## 2019 NAVISP Element 1 Work Plan

### List of Approved Activities

#### THEME 1

- Alternative Space-based PNT Data Layer

#### THEME 2

- GNSS science with commercial aircraft

#### THEME 3

- Collaborative Processing of Distributed Receivers of Opportunity for Jamming and Spoofing Mitigation
- Advanced Multi-Frequency low-cost high-gain GNSS antennas for next generation of mass-market devices
- Precise Timing for Indoor Small Cells
- Advanced concept for chip-scale atomic clocks
- Antenna and Transponder Unit for Underwater PNT
- AI-enabled baseband algorithms for High Fidelity Measurements
- Machine Learning to model GNSS systems
- Precise positioning for mass-market: optimal data dissemination demonstrator
- PNT Timing & Synchronisation for Aviation Systems and Networks
Workplan 2019 has been shared with EC/GSA, in line with agreed ex-ante coordination procedures (ESA/PB-NAV(2016)34):

- Comments received taken into account
- Description of Activities updated accordingly

Iterations with EC/GSA has confirmed that no duplication of E-GNSS related activities has been proposed within WP19
Emerging New Space-based PNT Concepts
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Alternative Space-based PNT Data Layer (1)

Rationale

• **Alternative concept** for provision of Space-based PNT Data Layer Services

• Monitoring Stations (MS) collect PNT data (e.g. from GNSS constellations) and uplink them to a satellite

• **On board** the satellite, a COM P/L receives and routes the data, e.g.:
  • Layer data to a PNT Processing unit
  • Integrity data to the Integrity Monitoring unit

• PNT Data Layer messages are computed and delivered to a satellite P/L for encoding, signal modulation and broadcast to users

• System Monitoring and Control is performed from a ground Control Centre (CC)
Objective:
- Study of a new Space-based Data Layer concept, alternative to “conventional” overlay systems (e.g. SBAS), based on advanced on-board p/l architectures and technologies

Starting point:
- Conventional standards

Innovation:
- Alternative concept, COM+PNT+on-board processing integration concept

Outcome:
- Feasibility and identification of technical challenges, ROM cost estimates

What it enables:
- Simplified PNT Data Layer architecture, improved performance and security, smart operations and maintenance, low OPEX

Duration: 12 months    Budget: €250k
THEME 2

• Innovative Use of Space-based Solutions in the PNT Context
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GNSS science with commercial aircraft (1)

Rationale

- Some advanced passive GNSS-based processing techniques (e.g. exploiting simultaneously direct and reflected signals) applied to commercial aircraft could provide scientific data with higher spatial and temporal resolution than current spaceborne instruments.
- Feasibility of using planes for remote sensing (Altimetry GNSS-R in PARIS-Alpha, GNSS-RO in ARO, imaging and radar in Skyflox) already assessed.
- Some GNSS-R experimental flight campaigns performed.
- Short time and small spatial scale ocean, atmospheric and land processes could be measured: ionospheric data; sea levels; winds profiles; soil moisture; vegetation; climate change variables.
- These measurements could potentially allow the study of Earth processes in areas (i.e. scatt. in coastal areas or ionosphere in the ocean) and in a scale not covered by spaceborne payloads, as an excellent complement.
Objective
• Demonstrate feasibility and end-to-end performance of innovative passive remote sensing techniques based on GNSS (multi-frequency multi-constellation) embarked on commercial aircraft as a complement/augmentation to EO spaceborne measurements
• Initial design of airborne instrument and definition of a representative end-to-end demonstration

Starting Point
• ESA activities conducted on GNSS-R altimetry and surface characterization with GNSS-R
• GSA activities (e.g. MISTRALE project)

Innovation
• Foster scientific usage of GNSS signals acquired by commercial aircraft, with higher spatial and temporal resolution than spaceborne

What It Enables
• Studies and monitoring of areas not sampled spaceborne altimeters and scatterometers, due to limited spatial resolution
• Excellent complement to IGS data (e.g. for ionospheric sampling on ocean areas)

Duration: 12 months  Budget: €250k
• **Proof of Concept of Promising PNT Techniques and Technologies**
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Collaborative Processing of Distributed Receivers of Opportunity for Jamming and Spoofing Mitigation (1)

Rationale

• The evolution of the Internet of Things (IoT), Cloud platforms and 5G standards is boosting new applications and technologies in the PNT field

• Mobile operating systems (e.g., Android) provide an increasing access to raw PNT measurements, including GNSS, WiFi and other sensors

• Current low-cost SDR platforms make relatively easy to jam and/or spoof a GNSS receiver.

• Receivers in close-by locations can be exploited as receivers of opportunity in a collaborative processing for the detection, mitigation and localization of jammers/spoofers
Collaborative Processing of Distributed Receivers of Opportunity for Jamming and Spoofing Mitigation (2)

Description

Objectives:
• Design, develop and demonstrate innovative collaborative processing techniques for mitigation of jamming and, in particular, spoofing attacks

Starting point:
• ESA internal R&D on distributed processing of receivers of opportunity; focus is on innovative distributed processing applied to jamming and, mainly, spoofing mitigation
• GSA FE project “Advanced interference detection and robustness capabilities”

Innovation:
• Exploitation of receivers of opportunity (and associated signals and measurements) for jamming/spoofing mitigation via advanced collaborative processing techniques

What it enables:
• Detection, mitigation and localization of jammers and spoofers without need of dedicated infrastructure

Duration: 18 months  Budget: €400k
Growing demand of precise Mass Market applications

- Mass-Market (MM) GNSS receivers in mobile phones typically use low cost antennas as simple PIFAs (Planar Inverted-F Antennas) suitable for any constellation in L1. Their linear polarization and low gain lead to several dB of signal loss. The antenna location is dictated rather by smartphone’s design than by RF constraints. This can result in sub-optimal locations where interaction with user’s hand further weakens reception of GNSS signals.
- Current Single Frequency Mass Market receivers can achieve positioning accuracies in the order of 7.5m. With Dual Frequency Antennas, positioning accuracy can be improved by 50% (0.9m) for MM antennas. In a real scenario with a mobile user, differences are expected to be even higher.

Proposed perspective

- Development of a multi-frequency (single and dual), low-cost, circularly polarized with higher gain antenna would be a major benefit for high accuracy PNT applications. In order to improve positioning accuracy, enhancement in carrier phase stability vs antenna phase center variation could be assessed for e.g. any device orientation.
- Techniques for miniaturization and radiation enhancement could be investigated including novel materials like EBGs or meta-surfaces that could also be applied to the new generation of flexible/wearable smartphones.

Objective
- Study of advanced techniques for miniaturization and radiation enhancement of GNSS antennas of a multi-frequency, low-cost, high-gain circularly polarized antenna for next generation of MM devices, including flexible and wearable smartphones

Starting Point
- Manufacturers are moving to Multi-Frequency multi-constellation solutions using propagation correction techniques, requiring the development of multi-frequency antennas and receivers
- GSA FE studies on MM Galileo MF antennas to be considered as a complement

Innovation
- New generation of mass-market devices includes flexible and wearable smartphones, requiring development of advanced techniques and technologies in terms of flexible materials for antennas

What does it enable?
- Application of Advanced Multi-frequency low-cost high-gain GNSS antennas for Mass-market devices would pave the way to new PNT services in harsh environments

Duration: 18 Months    Budget: €450k
Objective
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Precise Timing for Indoor Small Cells (1)

Rationale

• GNSS signals are broadly used for time synchronization in different applications, including telecom, finance and energy sectors. Their usage is typically limited to outdoor applications, which do not suffer GNSS reception degradations.

• Precise indoor time synchronization is expected to be of growing interest in future applications, e.g., small cells in indoor environments to be used in future 5G telecom networks (requirements around 50 ns or below).

• High commercial interest in the topic, e.g.:
  • LEO-based timing service for indoor applications based on Iridium, targeting accuracies in the order of 100 ns (1-sigma)
  • Wire-based solutions available (accuracy is topology dependent, requiring important investment in terrestrial infrastructure)
Precise Timing for Indoor Small Cells (2)

Description

Objective:
• Develop innovative GNSS-based time synchronization techniques enabling the exploitation of GNSS signals in Indoor Small Cells (e.g., 5G Small Cells or similar applications) and demonstration of achievable timing accuracy in representative mild indoor conditions

Starting point:
• ESA internal R&D work on the topic
• GSA funded studies on G2G Timing Service

Innovation:
• Advanced estimation techniques exploiting spatial diversity for compensating the dominant NLOS channel conditions responsible of timing performance degradation

What it enables:
• Achieving precise timing in indoor conditions based on GNSS signals, without need of additional infrastructure

Duration: 18 months  Budget: €400k
Advanced concept for chip-scale atomic clocks (1)

Rationale

• Compact and low power consumption chip-scale atomic clocks (aka CSAC’s) have demonstrated promising benefits for PNT in adverse environment

• CSAC’s enable development of anti-spoofing mitigation techniques, as well

• Current CSAC technology relies miniaturisation of macroscopic vapour cell concepts, entailing challenges in assembly and thermal design

• Various researches have identified alternative advanced concepts for CSAC’s, e.g. using solid-state materials as source of atomic resonator in place of vapour cells. These innovative concepts open new avenues in the miniaturisation, integration and power/thermal handling of such devices
Advanced concept for chip-scale atomic clocks (2)

Description

Objective:
• Investigate new advanced concepts and architectures for chip-scale atomic clocks with e.g. solid-state materials
• Prove feasibility of such concepts and architectures through a demonstrator

Innovation:
• New clock architectures providing an alternative and disruptive approach to design and manufacture of physics packages

What it enables:
• New avenues in miniaturization, integration and power/thermal handling of CSAC’s

Duration: 18 months    Budget: €450k
Antenna and Transponder Unit for Underwater PNT (1)

Rationale

- **Underwater** wireless communications links have almost exclusively been implemented using **acoustic systems**. **Underwater optical links** have proved impractical for many applications.

- Given modern operational requirements and digital communications technology, time is now ripe for using **electromagnetic signals in underwater environment**, e.g. from an antenna/transponder unit to underwater wrist units (a group of divers, for instance).

- **Above 10kHz**, electromagnetic propagation is more than a hundred times faster than acoustic. This has important advantages for command latency and networking protocols, where many signals have to be exchanged. Doppler shift is inversely proportional to propagation velocity, so is much smaller for electromagnetic signals.

- **Starting point**: Systems have been proposed that function through use of a small unit that is most commonly hung from a dive boat or a larger unit buoy (the "GPS gateway") with a pre-fixed transmitter at a fixed depth. The GPS gateway has a floating radio antenna in order to determine its exact location, and communicates with the wrist units via its underwater transducer portion. As a result of this communication, the wrist units know their range and bearing from the GPS gateway, as well as the exact position of the gateway. This allows the wrist units to calculate their own absolute position, independent of the position or motion of the GPS gateway. The gateway or the boat to which it may be attached is free to drift without affecting the position displayed. The position is displayed on the wrist mounted screen both as latitude and longitude values as well as a “dot”.

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[Antenna and Transponder Unit for Underwater PNT (1)](image-url)
Objective
• The objective of the activity is to design, manufacture and test a low cost low profile antenna and transponder unit that performs well in underwater environment

Innovation
• Use of Radio Frequency was impractical in old days, mainly due to technological limitations. Nowadays, innovative RF solutions based on modern antenna and amplifier technology can finally be developed
• Several R&D projects have demonstrated the advantages of using RF for underwater/through ice communications and PNT applications, emerging with short range communications/PNT requirements. Radio waves can use air-path or seabed to communicate between two sub-merged receivers.

What does it enable?
• Such innovative solutions can enable applications constrained by cost and complexity of current PNT systems, in particular in underwater environments. At the moment these applications are only supported by acoustic waves that brings major disadvantages, such as high latency

For this specific activity French economic operators will not be allowed to bid due to national delegation decision.

Duration: 18 Months    Budget: €450k
AI-enabled baseband algorithms for High Fidelity Measurements (1)

Rationale

• Critical applications (autonomous vehicles, machine control, etc.) require high fidelity raw measurements in challenging environments. The main challenges lie in handling transfer functions from baseband samples to high quality / high fidelity raw measurements which would then feed advanced and highly hybridized positioning / navigation engines (e.g., Kalman and particle filters, DPE, PPP/RTK).

• Current R&D efforts rely primarily on empirical solutions, as the environment cannot be properly modelled and its changes well predicted (e.g. new buildings, big vehicles obstructing Line-Of-Sight to satellites with good geometry, variation of canopy coverage attenuation along the year).

• AI and machine learning provide an opportunity to catalyze such empirical processes by feeding RF data collected in field trials with a reference trajectory.
Objective
• Innovative AI-enabled algorithm to provide high-fidelity GNSS raw measurements in support of critical applications operating in challenging environment

Starting Point
• Current R&D trend: empirical solutions derived from lessons-learned, data and observations made in the fields, not adapted for challenging and unstable environments
• GSA studies (e.g. ESCAPE for autonomous driving)

Innovation
• Empirical baseband algorithm for challenging environment, developed using AI and machine learning and exploiting massive amounts of raw measurements and raw RF samples becoming available (e.g. from GNSS)

What does it enable?
• High-fidelity raw measurements, along with quality indicators related to local environments (e.g. situational awareness: multipath, NLOS)
• Ability to improve algorithm during product lifetime thanks to availability of new sets of data and results

Duration: 12 Months  Budget: €300k
Machine learning to model GNSS systems (1)

Rationale

- Artificial Intelligence (AI) is seeing a rapid growth, with an estimated economic impact of $15.7 trillion by 2030 according to a recent study by PwC
- Machine learning (ML) techniques as part of AI can be trained to recognize the relationship between a set of input and output data, to then forecast the output to a given input
- GNSS system simulations are a process where large amounts of input data lead to required output data
- This study aims at using ML to train algorithms on real observation data, to create simulation tools with higher accuracy and more flexibility than current ones based on macro models
Objective
® Study the feasibility of machine learning algorithms to model GNSS systems for a couple of pilot cases.
® Training of one machine could use IGS station observables as input and final IGS orbit products as output data.
® Another machine could use RIMS measurement data as input and EGNOS NOF as output data.
® The goal is to use these trained algorithms to approximate GNSS processing facilities more accurately than current macro models on one hand and a fast macro-model based approach to the generation of GNSS navigation broadcasts on the other, offering more versatility for future case studies than current simulation tools.

Starting point
® A review of the state of the art of current machine learning techniques for problems of this amount of input and output data. Selection of variables from input (e.g. station observables) and output (e.g. navigation broadcast).

Innovation
® Development of new GNSS performance simulation tools based on innovative machine learning techniques with an improved tradeoff between result accuracy and computational cost as compared to current macro model tools.

What does it enable?
® The developed technology would improve GNSS simulation and analysis capabilities. Possible applications include improved performance monitoring and forecasting.

Duration: 18 months  Budget: €250k
Precise positioning for mass-market: optimal data dissemination demonstrator (1)

Rationale

• Existing services for high precision positioning are useable and accurate but their dissemination is not scalable to mass market (autonomous driving and UAV)
• Current RTK services rely on NTRIP, built on top of HTTP and TCP/IP. HTTP is a unicast application and TCP enables communication between two end points → hence, such solutions require two-way links between the data centre and each single user and, as such, dissemination is not scalable to mass market usage

Current RTK service (NTRIP protocol: Internet)

Evolution of RTK service (broadcast via cellular signals)

To be adopted in mass market applications, high-precession GNSS services should rely on broadcast technologies that allow all users within an area to use a single universal stream
Objective
• To develop a demonstrator to leverage future terrestrial broadcast technologies (e.g. 5G) for data dissemination and enable multi-GNSS precise positioning (e.g. RTK, N-RTK) for mass market users

Starting Point
• Ongoing R&D (e.g. ESA/TRP, GSA) on RTK and PPP positioning in urban environments
• Low-cost GNSS receivers with on-chip RTK algorithms and integrated cellular modems (e.g. u-blox F9P).
• Current trend in terrestrial broadcast: System Information, MBMS (Multimedia Broadcast Multicast Services), and DAB technologies

Innovation
• Change of paradigm in optimal multi-GNSS assistance data dissemination: no need for internet and no need of unicast two-way communication => broadcast over cellular signals in future terrestrial networks

What does it enable?
• A low-cost broadcast solution of multi-GNSS positioning information for mass market users (ADAS, UAV, IoT)

Duration: 12 months  Budget: €350k
PNT Timing & Synchronisation for Aviation Systems and Networks 
Rationale (1)

• GNSS is being used extensively in aviation, notably for:
  - positioning and timing for on board navigation purposes
  - timing and synchronisation for datalink communications (board to ground and vice versa)
  - timing and synchronisation on ground for Surveillance, Air Traffic Control (ATC) and communication networks

• GNSS time outages or unexpected anomalies may impact the aviation systems and networks. At the same time, other independent timing sources may be available to back-up/complement GNSS-based timing and synchronisation services, such as clocks, Low Frequency systems, NTP

• Innovative schemes need to be developed involving various PNT concepts/sensor technologies in order to improve robustness and security of timing and synchronisation for the specific needs of aviation systems and networks
Objective:
• To assess and perform demonstration of innovative PNT concepts in order to provide robust and secure timing and synchronisation services for aviation systems and networks, complementary to GNSS

Starting point:
• Assessment of GNSS critical dependencies for timing and synchronisation in aviation systems and networks
• GSA funded activities, e.g. G2G robust timing

Innovation:
• Innovative usage of GNSS time (e.g. GST or GPS time, multi-GNSS multi-frequency constellation)
• Integration with upcoming non-GNSS PNT sources (e.g. A-PNT systems, 5G)
• Alternatives to GNSS time (including emerging new space-based PNT concepts)

What it enables:
• Reduction of criticality of single source of timing and synchronization for the specific robustness and security CNS/ATM requirements of aviation systems and networks

Duration: 12 months  Budget: €250k