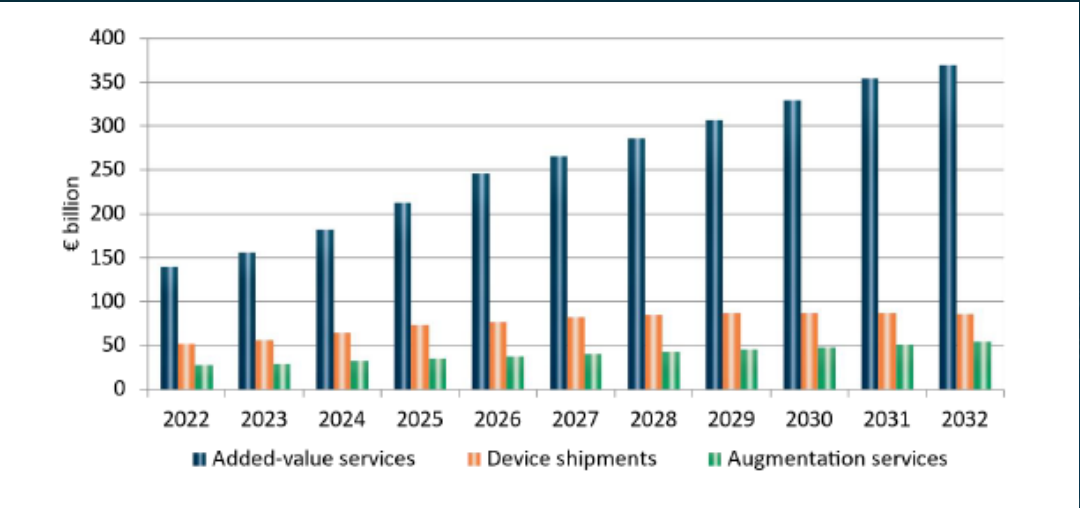


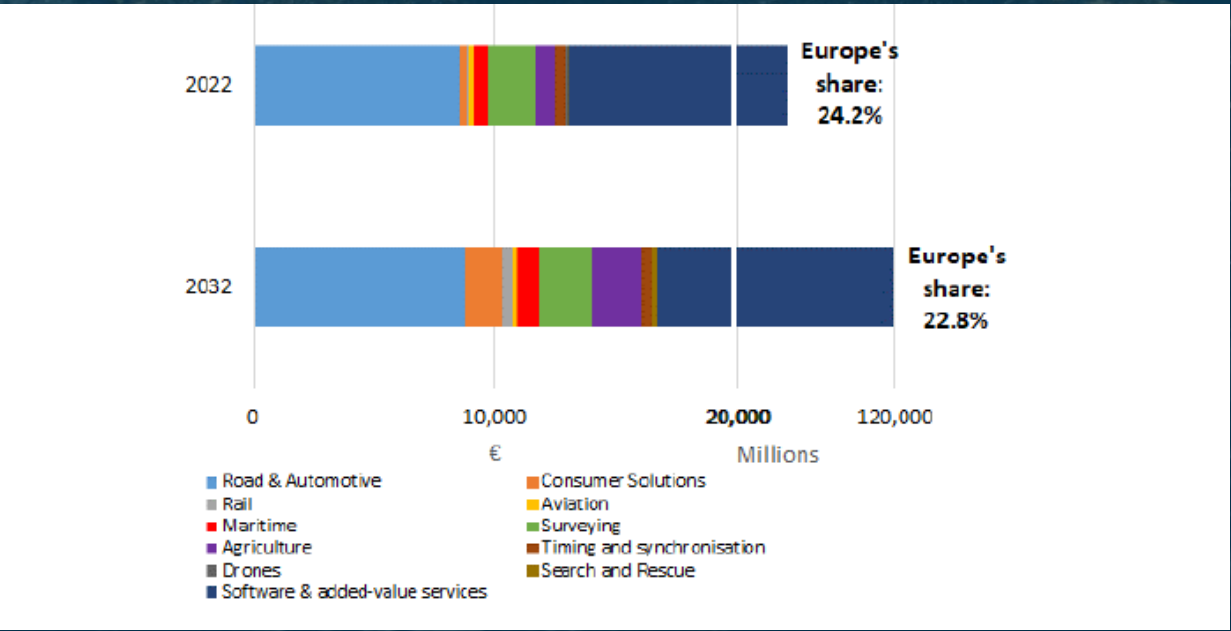
NAVISP & PPP

European Market share in the downstream GNSS



EIB-EUSPA GNSS study outcome:

Over the next 10 years remaining competitive will require a total investment need of EUR34.1bn - 42.7bn



Europe is the second largest provider of added-value and GNSS-based augmentation services, the segment which accounts for roughly 75% of all downstream GNSS market revenues. The segment includes GNSS-based augmentation systems (RTK, PPP, PPP/RTK, DGNSS) used in Agriculture, Surveying, and Maritime segments, as well as software and mobile apps that use geolocation (maps, delivery services, games, etc.). Europe's share (25%) is higher than that of the Asia-Pacific region (17%), but only half of North America's share – which stands at 51%.

This comes despite the fact that the majority of the consumption of these services is located in the Asia-Pacific region (40%), followed by North America (23%), and Europe (18%). Therefore, structural investments in development of superior products, expansion, and consolidations allowed **American companies to dominate the global market and use their competitive advantage to export their services to other regions, particularly to the fast-growing Asia-Pacific market.**

Financing: Increased interest for the space sector, brings in capitals coming from both private and institutional players

	Trends	Examples
Capital base 	▪ Flattened government funding from traditional space faring countries (other than China), growth driven by emerging players ▪ Increased military interest in space, looking at NewSpace to enhance their C4ISR capabilities ▪ Higher private funding, attracted by reduced CAPEX and faster envisaged ROI	▪ Global government space budget ca. \$79B in 2019, with 1% CAGR over 2010-19 ▪ Future growth driven by a revamp of military budgets (CAGR 19-29: ca. 3%) ▪ Global private investments ~€ 10 Bn in 2021
Funding actors 	▪ Funding from wealthy individuals, Venture Capitalists, commercial investors ▪ Increase in companies going public through SPACs ▪ Public grants/ contracts as a hook to private funding ▪ New countries gradually increasing their space ambitions and budgets	▪ VCs injecting ca. 45% of capital over the space private funding in 2009-2019 ▪ SPACs: Virgin Galactic, Planet, Spire, Astra, etc. ▪ Public grants as a catalyst for private funding ▪ Several emerging countries grew their space budgets at over 20% in the past 5 years (e.g. Egypt, UAE, Korea, etc.)

C4ISR: Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance

Policy making and regulatory framework



- | Trends | Examples |
|---|---|
| <ul style="list-style-type: none">▪ NewSpace policies to increase benefits for the public/people and support global challenges▪ New legislations to (attempt to) provide legal certainties for private investors▪ Encourage foreign and domestic investment into space through permissive regulations | <ul style="list-style-type: none">▪ New Zealand created a very flexible space law in less than 6 months▪ US and Luxembourg laws on space resource utilisation creating favourable legislations▪ UK increasingly supporting NewSpace ventures, e.g. developing commercial spaceports▪ Concerns over constellations sparked UN's long-term sustainability guidelines for space |

Public role and funding



- Government as a customer (captive demand, anchor tenancies)
- Public-Private Partnerships (PPP) and risk sharing between public and private funding (e.g. government backed space equity funds)
- Space no is longer solely an extension of national prestige & sovereignty

- DoD and NASA major SpaceX clients
- NASA COTS, Gateway Logistics Services, Human Landing System
- Rocket Lab micro-launchers deploying US payloads
- New public support instruments in Europe (e.g. €100 M EIF Space Equity Fund under EU InnovFin, CASSINI, etc.)
- ESA awarded space debris removal services contract in 2019 to Swiss start-up ClearSpace

Private-public partnerships provide benefits for private & public players

Private

1. Anchor tenancy contracts provide commercial players with a fixed and certain outcome
2. Public contracts are a source of ideas for new developments and systems derived from the joint requirements of the two parties
3. Access to knowledge and research from the public domain is provided to the private sector to facilitate their developments

Public

1. Provide anchor contracts, with transactions performed at pre-determined stages of development
2. Promote infrastructure- & local development in the private sector, alleviating the public entity's responsibilities

However it will not be easy to get private investors in a club deal

- NAVISP dealflow likely to be too limited to trigger automated VC investments
 - VCs typically invest in 1 out of 100 deals after harsh selection
 - VCs need to have comfort that they can multiply the value of their minority equity share in 5-6 years by 5/10x
 - VCs tend to invest in the market risk, not the technology risk
 - VCs take calculated bets on teams, the market potential and their proven technology
 - ESA is funding „projects“ rather than companies – often with technology still to be developed
 - Only a small portion of the NAVISP applicant companies will want to give up equity
 - Consortia are not attractive for VCs
- Although the time now seems right for Space-related VC funds, ESA still cannot invest in equity or even hold company shares
- VCs might be interested in leveraging NAVISP as a “non-equity consuming cofunding”
 - VC selects the deals, check if relevant for ESA
 - Propose to ESA & MS main contact point
 - VCs and MS need to be ultra fast to make their decision
 - Ideally pre-agree terms

PNT NAVISP Demo

TESTING / VALIDATION. POSITIONING PERFORMANCE ASSESSMENT AND TEST

It is important for designers, manufacturers and consumers of GNSS-products and applications to understand what to expect from GNSS systems.

Sources of errors:

- Signal blockage/external obscuration
- Multipath
- Jamming, interference, spoofing
- GNSS system errors(satellite clock, GNSS orbit, ionospheric and tropospheric delay)
- Receiver errors, performance metrics: Availability, Accuracy, Integrity and Timing performance.

High accuracy techniques offered features traditionally used for professional applications: transport sector will need to get to know abilities and test achievable performances of PPP and RTK in real operational scenarios.

AUTHENTICATION AND SECURITY-RELATED SERVICES

Spoofing: a clear impact on liability critical applications. Market needs expertise in authentication and access to the use and benefits of Galileo OS-NMA as a reality...

Car hacking. Vulnerabilities of modern vehicles

- Safer design
- Third-party testing
- Internal monitoring systems
- Segmented architecture
- Internet-enabled security SW updates

A possible concept of **one-stop-shop**, specifically dedicated to autonomous vehicles, ADAS and connected vehicles, RUC, etc..

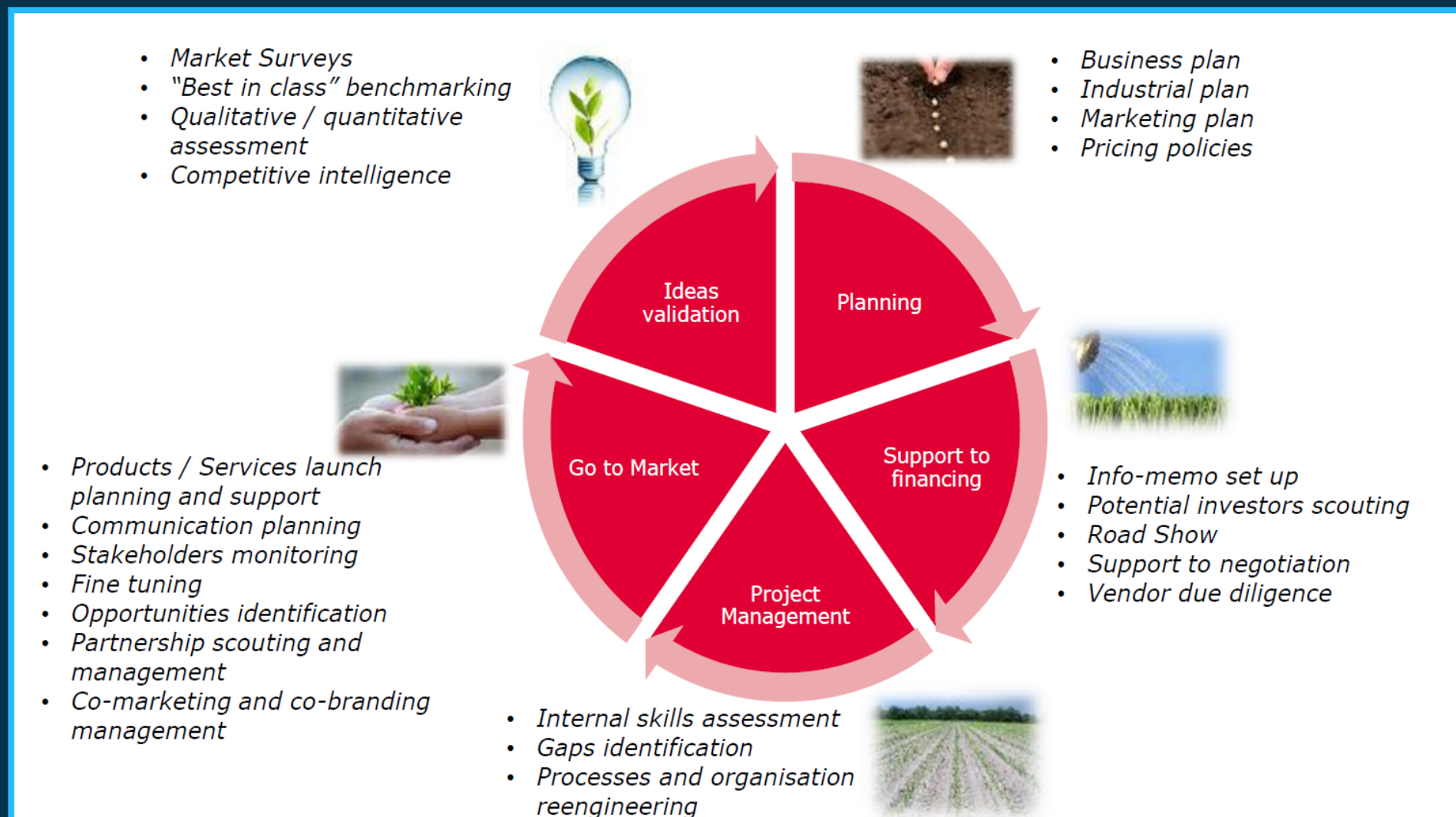
The testing services offered cover test and demonstration of following applications:

- **ADAS and AD** systems for different type of vehicles(e.g. passenger vehicles, buses,...)
- **Connectivity services** including cooperative communication(C2X), RUC, etc.
- Other applications requiring accurate positioning.

A follow up ambition...

To become a certification center of GNSS based applications for the transport industry:

While no certification process is established, the center may possibly offer to its customers own 'quality stamp' to the system tested guaranteeing compliance with standards and minimum performance.



How to attract PNT actors: *setting up of a road show to increase NAVISP outreach (1/2)*

- This road show shall have the goal to find new champions for the NAVISP programme;
- Exploiting the already existing contacts triggered via the key strategic assets such as the AP platforms deployed;
- Leverage on examples of past activities to demonstrate NAVISP attractiveness in new stakeholders' domains;
- Relevant national delegations should be encouraged to take the lead and coordination role to have the road show in place.

How to attract PNT actors: *setting up of a road show to increase NAVISP outreach (2/2)*

- Conduct one-on-one sessions with key potential industry players in all potential markets in each NAVISP MSs;
- Three outputs:
 - Subjective but realistic assessment of likely investment in their product portfolio;
 - Development of a core group of players to become new champions in NAVISP;
 - Understanding of the terms under which key players will participate.
- ESA and the national delegations will jointly take the driving seat, providing materials, programmatic contacts and technical elements and ad hoc logistic support (venues);
- Potential suitable industrial contacts will be found according to the available set of player collected so far.

Weak European GNSS downstream industry and lack of start-ups

We need to create opportunities for ENTREpreneurs not GRANTpreneurs



Business Ideas

Entrepreneurs

Risk and
growth capital

Bank Loan

Grant /
R&D Support

navisp

Hungarian activities and Element 1 Workplan 2023

NAVISP Program

ESA UNCLASSIFIED – For ESA Official Use

19/04/2023

→ THE EUROPEAN SPACE AGENCY



nausp activities are organized in 3 Elements

ELEMENT 1

ESA driven

**Analyse and develop new
PNT systems technologies**

Fully funded



ELEMENT 2

Industry driven

**Carry out ad hoc
technological developments
and pre-operational activities**

**Support the emergence of
innovative PNT services**

Co-funded



ELEMENT 3

Member State driven

**Support to MS National
Programmes along the whole
value chain**

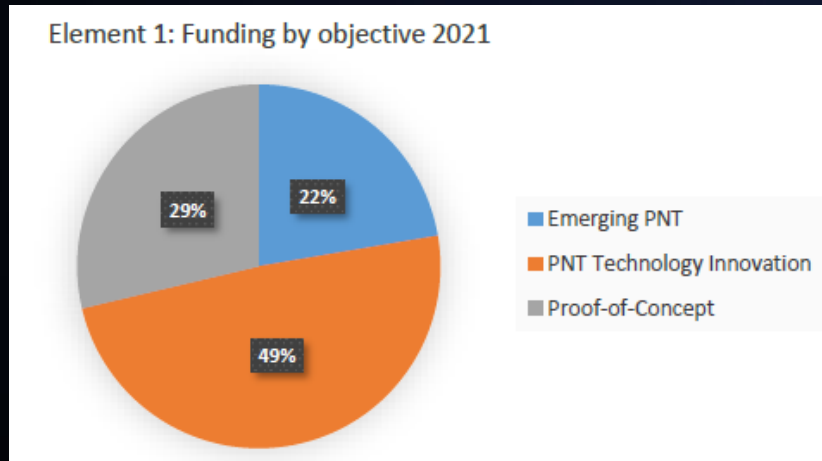
Fully funded



Projects need the support from national delegation to ESA

navisp Element 1

- Implemented through competitive Invitations to Tenders
- Activities defined in yearly workplans
- ~80 contracts awarded, 34M€ ESA funds



Through Element 1, ESA supports R&D on technical challenges or investigates new techniques

- Implemented through a permanent standard call for proposals
- 162 Outline Proposals received
- 124 contracts awarded, ESA co-funds 58M€
- 3 Thematic calls
- More than 200 different actors



Through Element 2, ESA supports Economic Operators to mature technologies and to prepare them for industrialisation and commercialisation

navisp Element 3

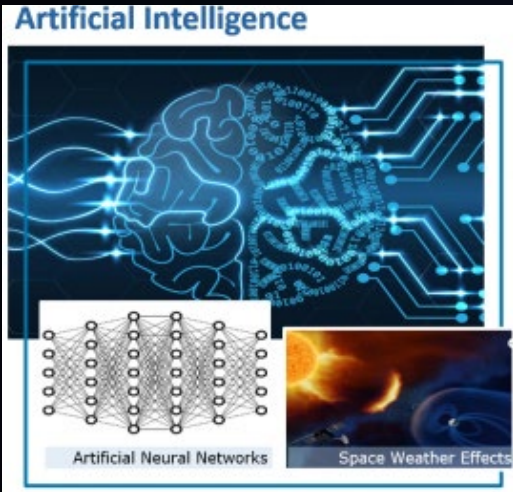
- Implemented through a permanent open call for proposals
- 32 outline proposals received resulting in 24 projects
- Test-Ranges
 - Maritime Autonomous Mobility
 - Land Autonomous Mobility
 - Drones and Urban Air Mobility
- PNT Resilience
 - Alternative/Back-Up PNT solutions
 - PNT Monitoring Services



Through Element 3, ESA can support Participating States strategic objectives in the field and public authorities to be equipped with demonstration facilities

HUNGARY in NAVISP

ID	Title	Company Involved	Role	Phase	Country	Status
EL1-035	Machine-Learning to model GNSS systems	Integricom	Prime	Phase 2	NL	Activity ongoing
		Iguassu	Subco	Phase 1	CZ	
		GeoX Kft.	Subco	Phase 2	HU	
EL2-098	Galileo signals in Hungary	Infobex	Prime	Phase 2	HU	Activity completed
		Forgeo Ltd	Subco	Phase 2	HU	
EL2-109	Anti-GNSS SP_S	Sagax	Prime	Phase 2	HU	Activity ongoing
		Pro Environ Kft	Subco	Phase 2	HU	
EL3-024	Integrated Galileo Reference Infrastructure and Technology Development for Height Modernisation	Lechner Nonprofit LTD (LTK)	Prime	Phase 2	HU	Activity ongoing
EL3-027	Test&Measurement Tool and Innovation Lab for GNSS/PNT Applications	National Instruments Hungary Kft.	Prime	Phase 2	HU	Activity ongoing



EL1-035 – Machine-Learning to Model GNSS Systems

GNSS simulations aid system engineering decisions and display key performance indicators. Current tools are either computationally intensive or limited to specific scenarios. Training machine learning algorithms on real data can create a tool that offers accurate results on a wider range of scenarios than macro models, while being user-friendly and low cost. The proposed activity aims to assess the usability of machine learning in GNSS system simulations by modelling selected system segments using ML algorithms. State-of-the-art Supervised Learning techniques for Multi-Target prediction will be reviewed, with a focus on trading-off different Machine Learning techniques. Subsequently, the selected ML algorithms will be trained on input observables and output data for two GNSS cases (e.g. IGS, augmentation systems or others). Once the algorithms are trained, their performance on test data sets that have been previously selected will be assessed. Through this process, any main issues that may arise when using ML to model GNSS behaviour will be identified. The results will demonstrate the usability of ML for GNSS modelling and implement ML techniques into tools for simulating GNSS capabilities and behaviours.

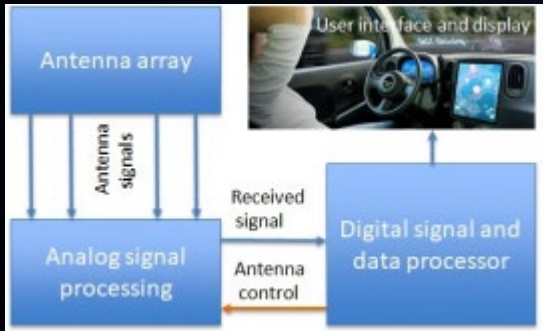
GeoX (HU), IntegriCom (NL), Iguassu (CZ)

EL2-098 - Providing Galileo Signals for ground Navigation

The project aims to establish a new, nation-wide VRS-type GNSS RTK correction service that utilizes Galileo GNSS-delivered positioning information. This development creates the opportunity to provide more accurate and reliable positioning with shorter initialization time, even under unfavourable circumstances, and offers significant advantages to users in Hungary.

Infobex Ltd. & Forgeo Ltd (HU)

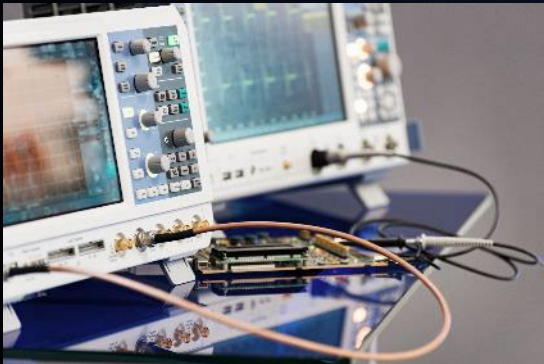




EL2-109 ANTI-GNSS Spoofing Solution for autonomous vehicles

Our society and industry including current and future autonomous mobility have embraced and depend on the global navigation satellite systems a lot. Delivering trusted and safe GNSS service is important for all area of life and industry. Jamming and spoofing of GNSS systems are real danger and can cause real damage in cyber physical systems like autonomous mobility. The project is working on GNSS anti-spoofing solution and the objective is to provide increased cyber security. The goal is to develop a special sensor which can detect and validate the origin of the GNSS signal available in the surrounding geographic area and it is able to send warning level in case of possible spoofing is detected.

SAGAX (Hungary)



EL3-027 ADG Innovation Lab (ADGIL)

This project will create an Open Innovation Laboratory (OIL), equipped with the latest Software-Defined-Instrumentation and Application Software for supporting innovative approaches for prototyping and testing new technologies for the space and ground segments. The OIL will be equipped with NI Modular Instrumentation and application software for a Wideband Multichannel Phase Aligned Transceiver System and other equipment. The validation of the wideband multi-channel phase aligned transceiver will be done at the ESA-ESTEC radionavigation laboratory.

NI Hungary Kft. (HU)



EL3-024 INGRIM - Integrated Galileo Reference Infrastructure and technology development for height Modernization

GNSS positioning is still under-represented in surveying for the determination of <1 cm accuracy physical heights, because of its high-quality demands and multi-technique features. The objective of the INGRIM project is to prepare the introduction of such modernized height system in the territory of Hungary by setting up a limited network of integrated GNSS/InSAR Sentinel stations supported by the necessary software to operate the network and obtain the height transformations to the national system, and prepare its future extensions.

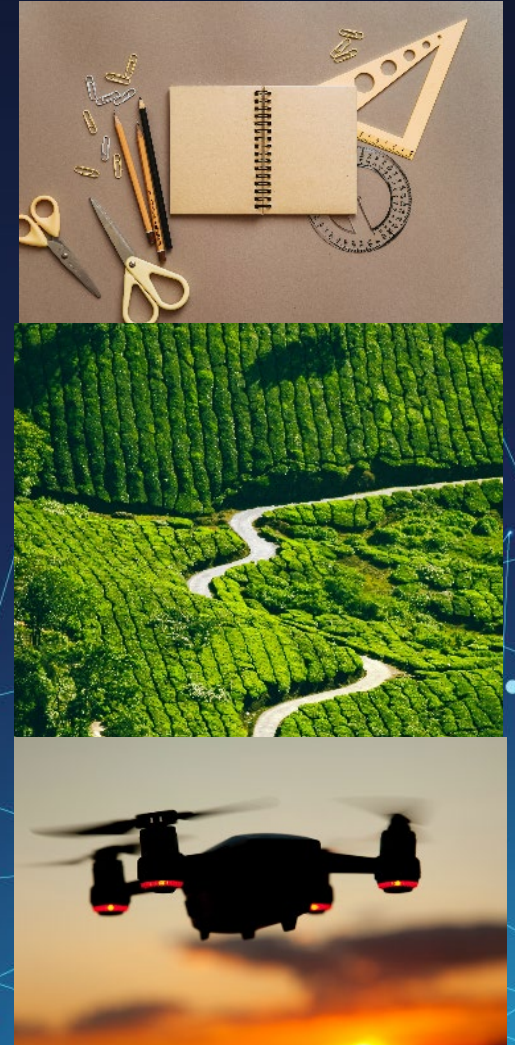
Lechner Non-Profit Ltd (HU)

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



Work Plan 2023 Fundings and Durations



ID	Name	Funding Required (k€)	Duration (months)
EL1-071	Technologies for Reliable Ambiguity Resolution (RAR) and Integrity in High Accuracy Positioning	300	12
EL1-072	Navigation Using Machine Learning Applied to Signals of Opportunity	450	24
EL1-073	Trusted PNT for Unmanned Aerial Systems	400	12
EL1-074	Assessment of authentication and encryption techniques on high-performance time-transfer over optical fibre	450	24
EL1-075	Bearer Independent Secure Time Transfer	400	12
EL1-076	Low SWAP optical clock control unit	650	24
EL1-077	Technological Enablers of Cellular Networks for PVT Assurance	600	12
EL1-078	Autonomous Alternative Absolute Navigation (AAAN) technologies for maritime	450	18
EL1-079	Reduced size Antenna for Earth Pulsar navigation	300	12
EL1-080	Miniaturised GNSS/LowRF receiver	450	18
EL1-081	Lithium Niobate Photonic integrated circuit based high speed, low voltage modulators for microwave photonics	350	12
EL1-082	Low noise frequency tunable microwave generation using photonic integrated microcombs	700	24
EL1-083	Deployable satellite navigation antenna	400	18
EL1-084	Digital Beamforming for GNSS-R Radio occultation payload	600	18
EL1-085	Navigation technologies for Shield nanosatellite	400	18



Work Plan 2023 Preliminary ITT schedule

[illegible]

- ITT expected to be released at the end of the Quarter containing the text "ITT" in the chart
- Expected contract execution as per grey area in the chart
- EL1-075 issued, close date 05/05/23

Where to find Tender Actions



General information: navisp.esa.int

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

← → ↺ 🏠 🔒 https://esastar-publication.sso.esa.int/search?s=EL1 🔍 ☆ ⚙️ Ⓜ️ Update

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1-11071

Intended

NAVISP EL1-061: NAVIGATION PAYLOAD DEMONSTRATOR OF FUTURE LCNS SATELLITES

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
Announcement Date: 03/11/2021

☆

1-11087

Intended

NAVISP-EL1-062: LUNAR SURFACE PNT BEACON DEMONSTRATOR

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
Announcement Date: 03/11/2021

☆

1-11043

Intended

NAVISP-EL1-052: ROBUST NAVIGATION OF AIRBORNE AUTONOMOUS SYSTEMS WITH CARRIER PHASE OF ARNS SIGNALS

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
Announcement Date: 18/10/2021

☆

1-10897

Issued
ISSUE 2

NAVISP-EL1-056: ADVANCED ALGORITHMS AND TECHNIQUES FOR RESILIENT TIME PROVISION - EXPRO+

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.

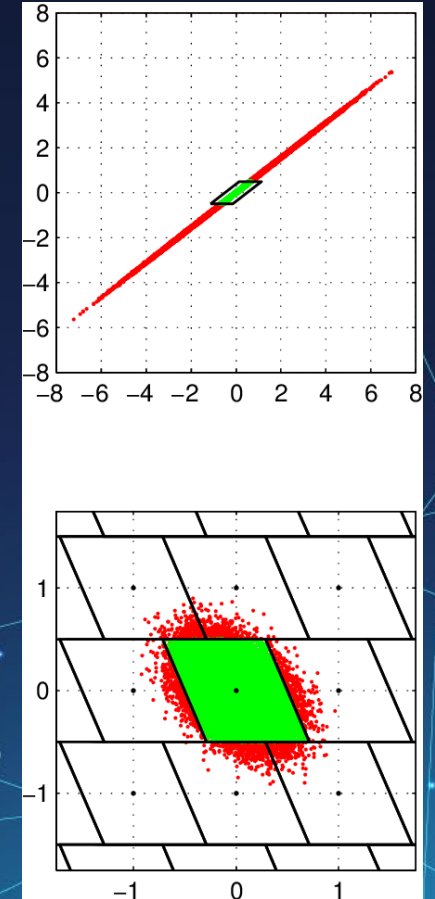
ESA Tender Action
Open Competition
Announcement Date: 04/10/2021
Open Date: 27/10/2021
Closing Date: 23/12/2021

☆

→ THE EUROPEAN SPACE AGENCY

Background and Rationale

- High Accuracy requires usage of phase measurements, which are ambiguous measurements: ambiguities must be fixed to relate phase measurements to ranges.
- Phase Ambiguity Resolution is a stochastic process which needs a minimization search for the correct ambiguities which can require a very large search to find the correct solution: such a search is very time consuming and the search space must be limited to avoid very long time processing, with consequent practical limitation in the reliability of the identified optimal solution.
- This limitation prevents performing integrity processing on high accuracy positioning because any feared event involving wrong ambiguity resolution or interruption of phase measurement would not allow to provide a boundary with a very high probability, as would be required by a reliable, accurate and precise positioning service.



There is the need to improve the AR and precise positioning processes and make them reliable.

071-Technologies for Reliable Ambiguity Resolution (RAR) and Integrity in High Accuracy Positioning



Activity Description

Objective: Apply the Artificial Intelligence (AI) to Ambiguity Resolution (AR) problem on the user side to increase the AR reliability, looking for approaches that focus on multi-frequency and multi-system, which do not necessarily follow the state of the art methodology for AR (float estimation + decorrelation + Integer Least Square).

Description of innovation/Tasks:

- Navigation signal ranging allowing reliable and fast ambiguity resolution in phase measurement.
- Solution for applying AI to AR to improve reliability of high accuracy positioning.
- Review studies on integrity for high accuracy positioning, e.g. TDE Enablers of range-domain rigorous integrity for future safety-critical applications.
- Review state-of-the-art of Ambiguity Resolution.

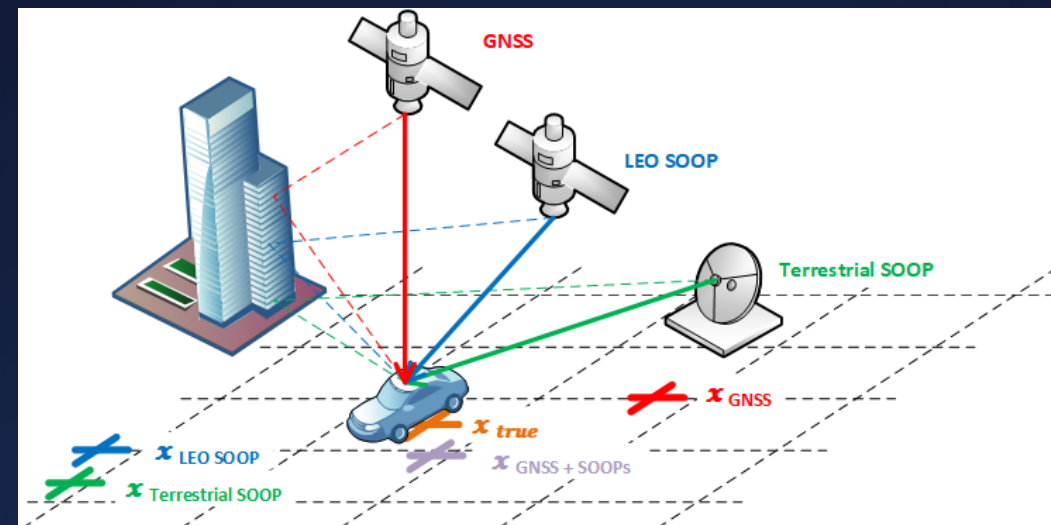
Expected output:

- Data package (reports, algorithms, results, etc.) providing a complete understanding of achievable capabilities of ambiguity fixing and related positioning performances.
- Real-time board and emulating real-time post-processing software, associated results and user manual.

Duration: 12 months

Budget: 300 k€

- There is an existing need to **optimise navigation** in **challenging environments**, such as deep urban or indoor, and to offer **alternative PNT**. For this purpose, the user may complement the GNSS with space-based (e.g. LEO SatCom) or terrestrial-based (e.g. cellular) **signals of opportunity (SOOP)** to optimise the PNT performance. SOOP could also be exploited similarly in a maritime environment.
- Traditionally, a Kalman Filter is used to integrate the sensor data in the navigation kernel. However, the use of **Machine Learning** may provide numerous benefits when **integrating SOOP** in specific situations:
 - a) when the signal characteristics (e.g. modulation, location of transmitter, etc.) are not accurately known;
 - b) when the statistical distribution of data is non-Gaussian (e.g. in multipath-rich environments).



Activity Description

Objective: To optimize PNT performance in challenging environments and offer alternative PNT. This shall be achieved by integrating GNSS and SOOP, or using SOOP only, applying Machine Learning.

Starting point: Traditional integration techniques (e.g. Kalman Filter), serving as benchmarks.

Description of innovation/Tasks: The activity will explore innovative use of Machine Learning for positioning and sensor integration at user level using SOOP, whose characteristics are not perfectly known, in challenging environments (e.g. road, maritime). The activity is novel as the previous machine learning activities focused on:

- EL1-020 Less challenging maritime environments with well-defined sensor characteristics without SOOP,
- EL1-053 Exploring machine learning at central processing facility level for integrity products and not at user level, also without SOOP.

Expected output: Optimized navigation in challenging environments, alternative PNT, and a better understanding of the benefits and the limitations of Machine Learning for Navigation

Duration: 24 months

Budget: 450 k€

073-Trusted PNT for Unmanned Aerial Systems

Background and Rationale

- Urban Air Mobility is expected to become a reality in Europe within 3-5 years. The first commercial operations are expected to be the delivery of goods by drones and the transport of passengers, initially with a pilot on board. [1]
- Satellite navigation systems and hybridisation with inertial sensors can provide high-accuracy uninterrupted solutions to UAS users (can be used for take-off and landing, or precision mission operations)
- Current failure rates of the aforementioned solutions prevent the adoption of UAS in safety-critical operations, because of the insufficient level of trust.
- SWaP considerations, cost of the components, as well as peculiar UAS dynamics (e.g. limited sky coverage) are key drivers of the PNT solutions.
- Protection level concepts could be defined for different navigation sensors, and thus, an integrity concept relying on hybridisation and/or diversification of sensors could be derived. This aims at investigating the aforementioned concepts.



[1] EASA website - <https://www.easa.europa.eu/domains/urban-air-mobility-uam>

Objective: The objective of the activity is to develop a proof-of-concept of a fused PNT architecture for UAS and showcase safe aerial navigation in the context of crowded and regulated airspaces. The developed system shall exploit hybridisation and diversification of navigation sensors for the determination of a trusted PNT solution.

Starting point:

- State-of-the-art in navigation sensors and PNT architectures for UAS and legacy integrity concepts.
- Urban Air Mobility use cases and associated requirements, and regulatory framework (FAA, EASA).

Description of innovation/Tasks: taking into considerations the outputs of past projects like DELOREAN, SONORA, DEGREE and GEODSEY, and UAV related EU Regulations, propose and develop PNT architectures and integrity concepts for autonomous or safety critical UAS operations, and assess the integrity concepts with respect to navigation performance needs (including time-to-alarm assessment within the proposed architectures logic).

Expected output:

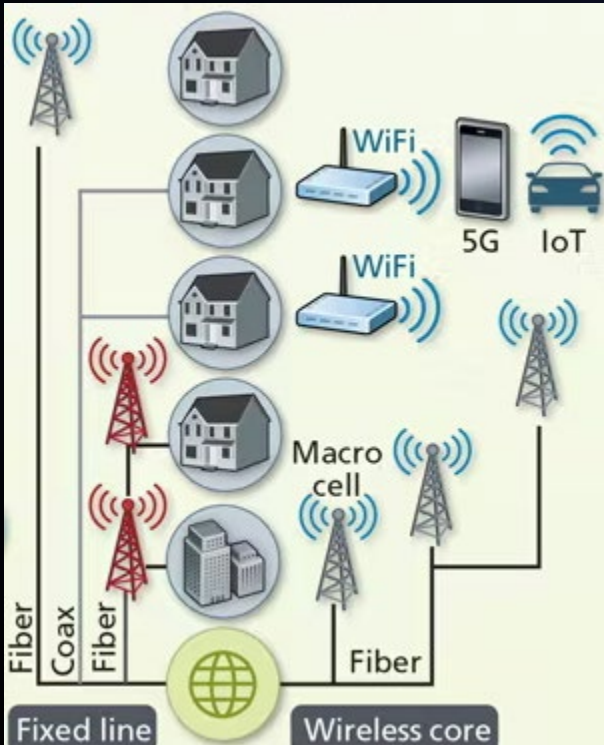
- PNT sensor architectures and associated integrity concepts/Proof of concept.
- Roadmap towards prototyping and a product, paving the way for industrial products, for instance through activities in NAVISP Element 2.

Duration: 12 months

Budget: 400 k€

Background and Rationale

Telecom

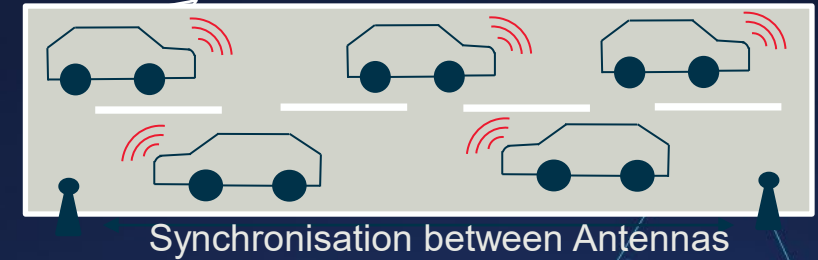


Synchronisation of ground infrastructure

Time synchronisation becomes more and more stringent and widely use on several markets such as telecom, finance, geo-localisation, estimation in real time of the road network, power grid... The performance requirements for time synchronization can reach up to 100 ns.

Nevertheless the performance should not be at cost of the security notably for critical infrastructure. Consequently implementing encryption and/or authentication on high performance time transfer solution over optical fibre would be a good alternative to improve current solution which are not providing high performance and secure time transfer together.

Geo-localisation



Finance



Time stamp shall be traceable to UTC!

Activity Description

Objective: To develop authentication and/or encryption techniques that are suitable for high performance time transfer over optical fibre, addressing the development of necessary critical building blocks up to a breadboard level.

Description of innovation/Tasks: Time Transfers via GNSS are performant but known for their vulnerability to jamming or spoofing. Alternatively current secure time transfer over optical fiber have low performance (10us accuracy) while high performance time transfer (sub nano-seconds) are not secure.

Combining high performance time transfer over optical fibre with an appropriate authentication and/or encryption method could provide a secure alternative to GNSS. Some timing distribution systems/services on various physical supports exists already (e.g. OPNT/WANTime/Tower), but they don't address fully the authentication and encryption of the information distributed.

Expected output:

- 2 integrated breadboards (master and slave demonstrators) including software and firmware
- report : trade off, design, manufacturing and test documentation and final report
- demonstration of secure time transfer over optical link with improved performance w.r.t current secure time transfer

Duration: 24 months

Budget: 450 k€

075-Bearer Independent Secure Time Transfer

Background and Rationale

A common requirement for achieving an assured Position, Velocity and Time (PVT) service is to securely initialize the receiver with coarse time synchronization.
For additional security, this information can be provided periodically during the mission.



A space-based infrastructure is the most attractive option to achieve a global service coverage.



Relying on external network provider might be difficult for some use case (e.g. limited coverage, cross border operations, different Quality of Service commitment).

Several telecommunication constellations are already operative and standardization is undergoing for the next generation (e.g. 5G non-terrestrial networks - NTN).



→ THE EUROPEAN SPACE AGENCY

076-Low SWaP Optical Control Unit

Background and Rationale



The need for high-accuracy, resilient holdover techniques to be available in the event of GNSS signal denial has been widely emphasised. Whilst current microwave GNSS satellite clocks, and best-in-class commercial microwave clocks, provide holdover for relatively short periods in situations where GNSS system disciplining is lost, it is clear that future resilient PNT systems will need to maintain improved accuracies over longer fly-wheeling intervals. One solution for this is to develop robust low-SWaP optical oscillators and clocks with better accuracies than microwave systems. Significantly higher accuracies (by factors of up to x100) have already been demonstrated by the best national metrology laboratory-based optical clocks.

Solutions focussed on future optically-augmented PNT applications include the use of high TRL optical reference cavities capable of operating either in space or in terrestrial mobile environments. Optical cavity-stabilised lasers, where the cavity material is ultra-low-expansion (ULE) glass, have demonstrated very low and well-characterised frequency drift at the level of 1 part in 10^{15} , where the frequency drift can be removed by opto-electronic feed-forward techniques.

Compared to other approaches (e.g. Horizon) where one single laser wavelength, or none, is foreseen, this Optical Control Unit is based on the requirement for the control of multiple laser sources: wavelength knowledge, wavelength drift control and duty cycle. For Strontium optical frequency standard/clock there are 6 wavelengths. With multiple wavelength requirements, additional complexity comes, but also vastly enhanced performance.



077-Technological Enablers of Cellular Networks for PVT Assurance

Background and Rationale

Cellular networks have various built-in security features including access control, mutual authentication, and key management, which could be evolved to provide technological enablers for PVT assurance.

An efficient solution to protect from PVT spoofing is the use of symmetric cryptographic mechanisms to render the ranging signal unpredictable to the potential attacker.

The concept requires sophisticated key management systems or frequent rekeying for scenarios in which the users cannot be trusted.

These workarounds could be facilitated by cellular networks technologies. In addition, cellular networks themselves have become relevant sources of PNT, using unencrypted signals.



Activity Description

Objective: To study, design, and demonstrate the use of the cellular networks technologies for PVT assurance and encryption of ranging signals, considering robustness against post-quantum cryptography.

Description of innovation/Tasks: The activity will study, design, and demonstrate the use of cryptographic information securely stored on the SIM card or secure element for the encryption of GNSS ranging signals and the provision of native encryption of cellular networks PNT signals to support PVT assurance. The feasibility of post-quantum cryptography for the aforementioned security solutions (e.g. delivery of longer cryptographic keys by cellular networks) also needs to be investigated.

Expected output:

- Survey of state of the art on cellular network technologies for cryptographic operations
- Breadboard and test report
- Roadmap for commercialization, including potential Navisp EL2 activities

Duration: 12 months

Budget: 600 k€

078-Autonomous Alternative Absolute Navigation (AAAN) technologies for maritime **Background and Rationales**

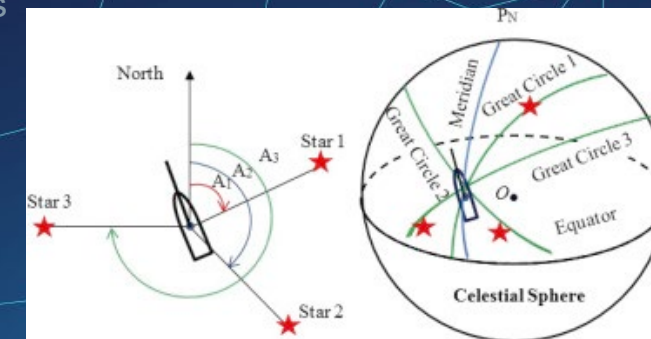
These days, GNSS is fundamental for navigating but it is still fragile: it can be spoofed or jammed.

Using a sextant to determine a star position relative to the horizon, sailors have marked ship locations for centuries using Celestial Navigation (CN). Nowadays technology would allow automatic adoption of this technique, extending its utilization to daylight and exploiting not only stars, but also artificial satellites as reference sources. The technology is being revisited for maritime use cases (e.g. DARPA). The technology can consider other celestial bodies as well as the sensing in non-visible spectrum to increase availability during daytime or in cloudy conditions.



Similarly to GNSS, CN can then be combined with different sensors, e.g. inertial sensors, to mitigate the drawbacks of each single technique, e.g. exploiting the CN for calibrating bias and drift of the inertial sensors while using inertial sensors to predict the motion in the short term.

The exploitation of Celestial Navigation with sensors allowing weather and light independent measurements for Absolute Autonomous Navigation and Timing for autonomous vessels can provide a safe and robust alternative to GNSS.



078-Autonomous Alternative Absolute Navigation (AAAN) technologies for maritime **Activity Description**



Objective: This activity aims to study and demonstrate new concepts for absolute autonomous PNT for the maritime environment, in particular for autonomous vessels in open seas.

It will include a detailed assessment, trade-off and demonstration via prototyping, of the tangible benefits provided by adopting Celestial Navigation with multi-band sensors for detecting natural and artificial celestial targets during night and day independently of the meteorologically conditions.

Description of innovation/Tasks:

- **At technological level:** modernisation of CN and comprehensive hybridisation of alternative technologies, with target accuracy better than the existing CN devices (<100m, TBC).
- **At the level of the vertical:** for the maritime, AAAN could become a fundamental resource for autonomous vessels, for resisting spoofing and jamming attacks, complementing and being an alternative backup solution to GNSS with Inertial/Visual Navigation.
- Review studies on autonomous vessels, e.g. NAVISP-EL1-020 Maritime AI-NAV
- Review state-of-the-art of APNT and CN for Maritime
- Develop absolute navigation solution alternative to GNSS adaptable to very different ship sizes.

Expected output:

- Autonomous continuous robust absolute navigation for autonomous vessels in open sea (depending on the achievable accuracy, could also support arctic navigation). Spin-off could benefit many more users (civil aviation, aid to Search&Rescue, etc.).

Duration: 18 months

Budget: 450 k€



079-Reduced size Antenna for Earth Pulsar navigation

Background and Rationale

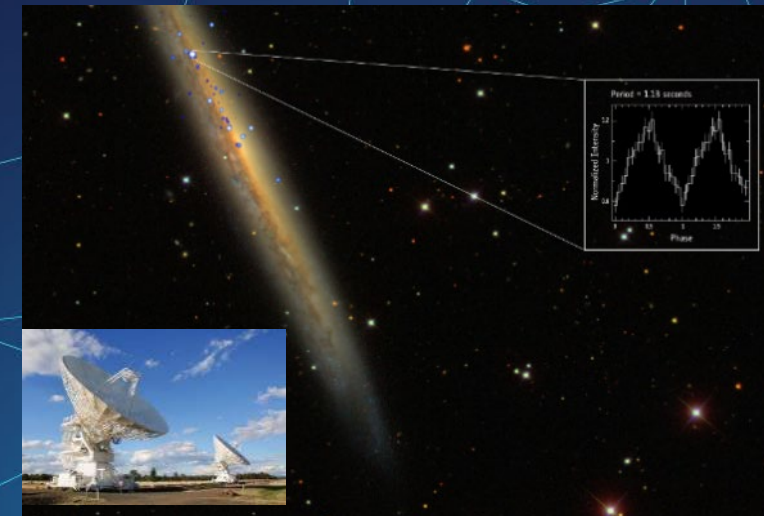
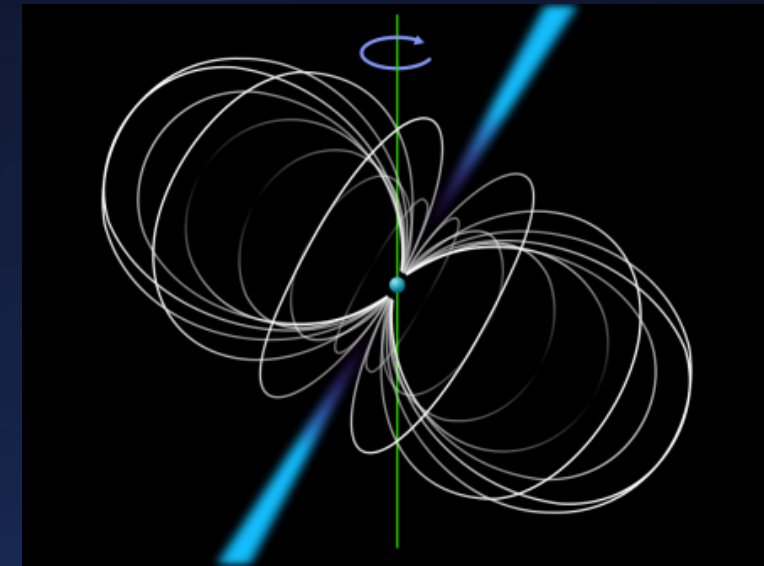
Pulsars are rapidly rotating neutron stars emitting beams of radiation periodically, some with very high stability.

Since every pulsar has a different frequency, they can be used in a navigation system like beacons, and in timing (see EL1-006).

Emission occurs in all spectrum (infrared, visible, RF, X-ray). For space navigation, detectors in X-ray are preferred for their size, but detectors in the visual range could also be used; on ground RF is preferred for accuracy, but this requires big RF telescopes.

Researchers also discuss current detector technologies such as silicon pore optics, silicon drift detectors and “active pixel sensors” that might be used in missions that would adopt the pulsar navigation.

The need for an autonomous navigation system and a pulsar’s natural time-keeping abilities will probably lead to pulsar navigation in the future.



079-Reduced size Antenna for Earth Pulsar navigation

Activity Description



Objective: Design a prototype reduced-size RF antenna, or antenna array, for usage with pulsars on Earth

Description of innovation/Tasks:

- Pulsar detection on Earth is limited in X-ray (atmosphere is opaque in that range), and RF detectors are currently large (typically 25m or more in diameter):
 - a novel way to focus EM energy at RF (around 200-1600MHz) on a newly shaped antenna, or onto an array of suitable antennas (exploiting for example aperture synthesis interferometric processing, see the Very Large Array), should allow to obtain a decent signal to noise ratio for the pulsar pulse train, at least for an appropriate class of pulsars
 - tradeoff will include high gain steerable for single pulsar observations, wide beam array for multi pulsar observations, and inputs for higher navigation processing operational concept
- survey the current Pulsar detectors technologies state-of-the-art
- identify potential use cases for application (maritime freight transport, military ships,...)
- design, develop and verify the prototype RF antenna, install it in a realistic environment and perform validation tests with real Pulsar data

Expected output:

Prototype antenna, or antenna array, with associated design and verification report based on real data collected on Earth, demonstrating the recovery of pulsar pulses with adequate signal to noise ratio

Duration: 12 months

Budget: 300 k€



080-Miniaturised integrated GNSS and Low Frequency Navigation Receiver

Background and Rationale



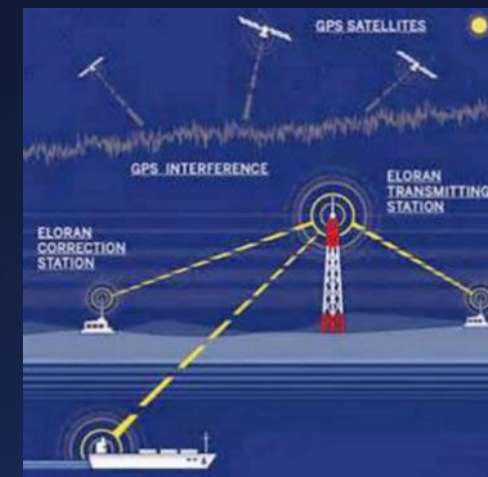
GNSSs are typically operating from MEO, using spread spectrum techniques and having a large coverage by each satellite, therefore the user receiver signal power received on ground is extremely low, 'buried' under the thermal noise level.

Because of that, the GNSSs susceptibility to RFI interference, both generated locally with inexpensive means like Personal Privacy Devices or more regionally with state-level RF counter-measures, is relatively high.

In this context, the complementary usage of Low Frequency navigation systems, with a completely different system design, performance and weakness, helps reducing the current societal dependability on GNSSs.

Enhanced-LORAN (eLoRAN) is the latest of the low-frequency Long-Range Navigation (LORAN) hyperbolic systems, and provides a PNT service for use by all modes of transport (land, maritime and aeronautic).

New eLoran infrastructure is being installed in a number of regions around the globe and there is renewed activity and interest in Europe.



Activity Description

Objective: Enhance geo-security and precision timekeeping with e-LORAN, through its jam- and spoof-resistant signal characteristics of high transmit power and low carrier frequency.

Description of innovation/Tasks:

- NAVISP-EL1-065 will develop a prototype eLoran miniaturised antenna for handheld applications; to complement and enhance this upcoming EL1 activity, it will be valuable to have a professional market, handheld, prototype miniaturised integrated GNSS and eLoran receiver.
- Taking stock of other activities on combining Medium Frequency DGNSS, AIS, and eLoran, design, develop and verify a prototype miniaturised integrated GNSS and eLoran receiver to investigate feasibility of a complete professional handheld low size, weight and power (SWAP) GNSS/eLoran terminal.

Expected output:

“Proof-of-concept” prototype miniaturised integrated GNSS and eLoran receiver with associated documentation.

Duration: 18 months

Budget: 450 k€

081- Lithium Niobate Photonic integrated circuit based high speed, low voltage modulators for microwave photonics **Background & rationale**

Recent advances in both the development and heterogeneous integration of Lithium Niobate (LiNbO_3) on Silicon Nitride for high-speed modulators have brought with it the possibility to combine several functionalities on a compliant heterogeneous platform. In the progress towards higher efficiencies, a reduction in system complexity and enhanced reliability for system critical applications such as navigation and PNT, can be envisaged. Navigation by RF techniques and timing can all benefit at system level, but some development first needs to be implemented.

Other transmitter/receiver and detector components are also facilitated directly by this technology. Frequency sampling, a substantial element of the Analogue to Digital Conversion (ADC) process, has been facilitated by the development of short pulse (mode-locked) devices. However no efficient mechanism and technological platform has been available to transform ADC, direct RF sampling to an adequate level of maturity, until now. With the level of heterogeneous integration now possible, and continually being enhanced, the possibility to include optical intersatellite communication and ranging in both the optical as well as RF frequency domain becomes possible.

LiNbO_3 modulators are the workhorse for the modulation of laser light, and key components in optical coherent communications systems and for microwave photonics. Triggered by the development of LiNbO_3 on insulator in China by NanoLN, ridge waveguide based integrated modulators that operate with CMOS levels have been demonstrated, that are now commercialized via Hyperlight in the US. These modulators have half voltages below commercial LiNbO_3 and can transform integrated photonics by offering a material with the highest Pockels coefficient.

However, to date, despite impressive advances, it is not possible to manufacture conventional photonic IC in this material due to the lack of suitable etching techniques. In addition, the losses are x10 higher than today's commercial foundry level silicon nitride, and a corresponding Process Design Kit (PDK) is not available. One can view the PDK as the design guidelines from which the entire photonic chip design can be simulated, virtually created, fabricated with high lithographic precision, and even virtually tested. Viewed more broadly Europe lacks a LiNbO_3 integrated photonics technology and foundry.

081- Lithium Niobate Photonic integrated circuit based high speed, low voltage modulators for microwave photonics **Activity description**

Objective: Based on a recent patented breakthrough (EPFL), it has been possible to deep etch LiNbO_3 with excellent optical losses and high lithographic precision based on a diamond hard mask. This process opens the route to a PDK that includes also complex photonic circuitry and a path towards commercial foundry scale deployment. The goal of this activity is to develop a full suite of high-speed devices, IQ (Quadrature) modulators, Mach-Zehnder (MZM) modulators, splitters and delay lines based on LiNbO_3 integrated photonics.

Description of innovation/Tasks:

- Develop a Process Design Kit (PDK) for LiNbO_3 integrated photonic strip waveguides to enable design methodologies to be implemented
- Demonstrate 100 GHz MZ modulator with half voltage below 2 Volts
- Demonstrated 100 GHz IQ modulators with large power handling and half voltage below 2 Volts
- Establish low loss coupling interfaces with 3dB fiber-chip-fiber losses
- Transfer the technology to a high-tech startup for foundry

Expected output:

The output of the project would be the development of a PDK for LiNbO_3 for the development of high-speed low voltage modulators for uses in PNT. Additionally, the development of MZ and IQ modulators shall also be functionally verified in domains of primary relevance to PNT.

Duration: 12 months

Budget: 350 k€

082- Low Noise Frequency Tunable microwave generation using photonic integrated microcombs



Background and Rationale

Ground based optical free space communication experiments have enabled >1 Tb/second communication links based on the multitude of carriers that are individually modulated to carry information. Optical frequency combs with line spacings that match the ITU grid have potential to implement free space communications in space.

These advances utilize the unique features of microcombs: in contrast to conventional mode locked lasers, microcombs (also called Kerr frequency combs) can operate with line spacings directly in the microwave range, relevant to optical communications, can accommodate clock signals, and can output spectra that cover a full optical octave, which are necessary for coherent microwave-to-optical frequency links. Despite major advances in microcombs, a challenge has been to develop microcombs that have sufficient power for direct use of the individual comb lines for free space-based communications, which necessitates the integration of amplifiers. Recent advances in both the development of heterogeneous integration of Lithium Niobate on Silicon Nitride for high-speed modulators, as well as the development of erbium on chip amplifiers, make high power transceivers that combine on a single die, or use multiple dies, to realize a wafer scale, foundry compatible, and low Size Weight & Power (SWaP) and power efficient transmitters and receivers.

Today's lowest noise optoelectronic oscillators achieve exceptionally low phase noise and are based on optical frequency division using femtosecond laser combs. However, these high performing solutions sacrifice spectral purity for size, weight, and power as well as environmental sensitivity, which makes them unsuitable for space applications. Over the past decade a new technology for frequency comb generation, soliton micro-combs, has emerged. The miniaturization and integration of frequency combs through lithographic microelectronic fabrication have established a new paradigm in optical microsystem capability, cost, performance, and manufacturability.

082- Low Noise Frequency Tunable microwave generation using photonic integrated microcombs



Activity Description (1)

Objective: One objective shall be to demonstrate the advantages of photonic integrated micro-combs and develop integrated laser sources with ultra-low phase noise performance to explore the implementation possibilities within PNT applications.

As a preliminary step the phase noise performance shall meet or exceed that of the best discrete oscillator modules yet occupy a compact volume typical of a far noisier chip-scale voltage-controlled oscillators (VCO).

The proposed development also requires a demonstration of wafer scale (manufacturable) photonic microwave generation systems. These shall provide low noise microwaves, based on the conversion of a soliton pulse stream into a microwave signal using direct detection with fast commercial diodes. The approach shall be based on recent advances that have demonstrated that soliton microcombs can generate low noise X- and K-band microwaves and the demonstration of hybrid and heterogeneous integration of this technology.

The platform, based on the ultra-low loss integrated photonics circuits based on Silicon Nitride shall also include MEMS based Aluminium Nitride (AlN) technology for ultrafast tuning of the generated microwaves over >25% of the carrier frequency for fast frequency reconfiguration. Together a demonstration of a new class of low noise microwave oscillators based on photonic integrated circuits based micro-combs shall be developed.

Finally, the capability of this type of platform to perform both transmission and receiver functions shall be included to position this technical approach for applications in free-space optical communication and ranging.

Description of innovation: The proposed project approach is to lay the foundation for space based optical communications in a navigation context, by developing a frequency comb-based transmitter for coherent optical telecommunication, which is space compatible, compact and in which all key components are based on photonic integrated circuits.

082- Low Noise Frequency Tunable microwave generation using photonic integrated microcombs



Activity Description (2)

Tasks: Demonstrate:

1. Greater than 1Tb/second data rate in a laboratory communication experiment
2. Optical Analogue to Digital Conversion (ADC) and Photonic assisted ADC
3. The transmission and detection capabilities for typical free space applications in LEO/MEO
4. Optical Oscillators delivering low jitter clock signals (Photonic Integrated Low Noise Microwave generation)
5. Photonic sampling (photonic RADAR and subnoise detection)
6. Laser oscillators using hybrid integrated III-V lasers (including laser integration and photonic packaging)

Expected output of Activity

The main output shall be the demonstration of the capability of photonically integrated optical frequency combs in the receiver and transmitter path for implementation in PNT systems for Optical ADC, low jitter clock signals and photonic assisted detection systems.

Duration: 24 months

Budget: 700 k€



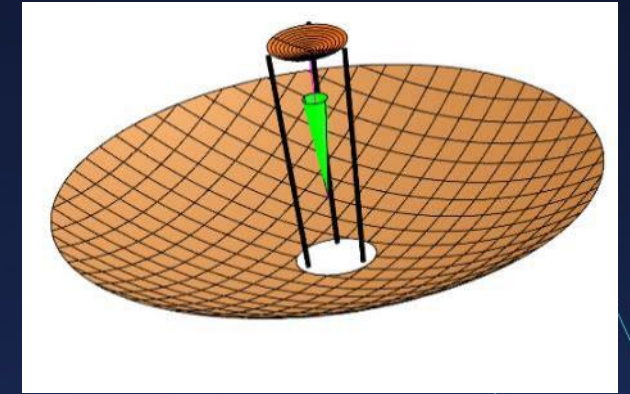
083- Deployable satellite navigation antenna

Background and Rationale

The flourishing of utilisation of small and nano satellites in LEO orbit, and the need for ever better navigation accuracy, suggests the study of (relatively) high gain deployable navigation receiver antennas, in new frequency bands, that can be stowed at launch.

In a small satellite, this antenna should allow to achieve better performance when deployed than equivalent non-deployable patch, (double-)helix or array antennas with similar size and weight at launch. In other words, a deployable antenna provides an increased antenna size compared to the size of the spacecraft, however with minimum impact on spacecraft weight.

With (relatively) higher gain, this antenna could also find application on satellites in cis-lunar regions and, if more antennas are deployed jointly, find application also for attitude determination.



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083- Deployable satellite navigation antenna

Activity Description



Objective: Design a prototype deployable satellite navigation antenna in X/Ku-Ka band

Description of innovation/Tasks:

- application of existing X-band satcom technology to satellite navigation
- review the state-of-the-art regarding deployable antennas
- identify possible use cases for the usage of deployable antennas on small satellites for the navigation function
- tradeoff different design solutions. Shapes could be paraboloids for high gain, high directivity antennas, but could be also different helix wider beam antennas, to avoid the need for pointing mechanisms. Appropriate attention to be placed on critical navigation requirements like phase stability, group delay stability and cross-polar attenuation.
- design, develop and verify the deployable antenna in a laboratory environment.

Expected output:

Prototype antenna with associated design and verification report based on laboratory data, demonstrating the reception of navigation signals with adequate signal to noise ratio.

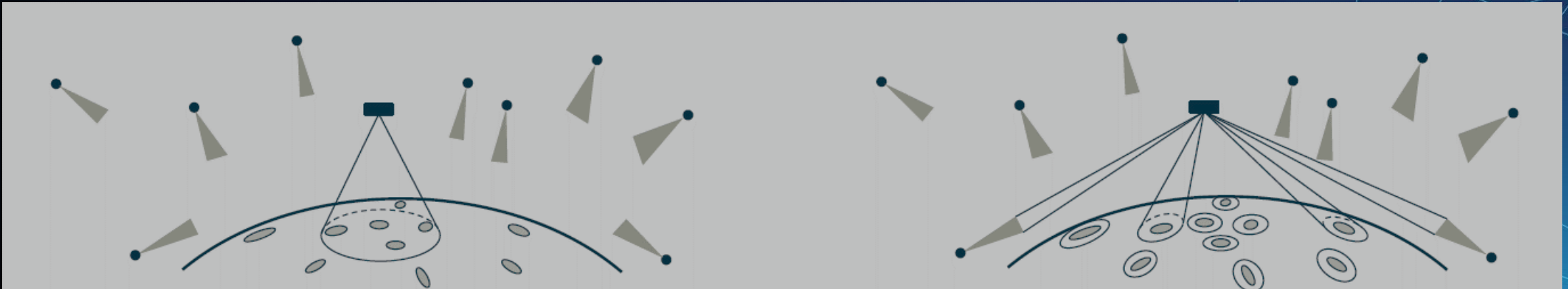
Duration: 18 months

Budget: 400 k€



Rationale

- GNSS Radio Occultation is a well-established technique while the younger GNSS Reflectometry has seen a rapid evolution around the world, in particular, after the launch UK-DMC satellite in 2003
- Some examples of GNSS-R missions flying today are: the NASA's CyGNSS 8-satellite constellation, the Spire Global cubesat constellation, the FSSCat cubesat, the Chinese Bufeng 1 Twin Satellites and China's FengYun-3E (FY3E) polar-orbiting meteorological satellite series
- ESA has plans to launch the PRETTY cubesat end of 2022 and HydroGNSS Scout mission end of 2024
- However, none of the GNSS-R and Radio Occultation payloads can take full advantage of the potential given by the many reflection points available from all GNSS transmitters, the reason being limited field of view coverage: a high performant beamformer would be a game changer.



State-of-the-art - Single beam = high gain but poor coverage
Only some reflections or radio-occultations received.
If large coverage is wanted, then SNR achieved is poor

Digital Beamformer = high gain and wide coverage
Many reflections and radio-occultations received,
High accuracy achieved

Activity Description

Objective: to design and prototype a digital beamforming processor, suitable for new space payloads for small/nano platforms, capable of generating multiple simultaneous beams for GNSS-R and Radio Occultation applications

Description of Innovation/Tasks: First time development of on-board autonomous digital beamforming of multiple beams for small/compact new space payloads, with medium/large number of channels supported. The innovation also relies on large number of channels, dynamic beamforming, low power.

The activity shall initially review the digital beamforming requirements for GNSS-R and Radio Occultation payloads, define a digital processor implemented in a power-efficient manner, develop power resource efficient digital beamforming techniques and algorithms and demonstrate the function in a representative breadboard.

Expected output

This activity will deliver a representative breadboard demonstrating:

- 1) Compact, New space compatible payloads with much higher measurement accuracy, thanks to highly improved signal-to-noise ratio,
- 2) Increased field-of-view per satellite

Duration: 18 months

Budget: 600 k€

085- Navigation technologies for a Shield nanosatellite

Background and Rationale

One of the ESA's accelerators for the usage of space is:

- PROTECTION OF SPACE ASSETS, to ensure resilient availability and functioning of space infrastructure on which Europe's economy and society relies for day-to-day life.

According to the DoD Space Surveillance Network, there are ~34,000 pieces of orbital debris with diameter greater than 10cm. This is the portion of objects "tracked".

There are also ~900,000 objects between 1 and 10 cm and ~128 million pieces smaller than 1 cm. Due to the extremely high orbital velocities (26,000km/h), the debris poses a high risk not only for human space flight, but also for satellite operations in general.

The usual measure, against the risk of collision with 10cm objects, is to perform a collision avoidance manoeuvre. ISS is also protected against non-tracked 1 cm objects by shielding (with "Whipple shields").

Complementary to the efforts of the Space Safety Program to deploy a constellation of satellites to statistically monitor the debris that cannot be detected from ground, in general, for the smaller objects, local dynamic protection could be established, taking inspiration from anti-missile protection weaponry (e.g. Patriot), UAV's automated navigation technologies and sixth generation fighters "loyal wingman" conceptual design.



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085- Navigation technologies for a Shield nanosatellite

Activity Description



Objective: Perform a system study on the navigation technologies enabling the design of a nano satellite that accompanies a master satellite, shielding it from small debris

Description of innovation/Tasks:

Instead of making the entire satellite mechanically more resilient (impacting heavily the mass budget), implement sturdiness on a small moving and agile small companion, assuming availability, in the near future, of suitable materials and shapes to ensure that unacceptable fragmentation does not occur after the impact. Study the design, development, operations of a (set of) slave inexpensive nanosatellite(s) which would fly along with a master satellite.

Main functions:

- Formation flying with master satellite, communicate with it, maneuver to put themselves in the trajectory of the debris, calculated with imaging and processing done on board, integrating the latest automation, navigation and communication means from drone technology
- Key features of nano-satellites (for which best effort assumptions will be taken in the study): sturdiness (composite, or other material, shield), rely on deflection or absorption, whichever provides more effective protection, maneuverability (gas jet only) also after being hit, capability to de-orbit or graveyarding, stripped-down to minimum, inexpensive

The main PNT technologies to be designed are: time synchronization with the master, formation flying (relative attitude/positioning and navigation determination and control), perception of the surrounding environment, impact trajectory and relative attitude calculation, maneuvers execution, de-orbiting/graveyarding

Expected output:

Report identifying use cases, navigation technologies required for the function, design of shield nanosatellite and master satellite data interface, cost and schedule estimates. Contract will be implemented in Phases.

Duration: 18 months

Budget: 400 k€



Thanks for your attention!



- For additional questions: navisp@esa.int

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