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| Aan | Dir WTOD |
| Via mail | To: [IRSD-KHID-WTOD-DIR-DL@mil.be](mailto:IRSD-KHID-WTOD-DIR-DL@mil.be) |

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| **Onderwerp:** | | **New study proposal WTOD/RSTD** | |
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1. Proposal details
   1. Project director: Alain Muls
   2. Title: **Public Regulated Service For Defence (PRS4Def)**
2. Proposal summary (max. 200 words)

Although under civilian control, the EU radio-navigation programme GALILEO, and especially its Public Regulated Service has the potential for military use, making it credible assets as Europe moves towards strategic autonomy[[1]](#footnote-1).

Yet, the defence dimension of GALILEO still needs to be enhanced by PRS engineering, user equipment development, PRS operations supported by the Competent PRS Authority and increased user involvement.

Public Regulated Service for Defence project will focus on the definition of testing tools and methodologies in order to support the assessment of PRS added value for defence applications. The project will also define and test PRS Operational Scenarios in the context of defence use cases (Air/Land/Marine).

To do so, the project will rely on the collaboration of the Royal Military Academy and M3 Systems Belgium, which already collaborate closely in the context EU PRS Joint Test Activities, for the radio-navigation expertise and of ACOS STRAT for the definition of the need and of the operational requirements.

PRS4Def aims at delivering test methodologies, tools and infrastructure, landscapes the GNSS usage within Defence, integrates PRS Position, Navigation & Timing specific capacities in real life operational environments for Belgian Land, Air and Marine forces and provide monitoring capabilities of the PRS spectrum.

1. Proposal Description (max. 4 pages, ref’s included)

The strong dependence on GNSS for PNT make security and defence forces vulnerable to unintentional radio-frequency interferences and intentional navigation warfare activities like jamming (to block or congest satellite signal bands), meaconing (interception and rebroadcast of navigation signals) and spoofing[[2]](#footnote-2) (satellite impersonation). These activities are very affordable, also for non-state actors, and easily achievable on open navigation services from GNSS systems[[3]](#footnote-3). The increased awareness of GNSS vulnerabilities leads towards considering this as an important planning factor for almost all ongoing operations, even during normal daily tasks.

The increased reliance on PNT availability from GPS' Standard Positioning Service (SPS) of both civilian (security forces, mobile communication infrastructure or critical infrastructures) and military actors demonstrate the almost blind faith of the public in an always perfectly performing GPS system. The United States, as owner of GPS, states that its responsibility ends once signals are in space[[4]](#footnote-4) and reports from the US Air Force demonstrate a nearly perfect functioning GPS system. Meanwhile the US Department of Homeland Security has called the Global Positioning System a single point of failure for critical infrastructure[[5]](#footnote-5). This is because GPS signals are essential to virtually every networked technology but are exceptionally weak[[6]](#footnote-6).

At the same time, military, economic, and scientific experts are aware of the little effort for adversaries and electronic enthusiasts to develop ways to interfere with GNSS. The Resilient Navigation and Timing Foundation published an analysis of the biggest threats to GNSS, ranking them by vulnerability, potential damage, and the intent and capacity to carry them out. The top three threats were on-going accidental jamming and the potential use of powerful jamming devices by either a rival military or terrorist groups. The 2018 NATO exercise, Trident Juncture in Norway, that involved thousands of US and NATO troops, reported that Russian military jammed the GPS signals[[7]](#footnote-7).

The EU flagship space programmes, GALILEO and Copernicus, essentially civil and commercial in nature, have the potential for military use, making them credible assets as Europe moves towards strategic autonomy[[8]](#footnote-8). GALILEO is Europe's initiative for a state-of-the-art global satellite navigation system, providing autonomous navigation and positioning services while maintaining interoperability with other GNSS systems such as GPS and GLONASS. The system, when fully deployed, will consist of 30 satellites and the associated ground infrastructure. One of the four GALILEO services, the Public Regulated Service (PRS) is an encrypted navigation service designed to be resistant to involuntary interference and spoofing[[9]](#footnote-9), designed to be used for military and civil security purposes[[10]](#footnote-10). The PRS is reserved for governmental authorised users and sensitive applications requiring high continuity. It is delivered through a security chain adapted to the needs of the EU Member States (MSs) and of the European Union[[11]](#footnote-11).

The objective of the PRS is to improve the probability of continuous availability of the Signal-in-Space (SiS) and the availability and robustness of the associated navigation services against interfering threats to security critical applications and users. This major PRS driver is obtained by the characteristics of its signal such as the modulation or the encryption, which protects it against jamming, meaconing and spoofing and the introduction of interference mitigation technologies. According to Blyth[[12]](#footnote-12), security is a fundamental issue in all space programmes and, as such, must be one that is embedded into the planning from the beginning. This is the reason why a security chain, from the GALILEO system to the PRS user forms an integral part of the GALILEO infrastructure from its conception.

The introduction of interference mitigation technologies and cryptographic techniques for the PRS carries with it a responsibility to ensure that access to these technologies is adequately controlled to prevent misuse of the technologies against the interests of EU Member States. The GALILEO Security Monitoring Center (GSMC) executes this specific function within the European GNSS Agency (GSA) ensuring that the GALILEO infrastructure is adequately protected[[13]](#footnote-13). Following an independent security accreditation process by the Security Accreditation Board (SAB), the GSMC serves as an operator inside the GSA performing following unique roles:

* Facilitating the centralization of the access to the GALILEO PRS for the EU Member States.
* Providing GALILEO security monitoring services and implementing operational measures aimed at maintaining the security of the infrastructure.

**Public Regulated Service For Defence** (PRS4Def) will support Belgian Defence to be ready for integrating the PRS navigation service once declared fully operational[[14]](#footnote-14) by:

1. **Developing standardised laboratory scenarios to validate Radio Frequency Interference (RFI) robustness of GNSS user equipment**

The STRIKE-3[[15]](#footnote-15) project investigated the presence of interference sources on GPS SPS navigation service. The joint test activity "PRS Pilot Project for Demonstration (3PfD)"[[16]](#footnote-16) performs similar observations on the PRS frequency bands. These projects demonstrate that RFI signals can be categorized into three main types: broadband, continuous wave (CW), and pulsed interference. Multiple GNSS performance metrics may be affected by such interferences, including pseudorange and carrier-phase measurement accuracy, phase lock status, acquisition time, carrier-to-noise ratios, .... By setting up standardised and repeatable laboratory procedures, defining key performance indicators (KPIs) and creating RFI test scenarios PRS4Def will support defence during its evaluation of operational GNSS systems.

1. **Landscaping the operational requirements of GNSS enabled devices or services within Defence**

Being NATO member Belgian Defence currently uses both the standard and precise positioning services of GPS for its PNT needs. With the upcoming FOC of Europe's GALILEO system Defence faces the decision to integrate the PRS into its processes and operations. Landscaping the current usage of GPS within Defence is a first step towards defining the PNT operational needs and Key User Requirements (KUR) of our forces. Current familiarity with the GPS system does not imply an identical operational use of PRS. Raising awareness of specific features (such as its associated chain of command) of the PRS navigation service and its impact on technical complexity and operational changes is a next step needed for a successful introduction of PRS enabled systems.

For each of the operational requirements depending on or enhanced by GNSS a defence-in-depth strategy should be put in place. Performing associated risk analysis should define operations contingency planning, practices and procedures in case of GNSS degradation or disruption.

1. **Evaluate the GNSS performance and robustness in operational environments (Air / Land / Marine)**

Performance and robustness assessment done in laboratory environments are not able to fully reflect real life conditions during operations. The dynamics of the vector, operating in degraded environments such as a dense canopy or in city centres, impact the capabilities of GNSS systems making it hard to quantify the KPIs in real time. Using a replay and playback (R&P) device during real operational scenarios offer an efficient solution allowing to analyse the operational performance of GNSS navigation services in post-processing mode. Such an approach requires proper data collections that allow the replay phase to test the GNSS-based positioning terminals and to test new GNSS equipment with these data sets.

1. **Testing the PRS Operational Scenarios (POS) chain from the Signal-in-Space (SiS) to a PRS user**

A nominated Competent PRS Authority (CPA) is required for each Member States using (or manufacturing) PRS technologies. The CPA plays an essential role in implementing and managing PRS and is the interface between the PRS user and the GALILEO system. Specific operational requests[[17]](#footnote-17) can be made by a PRS user or PRS user community. During the project PRS4Def will make different POS requests in coordination with operational units allowing to evaluate how to use and integrate these scenarios during operational missions.

1. **Real-time monitoring of the GNSS spectral bands**

RFI are a significant threat to the usage of a GNSS navigation service causing service interruptions or lead to a navigation solution steered by the attacker. By monitoring the several GNSS navigation bands, decoding the navigation messages, receiver observations and combination of the accumulated data, a RFI monitoring device can be created allowing to detect potential RFI attacks, the severity of the attack and what specific navigation service is under attack. The experience from the laboratory and real life-tests will support the definition of such a RFI monitoring device.

1. **Advising the Defense Staff in the domains of harmonisation and interoperability of GNSS sensors, the PRS key management and infrastructure and POS interactions with the Belgian CPA**

The experience gained from the above processes will allow the project PRS4Def to give expert advice to Belgian Defense with regard to the combination of GNSS sensors to use for specific operational missions, for defining the infrastructure and management tools needed to roll out the PRS within Defense.

1. Motivation & Relevance for Defence

*(Motivate the introduction of this study proposal and identify the relevance for Defence)*

Satellite PNT are horizontal enablers for all military capabilities. This strong dependence has clearly been understood by opposing states and non-state actors. The development of GNSS resilience will pass through the use of the upcoming military M-code from GPS, but also through the use of the EU independent counterpart which consists in GALILEO PRS. PRS is a strategic security technology for which developing capabilities requires a common vision between operational users (Belgian Defense), research centres (IRSD and RMA), national industrial partners (AntwerpSpace[[18]](#footnote-18) and M3Systems) and security bodies (Competent PRS Authority).

The proposed actions frame in the context of the Permanent Structured Cooperation (PESCO). More specifically, the action will take place in the context of the EU Radio Navigation Solution (EURAS) project, which aims at promoting the development of EU military PNT capabilities and future cooperation taking advantage of GALILEO and the PRS[[19]](#footnote-19). Within EURAS "GALILEO for Defense (GEODE)" is one of the projects with a financing scheme of the European Defense Industry Development Plan (EDIDP)[[20]](#footnote-20). This program recently started under French lead with 14 Member States, Belgium is one of the five actively participating member states of the project. The complete task matrix is not mature yet and will be refined by the steering committee manned by all 5 contributing MoDs.

GEODE covers all the necessary activities for the prototyping, testing and qualification on different platforms (naval, land, airborne) of PRS receivers, including the security module (SM), and the integration in military host equipment. GEODE will also define and test the common infrastructure for key management, PRS security management and other PRS information management as well as create standards for interfacing military GPS and PRS.

The expected impact of GEODE is to promote and facilitate the uptake of the GALILEO PRS service, create a equal playing field in the Defense PNT market for European industry and provide essential technologies for EU Defense interoperability.

Belgium has announced in a letter of intent (LoI) its intention to provide through national contracts and in-kind contributions a PRS Security Module and a PRS receiver board[[21]](#footnote-21) and test activities for access control and PNT accuracy during military exercises and operations of Belgian Defense. These latter activities typically fall under the scope of this proposal and thus cover the contributions in kind that Belgium MoD could propose within the GEODE framework. These contributions together with pure financing and potential contractual support will strongly be appreciated by BELSPO as the fair contribution from MoD in the Belgian participation.

1. State of the art.

*(Describe the state of the art related to this proposal at a national and international level)*

GALILEO declared Initial Services (IS) in December 2016 for the Open Service (OS), the Search and Rescue (SAR) and the encrypted Public Regulated Service (PRS), a first step towards Full Operational Capability (FOC). At that moment, GALILEO officially moved from a testing phase to the provision of live services. From then on GALILEO has made significant progress. There are now 26 GALILEO satellites orbiting the earth and the supporting ground station infrastructure has expanded[[22]](#footnote-22). The next important phase is the declaration of the Enhanced Services (ES) which will bring full ranging accuracy and enhanced ranging and timing availability for the Open Service. In preparation for PRS enhanced service delivery[[23]](#footnote-23), the GSA continues to update PRS functionalities and procedures and improve the navigation performance of PRS, which will benefit from the new satellites added to the constellation. During this phase pre-operational receivers will be tested[[24]](#footnote-24).

Understanding the RFI threats to GPS Standard Positioning Service (SPS)[[25]](#footnote-25) PNT capacity was first carried out on a large scale by the STRIKE3 project[[26]](#footnote-26) funded by the European GNSS Agency. Within the international STRIKE3 monitoring network, more than 50 sites have been set up over 20 different countries. This network has allowed the STRIKE3 project to make comparisons based on infrastructure, time of day, the number of events over a period of time, events with the highest power and many other variables. The international network as a result, has allowed site owners to understand their RF environment better and understand any threats that may be present in their area. The number of detected threats and the local impact raised awareness amongst specialists of the vulnerability of the SPS service, used by most critical infrastructures and security agencies for their operations.

The European GNSS Agency (GSA) launched in 2016 a call for proposals GSA/GRANT/03/2016 in support of PRS Pilot projects to be implemented by groups of Member States (MSs) as Joint Test Activities (JTAs). The aims of this call include amongst others the evaluation of the GALILEO PRS in a representative way, benchmarking the PRS PNT against other GNSS open services and to raise awareness of the potential benefit of PRS to potential users. Three projects were awarded and started their activities in 2018. Belgium, represented by the RMA and M3Systems, participates in 2 consortia:

* **PRS Pilot Project for Demonstration (3PfD),** led by BE CPA and coordinated by the Royal Military Academy with partners from Belgium, Germany, Finland, Poland and Sweden.
* **PRS European Tests for Robustness of User Segment (PETRUS),** led by French CPA and coordinated by CNES (Toulouse) with partners from France, Belgium, Portugal, Italy and Spain.

The consortia of these projects will be the first users having access to the pre-operational PRS receiver (P3RS2) with tamper proof security modules. The P3RS2 receivers, in addition to TUR-P receivers and other open service receivers, will be used during both 3PfD and PETRUS projects for laboratory interference tests (jamming, meaconing and spoofing) and for real life field tests with the aim to assess the robustness of all these GNSS services and receivers. The experience gained by RMA and M3Systems in these projects is an asset for the current PRS4Def proposal.

1. Global research context

*(In which global research context can this proposal be fitted (national & international, EDA, NATO)).*

The PRS4Def proposal combines elements fitting into several national and international projects. PRS4Def supports the in-kind contribution of Belgian Defense in the EURAS "GALILEO for Defense (GEODE)" project adding to the financial contribution of BELSPO in support of AntwerpSpace. The project will raise awareness within Belgian Defense of the vulnerabilities and robustness characteristics of different navigation services and introduces an in-depth protection strategy by performing risk analysis of GNSS dependant or enhanced operational concepts. Through the PRS4Def project Belgian Defense will gain from the experience obtained in the ongoing JTA projects 3PfD and PETRUS and support the contribution of AntwerpSpace, funded by BELSPO, within GEODE.

PRS4Def will also build the bridge and consolidate the existing experience and partnership between the current JTA projects and the next call for proposals by the GSA for a second round of JTA (namely JTA2). Towards declaration of PRS FOC Belgium has to define and set-up a final structure for the Competent PRS Authority who's tasks are described in classified annexes of the Common Minimum Standards (CMS). This document identifies security and operational tasks of a CPA. PRS4Def will develop techniques and procedures supporting the operational tasks of the CPA.

1. Research Strategy

*(Describe the methods, techniques and procedures by which the research will be conducted)*

The adopted research strategy is organised around following items:

* **Requirements collection and consolidation**
  + Several studies have raised the vulnerability problems of using a GNSS system for PNT services. These studies mainly focus on RFI effects on the open navigation services of GNSS and their impact on civil applications, such as critical infrastructures.
  + The study and synthesis of the state of the art publications on GNSS RFI will allow to translate the concerns and anticipated problems to the defense oriented navigation services, such as GPS military and GALILEO's PRS navigation services.
  + The analysis will lead to a list of interfering signals to be synthesized during the laboratory tests as well as meaconing and spoofing techniques.
* **Design of measurement set-ups and scenarios**
  + The laboratory set-up must allow a comparison between different receivers and different navigation services under the same circumstances. Defining and characterising the used equipment, such as GNSS sources, signal generators, cables and combiners/splitters, makes up the design phase of the laboratory.
  + Similar, for collecting real life data within all components of Belgian Defense, a mobile set-up has to be defined able to be integrated into our main weapon systems.
  + Document template for describing the interference tests will be developed.
  + Comparing devices and navigation services is based on a common set of key performance indicators based on international data formats.
  + The PRS operational scenarios and the chain between PRS user and the system will be detailed.
* **Development phase**
  + The defined laboratory and mobile set-up is developed and tested using available receivers.
  + Software for determination of KPIs based on international data formats is developed, revised and tested on reusable navigation services data sets.
  + In order to perform repeatable tests, the interference test procedure will be automated.
  + The GALILEO PRS chain, the security and operational tasks of the CPA and the implications for our defense forces will be briefed to Belgian Defense staff and components based on the Need-to-Know PRS prescription.
* **Validation and exploitation phase**
  + Common operational scenarios will be set-up with all components of Belgian Defense allowing operational data collection.
  + The KPI software will perform off-line testing of the robustness of different navigation services based on the collected datasets.
  + Different PRS operational scenarios will be performed during the data collection and evaluated on their operational usage.

1. Collaboration

*(Describe, when collaboration is intended, the role and complementarity of each of the partners and the planned coordination)*

PRS4Def as a ‘triple helix’ project proposal is based on a close collaboration between ACOS Strategy as governmental entity, RMA-CISS as academic research centre and M3Systems as industrial partner.

ACOS Strat is the client of PRS4Def and has expressed the vital and strategic interest that GNSS navigation services has within current and future military operations. Belgian Defense has committed to an active role within the EDIDP GEODE project and convinced BELSPO to provide financial support to Belgian industry.

RMA CISS is active within PRS since the first tests in 2013 organised by ESA. A close collaboration with interim BE CPA put Belgium on the European PRS map as a very active member state. The expertise and knowledge of the PRS operational concepts and of the PRS and other navigation services from both GPS and GALILEO are a valuable asset and form a solid basis to successfully complete the PRS4Def project. RMA-CISS, in close collaboration with M3Systems, will realise the laboratory and mobile infrastructure within the RMA, allowing Belgian Defense to perform reproducible GNSS tests.

M3SB has specialized in radio-navigation technologies (GNSS) and Air Traffic Management (ATM). M3SB commercializes GNSS dedicated test-beds used for the assessment of GNSS receiver performances. This expertise along with the in house developed tools for simulating open navigation services and automation of RFI scenarios are e robust basis for PRS4Def.

RMA-CISS will concentrate on development of scenarios for evaluating the PNT capabilities of navigation services while M3Systems will work on the implementation and automation of RFI scenarios.

1. Expected Outcome

*(Describe the expected research outcome and how this outcome will be managed and used by the research team after termination of the project. Demonstrate the innovative character)*

The main purpose of PRS4Def are to deliver:

* **Test methodology, tools and infrastructures**
  + Developing standardized laboratory scenarios to validate RFI robustness of User Equipment
  + Testing the PRS Operational Scenarios (POS) chain from the Signal-in-Space (SiS) to a PRS user
  + Evaluate the GNSS performance and robustness in operational environments (Air / Land / Marine)
  + Real-time monitoring of the GNSS spectral bands
* **Integrated PRS PNT in operational defense environments**
  + Landscaping the operational requirements of GNSS enabled devices or services within Defense
  + Advising the Defense Staff in the domains of harmonisation and interoperability of GNSS sensors, the PRS key management and infrastructure and POS interactions with the Belgian CPA
* **In-kind contribution of Belgian Defence in the GEODE project**
  + Belgian Defense, as active member of the GEODE consortium, offered as in-kind contribution to perform activities supporting the prototyping, testing and qualification on different platforms (naval, land, airborne) of PRS receivers, including the PRS operational requests operated by the security module (SM), and the integration in military host equipment.

1. Feasibility & Risk

*(Describe the elements which could jeopardize the achievement of the expected outcome)*

This section presents the SWOT analysis of the project.

* **Strengths**
  + PRS4Def will increase awareness about the robustness of different navigation services within Belgian Defense and introduces new operational concepts conceivable with the GALILEO PRS navigation service.
  + PRS4Def will identify GNSS dependant or enhanced operational concepts and services within Belgian Defense.
  + PRS4Def will clarify the relations and operational tasks of BE CPA in support of military operations.
  + PRS4Def will create a standardised laboratory and mobile set-up for Belgian Defense.
  + PRS4Def will strengthen the Belgian position in the domain of GNSS PNT, more specifically in GALILEO PRS navigation service.
  + PRS4Def will provide the in-kind contribution of Belgian Defense within GEODE.
  + PRS4Def will offer AntwerpSpace the ability to pre-test their development within GEODE in a dedicated laboratory and under operational constraints.
  + PRS4Def will strengthen the cooperation between academic resources and industry through close collaboration with M3Systems.
  + PRS4Def can start activities using the PRS TUR-P receiver available at RMA-CISS.
* **Weaknesses**
  + Operational PRS receivers are not yet available. The participation of RMA-CISS and M3Systems in the JTA projects ensures access to a pre-operational receiver (P3RS2) from GSA.
  + Non-attribution of EDIDP grant GEODE is not likely. In this case the current GEODE proposal will be truncated and based on national funding only. BELSPO has already committed 5 MEURO to AntwerpSpace within the context of GEODE.
  + The PRS navigation service is a critical asset of Europe and is under submitted to EU security rules. Moreover, a distinction is made between PRS users, PRS receiver manufacturers and PRS security module manufacturers. The support of Belgian Defense Staff and the creation of a secure zone within the department CISS are essential.
* **Opportunities**
  + PRS4Def offers the opportunity for future CPA to perform monitoring of the PRS spectrum, as described in its operational tasks by the CMS.
  + PRS4Def offers Belgian Defense staff the technical knowledge and support for negotiating about the set-up of a final CPA in Belgium.
* **Threats**
  + Dependence of PRS4Def upon GEODE project: a delay in the planning of GEODE, who will develop PRS receivers for defense, could impact the planning of PRS4Def.

1. Dual aspect

*(Explain how this research could be valuable for the civil sector)*

GALILEO Public Regulated Service is per definition a dual-use service operated by the European Commission. PRS receivers developed within the scope of GEODE will set the path for the second generation of mobile receivers aimed for equipment of civilian user communities. Typically, PRS receivers could be implemented for emergency vehicles, police cars, crisis response equipment or critical infrastructures.

PRS is a discretionary service for European Member States. No federal Belgian strategy for PRS exists yet but Belgium already took some decisions in favour of a national use of PRS, such as the creation of the Belgian CPA under the National Security Authority for instance.

The GEODE project has received strong support from the Federal Ministry for Scientific Policy (which reserved 5 MEUR on the civilian Space budget for the project) and from the Ministry of Mobility.

The GPS system is a "cross-sector dependency" for the Department of Homeland Security's (DHS) 16 designated critical infrastructure sectors. More specifically, DHS considers 13 of the 16 critical infrastructure sectors to be critically dependent on PNT while the other 3 sectors are considered to be somewhat dependent[[27]](#footnote-27). In the increasingly complex GNSS environment in which there is both unintentional and deliberate disruption of satellite signals, there is a need to permanently monitor the GNSS spectra and develop techniques and receivers which address the needs of the critical infrastructure user community, mainly energy generation and distribution, telecommunications and financial operators.

At present Belgium occupies a prominent position within the European PRS community due to the very active participation of both RMA-CISS and M3Systems in the JTA projects 3PfD and PETRUS. Furthering this close collaboration between research academy and industrial partner will perpetuate this reputation. By offering their expertise as in-kind contribution to GEODE, RMA-CISS and M3Systems also support the recent created PRS division within AntwerpSpace. Finally RMA-CISS and M3Systems could support operational aspects within the set-up of a final structure of Belgian CPA.

1. References.

*(Cite the 10 to 15 most relevant international publications on the topic)*

In depth publications about GALILEO PRS are not freely and openly available since PRS is considered a critical asset of the European Union and is thus subjected to confidentiality and a Need-to-Know.

1. Phasing of the project (max. 4 pages)

**Proposal start date:** 1 September 2021

**Work package 1: Project Management**

***Begin date: 01/09/2021 – end date 31/08/2025*** *(see Figure 1 for details).*

* *Description*

The project management will be performed by Prof Alain MULS, RMA-CISS in close collaboration with ACOS Strat, Cdt Nicolas GEROME.

* *Objectives (clearly state the different objectives)*

Overall coordination of the PRS4Def project including:

* overseeing project progress, coordinating the overall work plan and monitoring compliance by the partners with their obligations
* fulfilling financial and reporting obligations towards RHID
* coordinating with ACOS Strat, Cdt Nicolas GEROME.

**Work package 2: Set-up of a GNSS laboratory and developing standardised laboratory scenarios to validate RFI robustness of GNSS user equipment**

***Begin date: 01/09/2021 – end date: 29/02/2024*** *(see Figure 1 for details).*

* *Description*

Setting up a GNSS laboratory and develop standardised and repeatable laboratory procedures, defining key performance indicators (KPIs) and creating RFI test scenarios

* *Objectives (clearly state the different objectives)*
* WP-2.1: set-up of a GNSS laboratory which allows to perform repeatable RFI scenarios on different types of GNSS receivers
* WP-2.2: identify waveforms interfering with navigation services from GPS and GALILEO
* WP-2.3: define interference scenarios targeted at different GNSS navigation services
* WP-2.4: perform interference scenarios in a controlled laboratory environment under repeatable conditions
* WP-2.5: examine KPIs to validate influence of interferences on navigation services from COTS receivers, PRS (pre-)operational and military GPS receivers

**Work package 3: Landscaping the operational requirements of GNSS enabled devices or services within Defense**

***Begin date: 01/09/2022 – end date: 31/08/2024*** *(see Figure 1 for details)*

* *Description*

Create an overview and define the PNT operational needs and requirements of Belgian Defense.

* *Objectives (clearly state the different objectives)*
* WP-3.1: make a survey of current and future usage of GNSS navigation services
* WP-3.2: synthesise and define the PNT operational needs and requirements of our forces
* WP-3.3: perform risk analysis on a selected operational need
* WP-3.4: define contingency plan in case of GNSS degradation or denial

**Work package 4: Evaluate the GNSS performance and robustness in operational environments (Air / Land / Marine)**

***Begin date: 01/09/2021 – end date: 31/08/2024*** *(see Figure 1 for details)*

* *Description*

Analyse the operational performance of GNSS navigation services in post-processing mode

* *Objectives (clearly state the different objectives)*
* WP-4.1: identify operational scenarios supported by or depended on or enhanced by GNSS navigation service within Belgian Defense components
* WP-4.2: create equipment set-up for logging GNSS navigation services during military operations
* WP-4.3: coordinate with Belgian Defense components and scenario execution
* WP-4.4: post-processed analysis of scenario and determination of the KPIs
* WP-4.5: comparison of the operational usefulness of different GNSS navigation services

**Work package 5: Testing the PRS Operational Scenarios (POS) chain from the Signal-in-Space (SiS) to a PRS user**

***Begin date: 01/11/2022 – end date: 31/08/2024*** *(see Figure 1 for details)*

* *Description*

Evaluation of the PRS operational chain from user to signal in space.

* *Objectives (clearly state the different objectives)*
* WP-5.1: introduce the PRS Operational Scenario (POS) requests
* WP-5.2: translate POS requests into military operational concepts
* WP-5.3: define operational concepts based on POS requests in cooperation with BE Defense components
* WP-5.4: evaluate the execution of these CONOPS in collaboration with BE Defense component

**Work package 6: Real-time monitoring of the GNSS spectral bands**

***Begin date: 01/09/2021 – end date: 31/08/2024*** *(see Figure 1 for details)*

* *Description*

Realisation of a real-time monitoring GNSS navigation services device.

* *Objectives (clearly state the different objectives)*
* WP-6.1: definition of GNSS signals, measurements and data to be monitored
* WP-6.2: market research for GNSS monitoring device
* WP-6.3: adding missing functionality to cover the needs for Belgian Defense (identified in WP-2)

**Work package 7: Advising the Defense Staff in the domains of harmonisation and interoperability of GNSS sensors, the PRS key management and infrastructure and POS interactions with the Belgian CPA**

***Begin date: 01/09/2024 – end date: 31/08/2025*** *(see Figure 1 for details)*

* *Description*

Become the GNSS expertise centre for Belgian Defense

* *Objectives (clearly state the different objectives)*
* WP-7.1: raise awareness of the capabilities and issues of different GNSS services
* WP-7.2: give expert advice to Belgian Defense for defining, purchase and deployment of GNSS devices

**Proposal end date:**1 September 2025



Figure 1: PRS4Def Work Package Breakdown Structure and Planning

1. Expertise of the project proposers (max. 2 pages)
2. Expertise

*(Describe the expertise present/available in the research team/dept with respect to the proposal)*

|  |  |
| --- | --- |
| **Partner** | **Background and expertise** |
| RMA-CISS | Prof Alain MULS from the Department CISS of the Royal Military Academy is active in GALILEO since 2013. He participated in the first PPTI[[28]](#footnote-28), organised by the European Commission (EC) and the European Space Agency (ESA), tests when only four In Orbit Validation (IOV) satellites were available. Since then he is the only Belgian PRS user having access to a (semi-)permanent operating TUR-P receiver. During the summer of 2016, in the frame of the BELSPO funded project Belgian GALILEO PRS In Orbit Service validation (BEGPIOS), Prof MULS represented Belgium in the Initial Service Validation Campaign (ISVC) and review (ISVR) meeting. As only EU Member State Belgium[[29]](#footnote-29) presented the results and problems encountered during the confidential PRS part of the IOVC. Prof Muls performed all operational tasks until July 2019 and he represented the interim BE CPA at different PRS working groups. Since June 2018 Prof Muls is the coordinator of the 3PfD consortium and actively participates in the French led PETRUS consortium. |
| M3Systems | M3 Systems is a SME located in Brussels and Wavre (Belgium) which provides services in the Space and Aeronautics domains.  In the field of satellite Radio-Navigation M3 Systems has gained a recognised expertise in:  signal processing studies – specification, modelling and simulation of GNSS signal, Analysis of interferences issues on PRS signal;  GNSS performance evaluation – GNSS Signal Quality Monitoring methodologies and tools, GNSS data collection and analysis;  GNSS test and measurement solutions – development of reference trajectory equipment, GNSS signal simulator, record and playback, interference and attack generator in order to assess the robustness of GNSS under intentional and/or unintentional interference conditions;  It is to be added that M3 Systems is involved in two of the three PRS Joint Test Activities under the umbrella of the GSA. In these projects, M3 Systems brings its expertise and solution for the assessment of PRS added value in terms of robustness to interferences. |

1. Publications

*(List of publications over the five last years of the study director and the concerned researchers)*

Since 2013 Prof Alain Muls has made several reports and presentations about GALILEO PRS during specific working groups organised by ESA, the EC and GSA (See table [1](#tbl:wg)). Unfortunately these reports and presentations are classified with a Need-to-Know clause.

Table 1: Working Groups attended by Prof Alain Muls

|  |  |
| --- | --- |
| **Working group** | **Purpose** |
| **WG-NET** | Working group National Expert Team advises and reports to the GNSS SB on all issues relating to support of the Program on security, e.g. supporting the Commission in defining the applicable security requirements (SSRS) and on the threat and vulnerability analysis. |
| **WG-PRS** | Working group Public Regulated Service advise and report to Security Board on all issues relating to PRS service development. |
| **WG-PUSS** | Working group PRS User Segment Standards is to propose, develop and assess PRS user segment standards to: maintain competition, respect security, sustain development, and sustain interoperability. |
| **WG EU CPA** | Meeting of the representatives of the CPAs from all MSs to align their vision about further evolution and developments |

As co-applicant for the JTA projects 3PfD and PETRUS both Prof Alain Muls and Ir Olivier Desenfans made reports and presentations with similar restrictions.

Yet, some publications related to the assessment of interference impact on GNSS Open Signals can be provide:

* Ioana Gulie, Jan Wendel, Frank M. Schubert, César Roda Neve, Olivier Desenfans, Ruediger Weller, *Finding Interference Threats*, NAVITEC 2018.
* Olivier Desenfans, Willy Vigneau, Marc Pollina, Raffaele Fiengo, *Impact of interferences signals on GNSS performances and review of state-of-the-art of mitigation techniques*, NAVITEC 2014

Two national conferences on Galileo have been organised by Prof Muls with participation of ir Olivier Desenfans:

* The Public Regulated Service of the European Galileo Navigation Satellite System, 26 June 2014
* GALILEO Initial Service Declaration of The Open Service, The Rescue Service, The encrypted Public Regulated Service, 9 March 2017.

1. Required equipment and staff (max. 2 pages)
2. Equipment

*(Describe and justify the necessary equipment (software, hardware, other). Estimate the cost if the equipment is not available within department or Defence)*

Setting up the GNSS laboratory and the mobile recording facility requires the purchase of small equipment such as GNSS combiners, splitters, cables, .... The needed signal generators, spectrum analysers and COTS and PRS receivers are available at both the Department CISS as M3Systems. The automation of the RFI scenarios will be done using specific developed equipment owned by M3Systems.

For setting up the real-time monitoring of the GNSS spectral bands a GNSS monitoring device will be purchased. This device needs to cover all bands of the GNSS spectrum. During the course of this project the specifications for this device will be defined.

1. Staff

*(Describe and justify the necessary staff. Describe the required level of its expertise)*

PRS4Def requires:

* **at RMA-CISS**
  + a researcher with an engineering degree, preferably having some years of experience. This researcher will define in close collaboration with Alain Muls the elements, the set-up and the security of GNSS laboratory as well as the mobile recording facility. He will perform, execute and analyse the RFI scenarios.
  + a part-time (2/5) laboratory technician with experience in RF signals and interference detection. He will assist in setting up the environments, characterising and calibrating the used RF equipments (splitters, combiners, cables, antennas, ...) and perform the laboratory tests
* **at M3Systems**
  + a full time dedicated engineer with experience in signal processing and more specifically in GNSS, including performance assessment and RF interference impact analysis. Besides this engineer, the M3 Systems team will support with the expertise in test and measurement solution development in order to support the definition, development and deployment of the laboratory and mobile test infrastructure.

The current team involved in the JTA projects, will also support to leverage on the experience and lessons learned.

Most likely, all persons directly involved PRS4Def will need to have a personal security clearance of level CONFIDENTIEL UE/EU CONFIDENTIAL and PRS authorisation in order to have access to specific PRS equipment.

1. Budget (Annex D)

*(Estimation of necessary budget for equipment, personnel and travel has to be filled in using annex D)*

The PRS4Def budget table is in file PRS4Def - Budget Table Bijl D.xls.

1. Proposed experts (max. 1 page)

*(Propose two national experts in the related domain that could evaluate the present proposal. Also provide their contact details)*

Table 2: Expert contact information

|  |  |
| --- | --- |
| **Name** | **Contact details** |
| **GROGNARD**, Peter | Is founding father and former CEO of Septentrio Satellite Navigation. Currently he is Managing Director of the von Karman Institute.  grognard@skynet.be  Mobile +32 477 650079 |
| **WILMS**, Frank | Is GALILEO PRS project coordinator, formerly at Septentrio Satellite Navigation, currently at AntwerpSpace.[[30]](#footnote-30)  frank.wilms@septentrio.com  Work +32 16 300805  Mobile +32 479 296262 |
| **VERMEIRE**, Bruno | Mr Vermeire is member of the Nationale Veiligheids Overheid (NVO) and is since June 2019 President of the Security Accreditation Board (SAB) at Prague  bruno.vermeire@diplobel.fed.be  Mobile +32 476 994896  Work +32 2 5014573 |

1. Proposal summary table (max. 2 pages)

|  |  |
| --- | --- |
| Domain | DAP/MSP/HFM |
| Study director | Prof Alain MULS is active in GALILEO since 2013. He participated in several PRS test campaigns and presented his reports during meetings with ESA, the EC and GSA. Since June 2018 Prof Muls is the coordinator of the 3PfD consortium and actively participates in the French led PETRUS consortium. |
| Research Unit/Staff Dept | *Photo and short CV* |
| Title | Professor |
| Aim of the study | PRS4Def aims at delivering test methodologies, tools and infrastructure, on the one side, and integrate PRS Position, Navigation & Timing (PNT) specific capacities in real life operational environments for Belgian Land, Air and Marine forces. |
| Research strategy | The WBS breakdown illustrates the logic steps towards the goals of PRS4Def |
| Innovative character | RMA-CISS is since years the only real user of the PRS navigation service. Sustaining and elaborating on the expertise of RMA-CISS and M3Systems, both involved in the JTA from the European GNSS Agency, will allow Belgium to have a appreciated vote in the evolution of the PRS navigation service within Europe. |
| Dual character | PRS4Def offers a strong support to Belgian Defense and will raise awareness of the vulnerability and robustness of different GNSS navigation services. This expertise is also benevolent for critical infrastructures. The final set-up of Belgian CPA, in which Belgian Defense will play an important role, will profit from the experience gained during PRS4Def. |
| Relevance for Defence | GNSS is directly and indirectly used in many weapon systems as a horizontal enabler for all kind of operations. |
| Partnerships | RMA-CISS, M3Systems and ACOS-Strat |

Name

Rank

Function

1. “European space community steps up to Security and Defense.” [↑](#footnote-ref-1)
2. Spoofing can be subdivided in *measurement spoofing* or mimicking the broadcasted satellite signals and *data spoofing* which introduces incorrect digital data into the receiver. [↑](#footnote-ref-2)
3. Nicolas GÉRÔME, “Rapport meeting CT Joint Space nr.2.” [↑](#footnote-ref-3)
4. “Double trouble: GNSS over-reliance and its costs.” [↑](#footnote-ref-4)
5. FOUO, “National risk estimate: Risks to U.S. critical infrastructure from Global Positioning System disruptions.” [↑](#footnote-ref-5)
6. RNTF, \**Prioritizing Dangers to the United States from Threats to GPS - Ranking Risks and Proposed Mitigations*\* [↑](#footnote-ref-6)
7. Ryan Browne, “Russia jammed GPS during major NATO military exercise with US troops.” [↑](#footnote-ref-7)
8. “European space community steps up to Security and Defense.” [↑](#footnote-ref-8)
9. “PRS – the future is bright!” [↑](#footnote-ref-9)
10. “Space is an enabler of security and defense.” [↑](#footnote-ref-10)
11. “EU space infrastructure guarantees leadership in security and defense.” [↑](#footnote-ref-11)
12. “The security factor.” [↑](#footnote-ref-12)
13. “The GSMC: An integral part of the Galileo infrastructure European GNSS Service Centre.” [↑](#footnote-ref-13)
14. The official date for Full Operational Capability (FOC) is 2020 but will most likely slip up to 2022. [↑](#footnote-ref-14)
15. Dumville, \**Standardisation of Gnssthreat Reporting and Receiver Testing Through International Knowledge Exchange, Experimentation and Exploitation. STRIKE-3, final Report*\* [↑](#footnote-ref-15)
16. 3PfD-Consortium, “PRS Pilot Project for Demonstrations.” [↑](#footnote-ref-16)
17. PRS Operational Scenario (POS) can not be detailed in the scope of this document. [↑](#footnote-ref-17)
18. AntwerpSpace, with financial support from BELSPO, will develop a Belgian PRS Security Module and a PRS receiver board. [↑](#footnote-ref-18)
19. “EU Radio Navigation Solution (EURAS) PESCO.” [↑](#footnote-ref-19)
20. “Development of European standardized and sovereign Galileo PRS navigation receiver capabilities compatible with GPS/PRS solution for military purposes.” [↑](#footnote-ref-20)
21. Belgian financing for national industries participating in the consortium (AntwerpSpace) is guaranteed by BELSPO around 5 MEUR. This amount is foreseen to support the first bullet of Belgian intentions (PRS Security Module & PRS receiver board). During this time he attended the following working groups: [↑](#footnote-ref-21)
22. “Constellation Information European GNSS Service Centre.” [↑](#footnote-ref-22)
23. “Directions 2019: Galileo moves toward FOC - GPS World.” [↑](#footnote-ref-23)
24. “GSA supporting development of all PRS user segments GALILEO.” [↑](#footnote-ref-24)
25. The Standard Positioning Service (SPS) is used in almost all civil geo-location, navigation and timing applications and is based on the civil signals from the legacy GPS system. [↑](#footnote-ref-25)
26. Dumville, \**Standardisation of GNSS Threat reporting and Receiver testing through International Knowledge Exchange , Experimentation and Exploitation - STRIKE3*\* [↑](#footnote-ref-26)
27. Rutkowski, “Critical Infrastructure in the 21st Century (GNSS & PNT Solutions).” [↑](#footnote-ref-27)
28. PRS Participants trials in IOV [↑](#footnote-ref-28)
29. France also made a presentation but withheld all information about the type of measurements or tests performed during the ISVC. [↑](#footnote-ref-29)
30. The Aeronautics and Defense Division of Septentrio has recently been acquired by AntwerpSpace. The relocation is not yet finalised so that the contact details of Mr Wilms are still those of its former employer. [↑](#footnote-ref-30)