorporating **height information provided by Digital Elevation Models**. **Road Network data**, on the other hand, comprise already an important element of commercial in-vehicle navigations units, and in conjunction with **map-matching algorithms** can reduce the accuracy of GNSS position fixes down to the road-level (i.e., 2-5m), even in deep-urban environments.

Finally, pre-computed **3D Building Models**, **ray-tracing** and **feature matching algorithms** offer the unique opportunity of exploiting (instead of detecting and excluding) Non-Line-Of-Sight measurements for positioning purposes, thus eliminating the last critical barrier that degrades the performance of GNSS receivers in challenging environments (e.g. urban).



Activity Description

Objective: The objective of this activity is to define and demonstrate the **exploitation of Geo-spatial data for Connected, Cooperative and automated vehicles**, and identify the key enabling technologies, together with their maturity state, for its realisation.

Description of innovation/Tasks: The main innovation element of this activity will be the detection, and more importantly cost effective and computationally efficient exploitation of heavily biased GNSS measurements for accurate positioning in urban/deep-urban environments, with the **aid of a multitude of geo-spatial datasets**. **User-terminal algorithms** are to be developed for the **computationally efficient consumption of geo-spatial datasets** by the positioning engine. Existing European space assets (e.g., Copernicus mission), but also novel imaging/reconstruction techniques for the generation of relevant geo-spatial products that can be upscaled to future ESA missions are to be considered.

Expected output:

- Survey of state of the art on **geo-spatial data products** generation methods and instruments
- An end-to-end software emulator of the overall high-accuracy service
- Roadmap for large scale service provision of geo-spatial data products for positioning applications

Duration: 24 months

Budget: 600 k€

- Significant progress of image processing technologies onboard handheld devices, currently deployed on high-end products such as tablets:

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- GNSS
GPU / AI
Etc.
- Barometer
Accelerometer
- Multiple
cameras

GNSS,
GPU / AI
Etc.

Barometer
Accelerometer

Multiple
cameras

Microphone

- 

→ THE EUROPEAN SPACE AGENCY

Advanced visual INS for high-end handheld devices

Activity Description



Objective: to demonstrate advanced navigation engine for handheld devices, combining vision-based navigation derived from multiple cameras onboard with other PNT sensors available in high-end handheld devices

Description of innovation/Tasks:

- Survey state-of-the-art (e.g. Visual INS, handheld sensors, SLAM for AV) and define preferred use cases plus performance targets
- Define and design solutions for proof of concept, with tailoring of existing technologies for automotive and robotic domain to handheld needs and capabilities, Incremental and agile development (innovative tailoring, optimisation) leveraging ability to perform small scale field trials during design and development phases using available hardware and evaluation platforms.
- Proof of concept (TRL5) in real world conditions, but non-real time processing, sizing of additional effort to implement algorithms real time (optimisation of onboard resources and graphical processing units)
- Road-map to commercial products

Expected output:

- Survey of state of the art on Visual INS and SLAM processing for handheld devices
- Breadboard and test report
- Roadmap for commercialization, including potential NAVISP EL2 activities

Duration: 15 months

Budget: 450 k€



Background and Rationale

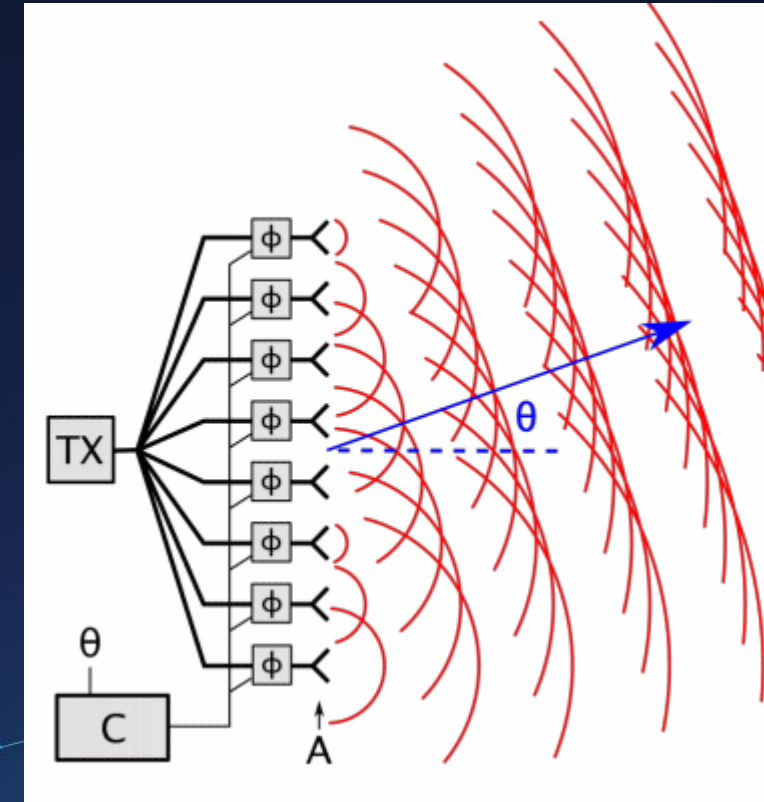
Controlled Reception Pattern Antennas (CRPAs) in GNSS receivers are known as a fundamental resource for jamming and spoofing counteraction; they are excellent for multipath mitigation too as well as NLOS signals exclusion. CRPAs in L-band impose arrays with significant dimensions (more than four antenna elements quickly reaching square-meter areas).

Further improvements can be obtained if a more complex architecture based on space-time adaptive processing (STAP) or space-frequency adaptive processing (SFAP) is used. This generally allows much higher levels of jammer cancellation against a wider range of threats.

Compact arrays, with inter-element spacing significantly lower than the half-wavelength, reduce the physical dimension at the cost of suboptimal spatial filtering performance; on the other hand, the loss can be balanced thanks to an increased number of elements ("dense" array). A trade-offs between narrow inter-element spacing and number and placement of antenna elements is worth investigation.

Real-time adaptive beam-steering capability is necessary to maximize the efficiency of the spatial filtering, since the directions of the signals of interest and of the interferers to suppress are unpredictable and vary over the time.

In the perspective of boosting the potential effectiveness of CRPAs for GNSS receivers, advanced real-time adaptive architectures with medium number of antenna elements, compact dimensions, and possibly space-time adaptive processing, are extremely promising with the specific purpose of interference, spoofing and multipath suppression. However, because of the considerable number of variables to adapt in real-time, such an optimization problem is complex to model and to resolve in an efficient way.



Activity Description

Objective: To investigate the usage of Machine Learning (ML) algorithms for smart antenna arrays design, which has been recently discussed in an increasing number of publications, typically addressing the communication domain (5G/6G in particular).

Many ML algorithms exist, e.g. multi-objective genetic machine learning, multi-label convolution neural network, Support Vector Machine algorithms, etc.. However, a clear consensus about the best choice for antenna array optimization has not been reached yet. Furthermore, the training model for the problem of optimizing the space-temporal filtering capability of a compact array, in the presence of unpredictable and time-variant signal geometry, still needs to be identified. Effectiveness of a ML design has to be proven with respect to more conventional CRPAs.

Description of innovation/Tasks: The proposed activity targets a new approach in the real-time adaptive control of CRPAs for GNSS, based on the use of ML to optimize in real-time the CRPA space-time filter coefficients. The possible use of dense arrays should will be investigated, with trade-off analysis with respect to conventional CRPAs. In the ML context, objectives should be the formulation of the optimization problem, the definition of the training model and generation of the datasets.

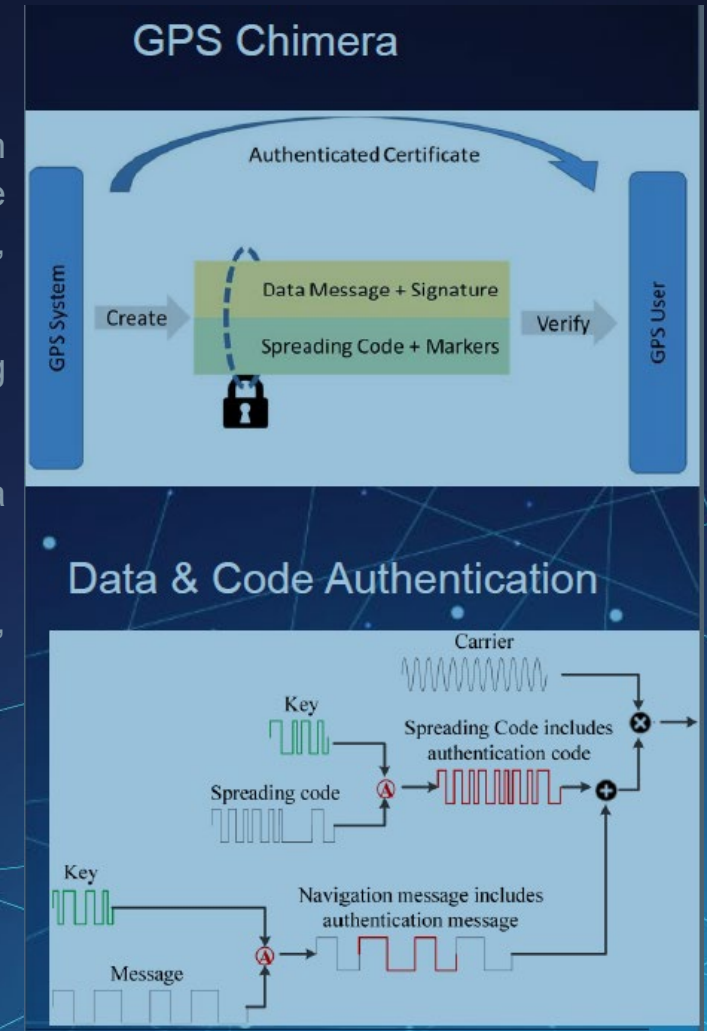
Expected output:

- Choice of the best ML algorithm family for the adaptive CRPA control
- Trade-off analysis of the addressed CRPA architectures
- ML training model formulation and guideline for the generation
- ML training datasets definition (examples for a few relevant cases)

Duration: 24 months

Budget: 800 k€

- All 2nd Generation GNSS are making use of Authentication (civil signal anti-spoofing).
- The potential spoofing attack vectors are known: Meaconing, record & replay, fake-signal generation.
- Different Authentication schemes (system level) will be used and applied as counter-measures in addition to user related measures. However, a gap exists in the evaluation methodology of the robustness performance: it is unclear how the authentication methods perform against meaconing, replay and fake attacks in a quantitative way.
- The focus of the project is to develop a single or a set of metrics to measure the anti-spoofing performance of GPSIII(Chimera), BDS III, QZSS.
- Possible authentication metrics (J. Anderson et al. CHIMERA for GPS civilian signals, 2023) as a starting point could be:
 - System openness (keys), Time-to-First authenticated channel, Time between- Authentications, bit-strength, correlation loss, authentication error-rate, ...
- For comparison Galileo (G1G) NMA and CAS could be used as a reference



Objective: Develop, test and verify a methodology to evaluate the performance of GNSS authentication

Description of innovation/Tasks: Technical information on authentication schemes across the 2nd generation GNSS (GPS III, BDS III, QZSS, Galileo) have to be collected and analyzed in detail. In the literature, proposed metrics are considered as a starting point, mapped into mathematical descriptions. The potential of the metrics for authentication performance definition has to be evaluated. New possibilities should be proposed. The result is a set of useful evaluation algorithms for authentication robustness and performance.

Three spoofing cases (meaconing, replay, fake signal) for spoofing attacks are defined in a parametric way. The metrics declared useful, are in a first step tested by S/W simulations and in a second step by using a GNSS constellation simulator and a real receiver. The results for different GNSS are compared.

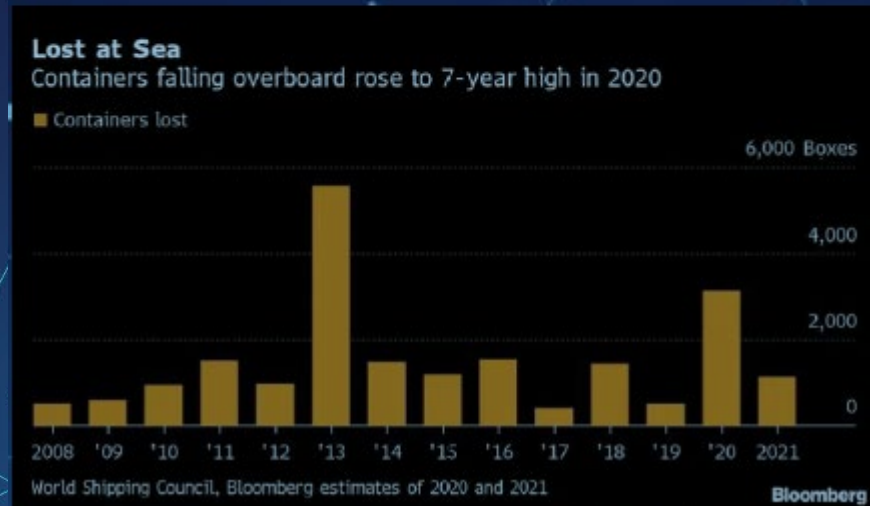
Expected output:

- Ability to define the performance and robustness of GNSS authentication in a systematic way
- Establish a Learning curve for LEO-PNT authentication

Duration: 18 months

Budget: 400 k€

- Each year 226 Million container boxes are shipped. About 1600 boxes/year (0,002%) are lost at sea. The boxes are afloat for days to weeks before they are sinking & grounding
- Reason: Top-heavy container stacks (unstable), increasing bad weather (storms) by climate change and time pressure on ship crews (higher on the supply-chains after COVID)
- The number of boxes lost at sea seems to be small. However:
 - Economic loss of \$ 90 M in cargo value
 - Contaminate the ocean and beaches, partly with dangerous goods
 - Collision danger for smaller vessels (safety issue)
 - Negative effect on sea-life
- IMO sub-committee on the Carrying of Cargoes will focus on this issue. However, no specification of “Tracking and Tracing Devices” elaborated so far.



Activity Description

Objective: Study, Design & Develop a location and tracking system for lost containers at sea based on PNT-infrastructure (GNSS, MEO-SAR) plus IoT based PNT-COM package (Tracking & Tracing Device)

- Primary problem area: L-Band antenna could be under water (~2m), which causes high absorption loss in RF.

Description of innovation/Tasks: Study the issue of lost containers, consider absorption of RF-Signals in seawater

as function of frequency and penetration depth, establish contact to IMO, discuss possible directions of

solutions: a) Detect loss of cargo effect with accelerometer and last GNSS up-date and fuse with sea-surface current

model, b) Use of redundant (4) antennas or 4 GNSS-IoT's on a container, c) Use of mass market MEO-SAR buoy.

Establish low-frequency tracking transmitter to support salvage, build-up an experimental system, conduct tests in the North Sea.

Expected output:

- Survey and understanding of the problem, realistic directions, IoT design, first experimental result in sea water
- Remark: Question posed by BMDV (German Ministry of Transport)

Duration: 18 months

Budget: 500 k€

Where to find Tender Actions



General information: navisp.esa.int

Official Tender information esastar-publication-ext.sso.esa.int/

The screenshot shows the ESA Star Publication website interface. The browser address bar displays the URL <https://esastar-publication.sso.esa.int/search?s=EL1>. The page header includes the ESA logo and a search bar with the text "All EL1". Below the header, the search results are displayed for "Search - EL1". The results show 72 items found, sorted by relevance. The first four results are listed below:

Item ID	Title	Status	Description	Action Type	Announcement Date
1-11071	NAVISP EL1-061: NAVIGATION PAYLOAD DEMONSTRATOR OF FUTURE LCNS SATELLITES	Intended	In complement to the Agency's Lunar Communications and Navigation Services (LCNS) Phase A/B1 system study, this activity will provide a detailed assessment of the critical technologies associated with the Navigation Payloads on-board the future lunar orbiting satellites, whose main function is to provide additional navigation signals from lunar orbit to future cis-lunar users (e.g. moon orbiters, moon landing/ascent and moon surface operations). The activity aims to develop an Elegant BreadBoard (EBB), including all critical functionalities of the future payload flight models. This EBB should provide a good indication/reference of the achievable performance for this payload and of the associated mass/power/thermal/size/environmental and interface requirements, as well as confirming the compliance against the LCNS system concept and system performance allocated to the navigation payload. This activity will also define the specifications for the navigation antenna.	ESA Tender Action Open Competition	03/11/2021
1-11087	NAVISP-EL1-062: LUNAR SURFACE PNT BEACON DEMONSTRATOR	Intended	In complement to the Agency's Lunar Communications and Navigation Services (LCNS) Phase A/B1 system study, this activity will provide a detailed assessment of the critical technologies associated with the a PNT beacon transmitter/reference station, which may complement future LCNS satellites, providing additional ranging sources (from the Moon's surface) and supporting their accurate orbit determination as well as having the potential to provide localised relative positioning and to support selenodetic/scientific applications. This Moon PNT beacon element may as such, become an essential subsystem of the future LCNS system, providing significant benefits to future lunar PNT users (e.g. moon landing/ascent and moon surface operations). The objective of this activity is to develop an Elegant BreadBoard (EBB) of a PNT Moon surface Beacon and Reference Station demonstrator as part of the future LCNS System. An EBB in this context is a candidate model of the final LCNS lunar surface station that is in between a simple Breadboard and an Engineering Model in terms of representativeness and Technology Readiness Level [TRL].	ESA Tender Action Open Competition	03/11/2021
1-11043	NAVISP-EL1-052: ROBUST NAVIGATION OF AIRBORNE AUTONOMOUS SYSTEMS WITH CARRIER PHASE OF ARNS SIGNALS	Intended	In the search for robust and resilient positioning alternatives, users have already looked at signal-of-opportunity (SOOP) techniques that make use of radiofrequency signals broadcasted for different purposes (e.g. wireless, TV, etc.). In recent studies, the feasibility of using carrier phase positioning techniques has also been demonstrated over the cellular networks and other types of SOOP. It is therefore envisaged that similar techniques could also enable high-accuracy alternative PNT solutions for UAV, if they are based on reliable and certifiable signals-of-opportunities such as the Aeronautical Radionavigation Service (ARNS) signals. In order to use ARNS signals in safety-critical UAV operations such as autonomous landing, take-off and BVLOS navigation, one would also have to be guaranteed on a certain level of trust in the PNT solution and be provided with timely alerts when the criticality threshold is exceeded. Although the consolidated knowledge on safety cases and feared events for UAV operations is not yet mature, the precise characterisation (e.g. position and clock parameters) of ARNS transmitters could facilitate the definition of integrity, integrity risks, and integrity monitoring concepts. This activity aims at developing an ...	ESA Tender Action Open Competition	18/10/2021
1-10897	NAVISP-EL1-056: ADVANCED ALGORITHMS AND TECHNIQUES FOR RESILIENT TIME PROVISION - EXPRO+	Issued ISSUE 2	This activity comprises the review, analysis, development, implementation and validation of advanced techniques and algorithms for the generation of a resilient time reference based on a multiplicity of time sources (local clocks, GNSS, NTP, PTP/WR, signals of opportunities etc.). In particular and as a minimum, algorithms based on hybrid (frequency-time) Kalman filters and including machine-learning techniques shall be considered. The software algorithms will be combined with hardware prototypes in order to validate the performance for both high-end metrological users and commercial users.	ESA Tender Action Open Competition	04/10/2021 Open Date: 27/10/2021 Closing Date: 23/12/2021



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