RIPTIDE PHASE 2

RESILIENT PNT FOR THE BLACK SEA AND DANUBE REGION: DEMONSTRATOR

Final Presentation Meeting

Agenda

Project Team
Project Context
Technical Approach
Demonstrator Design and Implementation
Trials Preparation
Performance Analysis
Future RIPTIDE Phases
RIPTIDE Pilot Phase
Transversal Application Assessment

Project Team

RIPTIDE Phase 2 Consortium

GMV Romania - prime contractor for RIPTIDE PHASE 2 – was responsible for all activities related to the development of the resilient PNT solution for the Black Sea and Lower Danube Basin region, laboratory and field testing as well as Project Management activities.

MHD is the national entity under the MoD responsible for managing the maritime hydrographic system and developing, managing and updating the information contained on cartography, marine geodesy and maritime navigation. Furthermore, MHD is the national authority representing the Romanian Government in relation to IALA / AISM and OHI.
In **RIPTIDE PHASE 2**, MHD supported the campaigns by providing access to vessels and lighthouses to host the ground infrastructure and also continued its role from RIPTIDE 1 to provide an essential view from the regulatory and standardization perspective.

ROSA RC is a research centre and an essential partner to the consortium, due to their experience in GNSS related activities and strong knowledge of the strategic national directions (representing Romania in relevant bodies at the level of EU, ESA or `other international institutions).
In **RIPTIDE PHASE 2**, ROSA RC managed the transversal applicability assessment of the solution and how it can be exploited to other domains of applicability – as an element of particular interest at national level.

Initial support of:

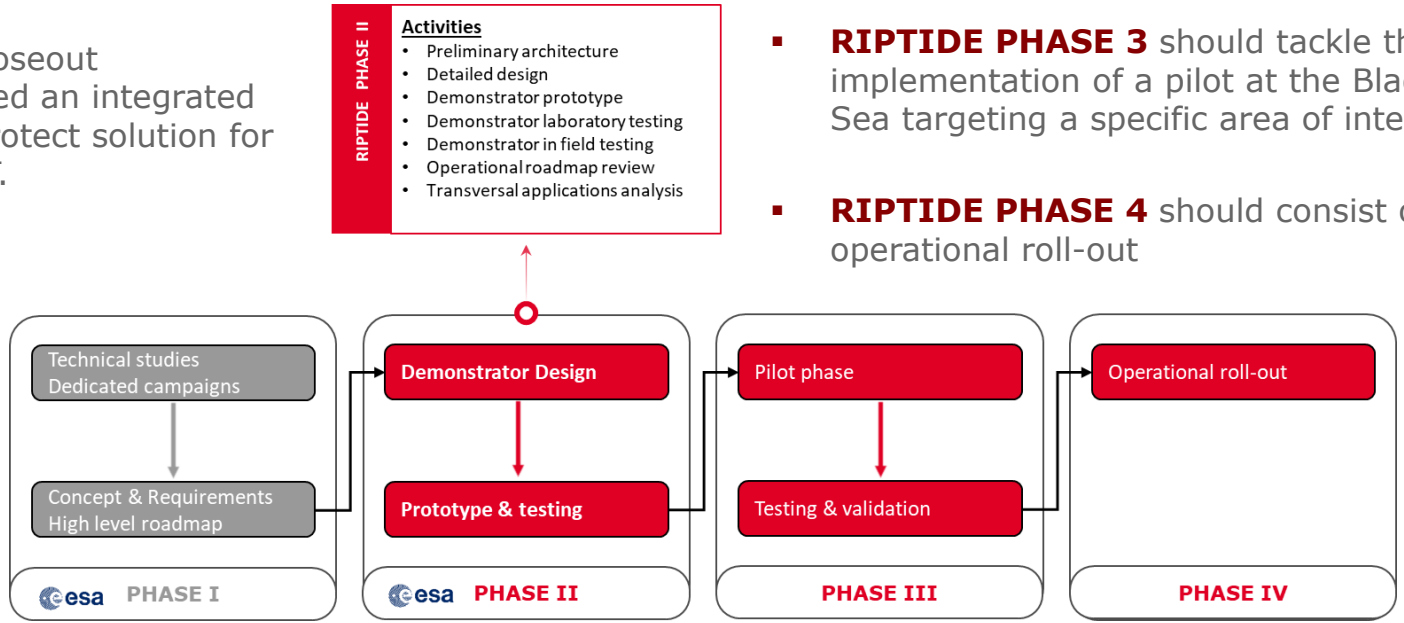
The German Federal Waterways and Shipping Administration (WSV) – the entity responsible for general aspects of aids to navigation in DE. **WSV** provided initial support on the project in R-Mode topics through the in-kind support of late R-Mode expert **Michael Hoppe**.
WSV and **EUSPA** provided the WANtime units used to synchronize the VDES-R transmitters.

Project Context

The RIPTIDE endeavour

- The overall **RIPTIDE** endeavour kicked-off in Q4 2020
- **RIPTIDE** closeout recommended an integrated Monitor & Protect solution for resilient PNT.

- **RIPTIDE PHASE 2** is the continuation of the study with a demonstrator development phase which underwent laboratory and field testing.
- **RIPTIDE PHASE 3** should tackle the implementation of a pilot at the Black Sea targeting a specific area of interest
- **RIPTIDE PHASE 4** should consist of the operational roll-out



Project Context

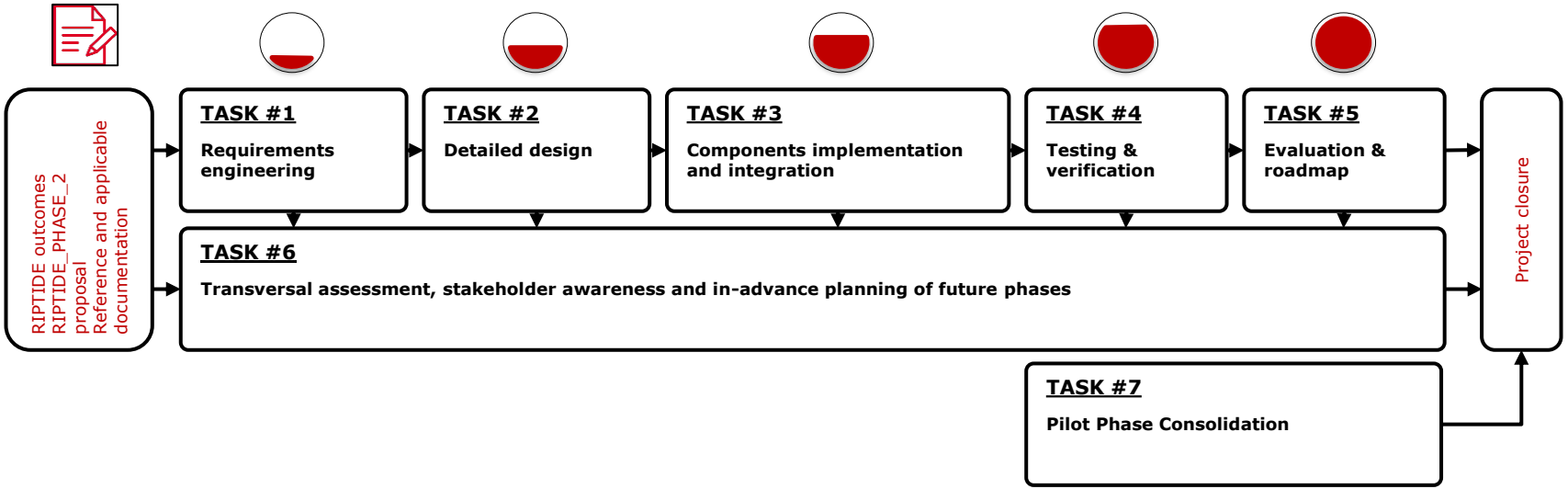
- **The Black Sea sets the Eastern borders of both the EU and NATO**
- **Complex geopolitical context**
- **Important oil and gas resources**
- **Link between Europe, Asia and Middle East**
- **Russia-Ukraine military conflict led to:**
  - → Increased risk of electronic warfare in the Black Sea area
  - → NATO / EASA warnings about jamming/spoofing in the area
  - → Mining activities – adrift mines in RO waters
  - → New energetic needs involving offshore gas exploitation platforms in the Black Sea
  - → Constanta and Sulina ports under exponentially increased pressure
  - → Romania-Ukraine border and Snake Island were the centre of important military activities

Project Objectives

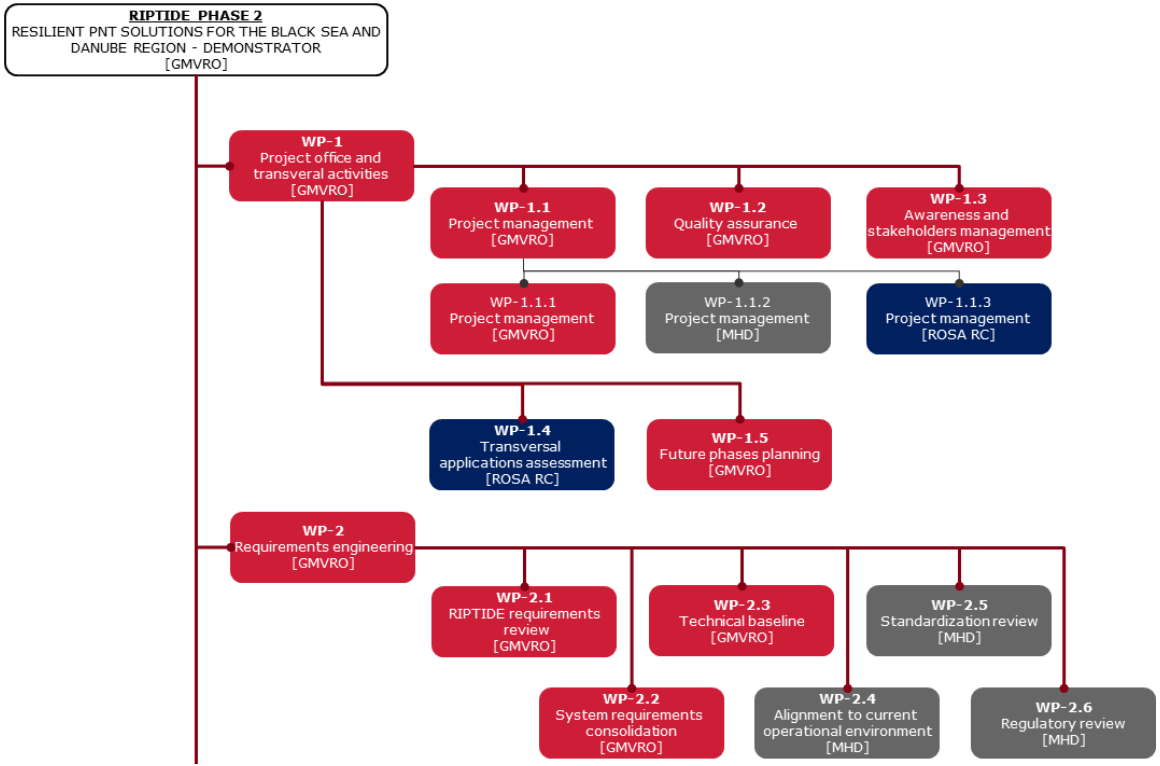
- The RIPTIDE Phase 2 project targets the **second phase in the development of a resilient PNT solution** dedicated to the particularities of the Black Sea and Danube Lower Basin region.
- Specific objectives:
  - Review and consolidate the requirements for the resilient solution
  - Propose solution architecture and system design
  - Iteratively assess alignment with regulatory, standardization, and operational frameworks
  - Implement the *Monitor* and *Protect* components of the system
  - Test in laboratory and Black Sea field environment to assess the performance
  - Evaluate the technology readiness and update the operational roadmap
  - Assess applicability in other domains – non-maritime applications
  - Engage stakeholders and plan future steps towards operational development

Technical Approach

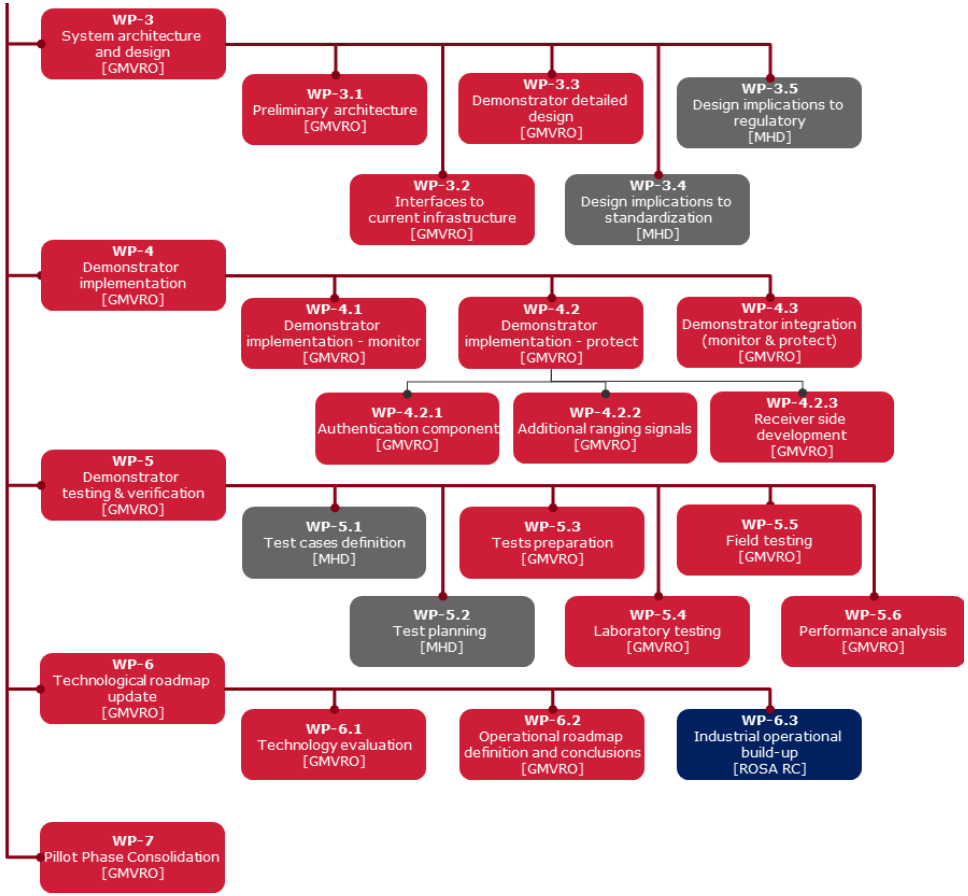
Task Logic



Work Breakdown Structure (I)



Work Breakdown Structure (II)



Demonstrator Design and Implementation

RIPTIDE 1 Proposed Solution

Integrated Monitor & Protect Approach

RIPTIDE 1 recommended an integrated monitor and protect approach based on the following concepts:

Applicable at authority level:

- GNSS interference monitoring of coastal areas and ports
- Provision of additional ranging signals, such as VHF R-mode based on AIS/VDES infrastructure
- Distribution of authentic/verified NM based on a SIS NMA(OSNMA/CHIMERA) or AGNSS approach using the AIS/VDES infrastructure

Applicable at vessel/user level:

- Usage of DF-MC or MF-MC GNSS receivers
- Usage of NMA-enabled GNSS receivers as soon as they will be available
- Usage of R-mode receivers or GNSS/R-mode multi-system receivers to benefit from the additional ranging signals
- Usage of vessel level interference detection and mitigation techniques

RIPTIDE 2 Demonstrated Solution

Integrated Monitor & Protect Approach

RIPTIDE 1 recommended an integrated monitor an
following concepts:

Applicable at authority level:

- GNSS interference monitoring of coastal areas and port
- Provision of additional ranging signals, such as VHF R-m infrastructure
- Distribution of authentic/verified NM based on a SIS NM approach using the AIS/VDES infrastructure

Applicable at vessel/user level:

- Usage of DF-MC or MF-MC GNSS receivers
- Usage of NMA-enabled GNSS receivers as soon as they
- Usage of R-mode receivers or GNSS/R-mode multi-syst additional ranging signals
- Usage of vessel level interference detection and mitigat

RIPTIDE Phase 2
Black Sea Demonstrator

Applicable at authority level:

- GNSS interference monitoring
- VDES-R/R-Mode implementation
- Distribution of trusted NM using ASM (structure of AIS Message 26)

Applicable at vessel/user level:

- Usage of DF-MC GNSS receivers
- Usage of VDES-R/R-Mode receivers
- Usage of vessel level interference detection and mitigation techniques

Monitor & Protect Cross-Checks Workflow

Interference alert check

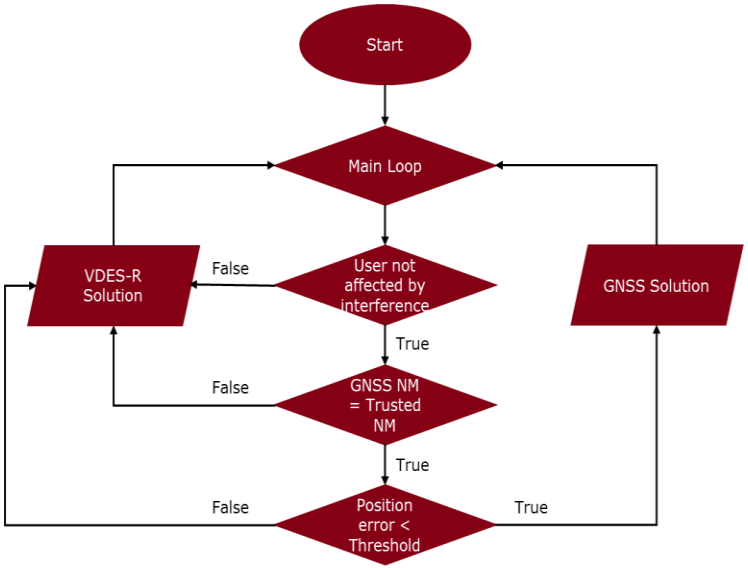
If the result indicates the user is in an interference impacted area, the VDES-R solution is used

GNSS Navigation message check

The NM check compares GNSS navigation data recorded using the on-board GNSS receiver with navigation data coming from the NTRIP server. If the NM check fails, a VDES-R solution is used.

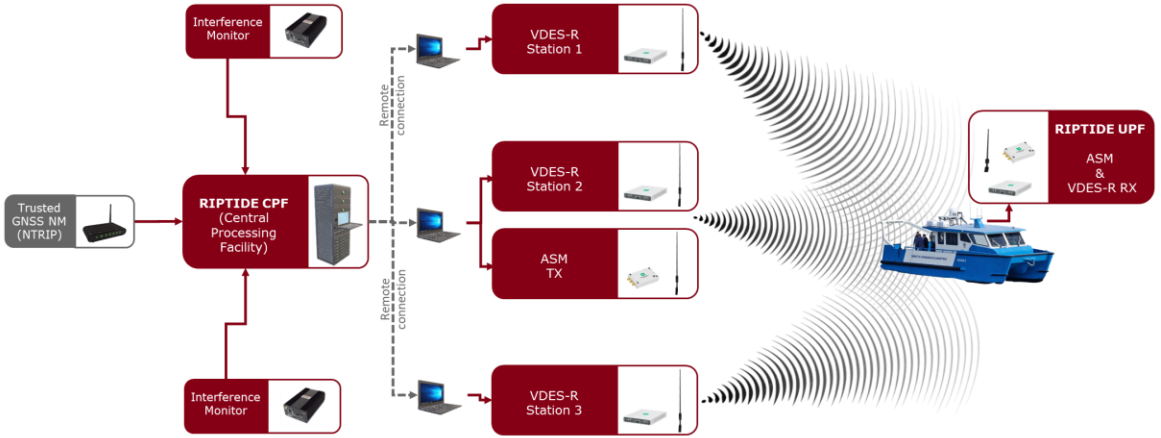
PVT solution cross-check

The cross-check is performed under the assumption that VDES-R is functioning fault-free. If the cross-check fails, the VDES-R solution is used, otherwise the GNSS solution is outputted.

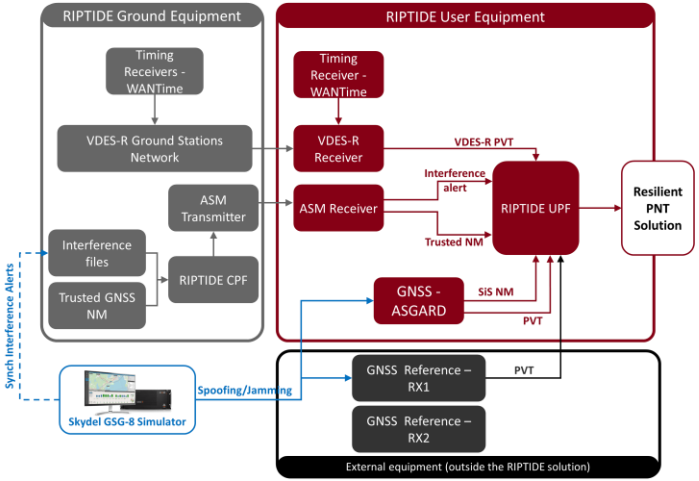


Design and Implementation Overview

High Level Architecture



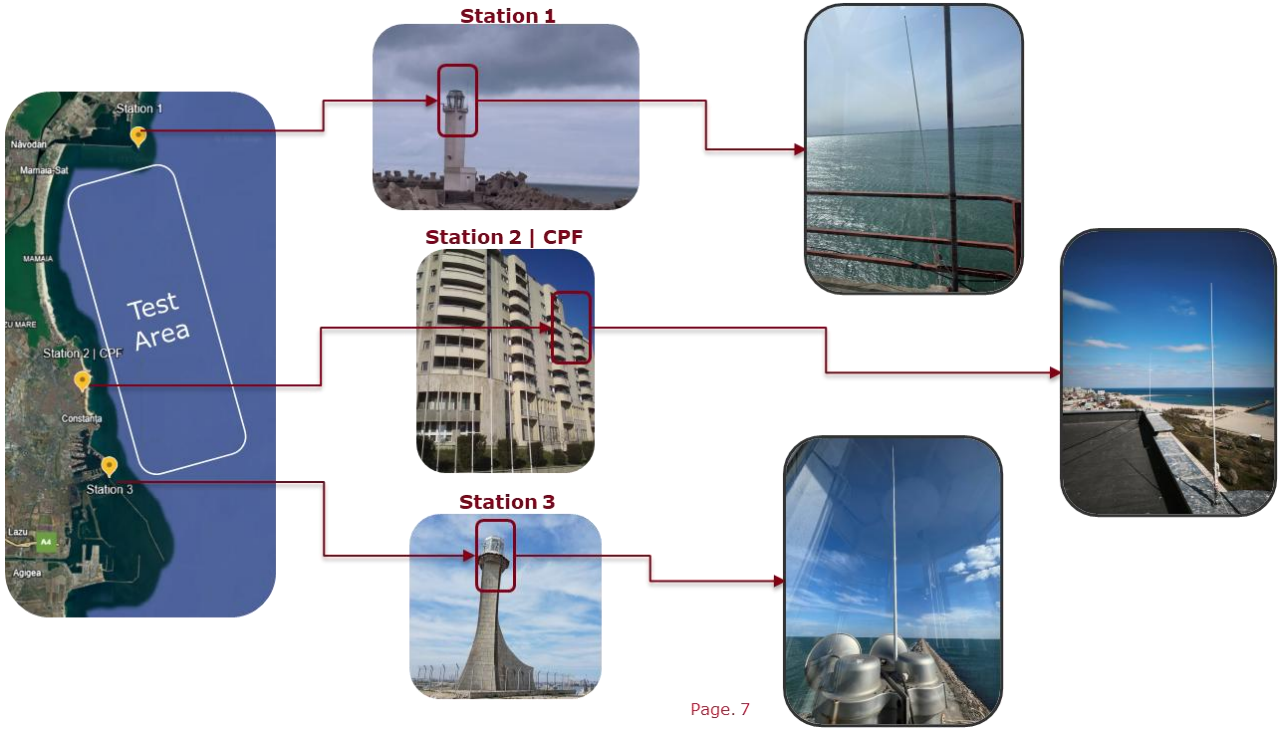
Functional Blocks Diagram



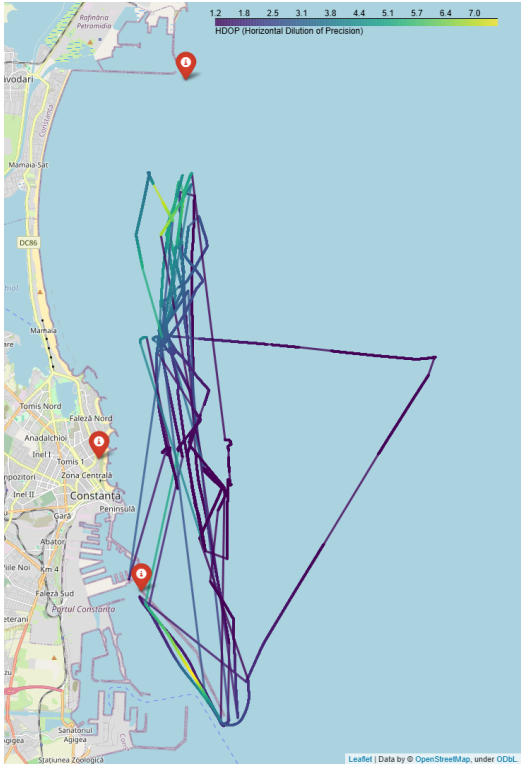
Trials Preparation

Test area and transmitter stations

Test Area



DOP Heatmap



Test Equipment Configuration

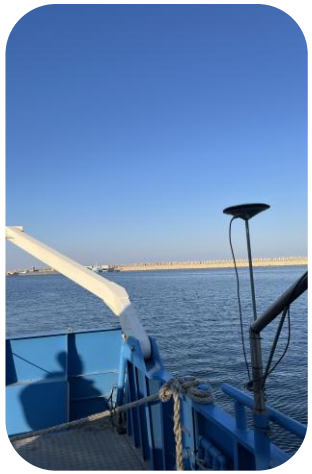
- Test vessel Ocean 2, owned and operated by MHD
- Hydrography equipped research vessel
- Dedicated project equipment deployed on board

Ocean 2 Vessel Antenna locations

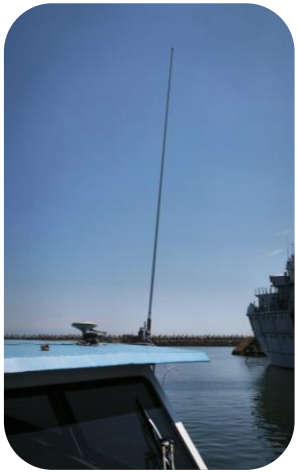
UPF, GNSS and VDES-R Receivers

Skydel Simulator

GNSS Antenna



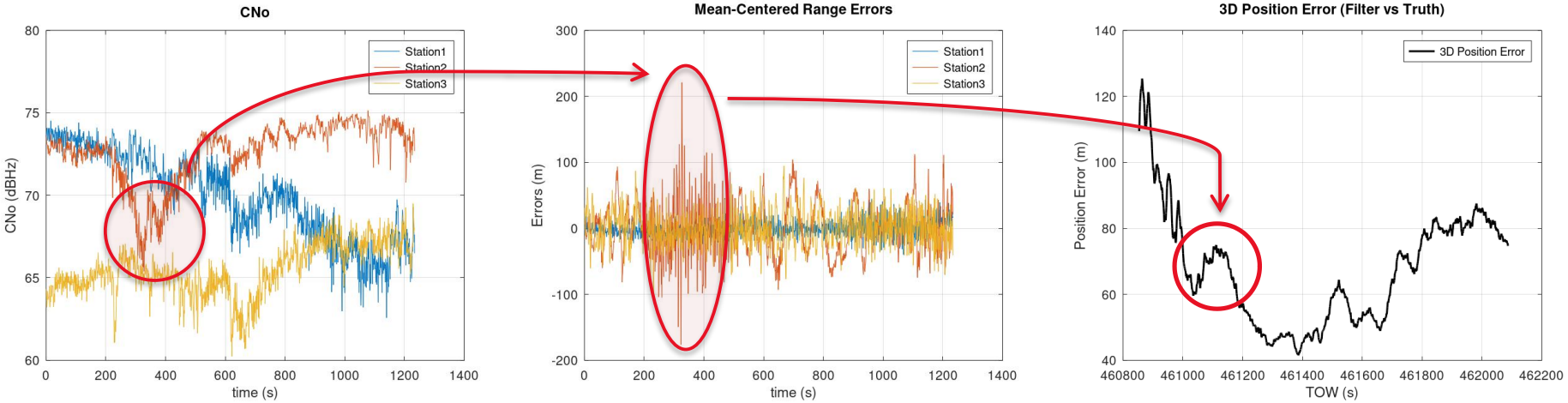
VHF Antenna



Performance Analysis

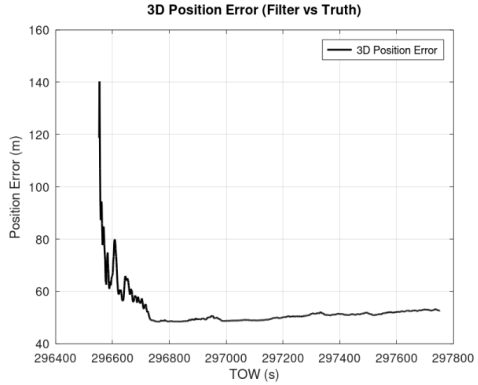
VDES-R performance in nominal conditions

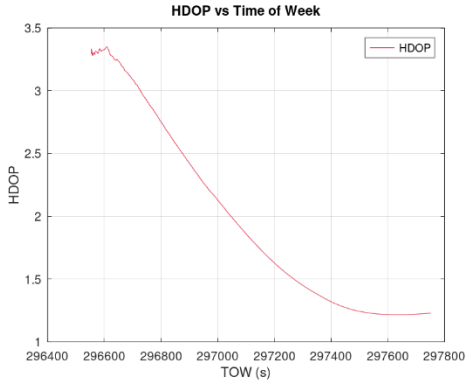
Correlation between CN0, pseudoranges quality and position accuracy

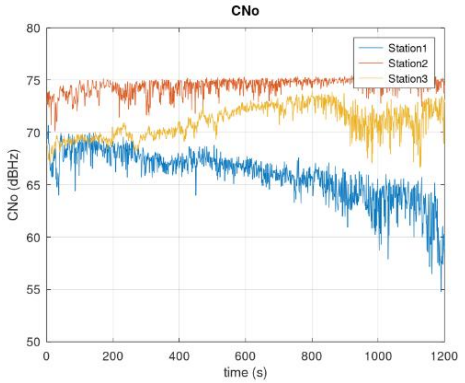


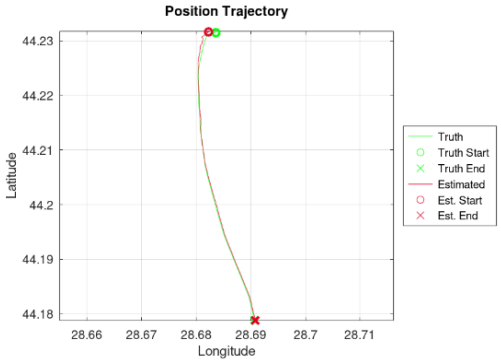
VDES-R performance in nominal conditions

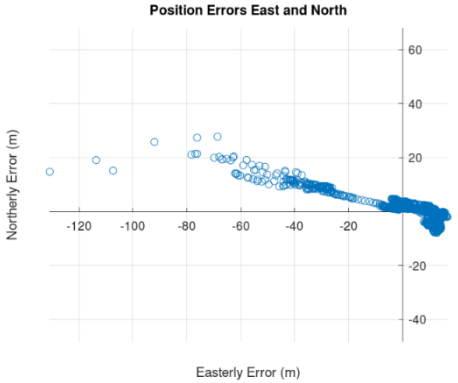
Dataset I

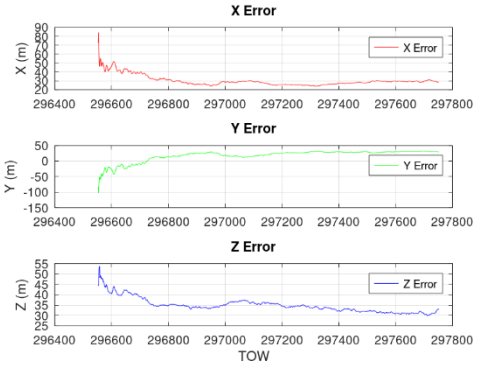






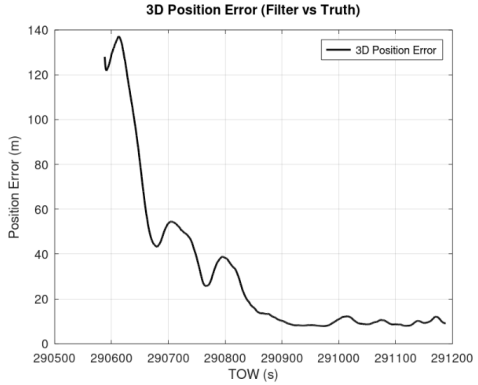


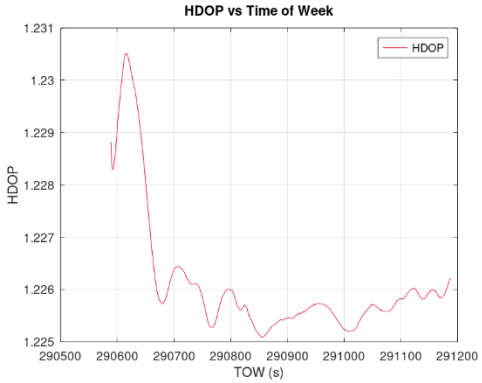


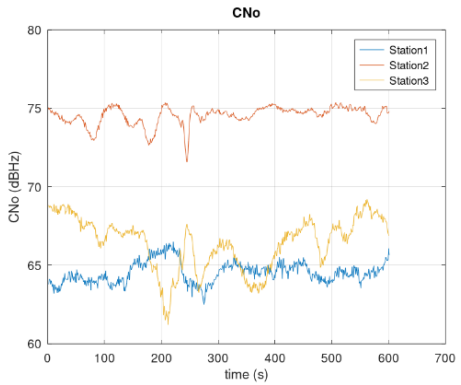


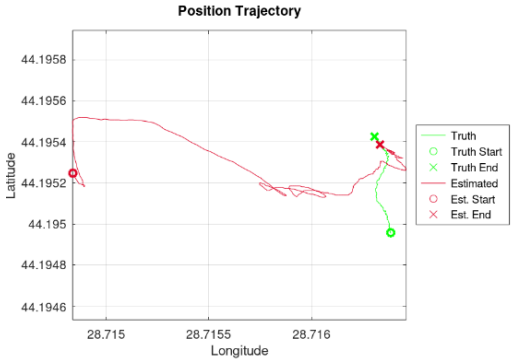
VDES-R performance in nominal conditions

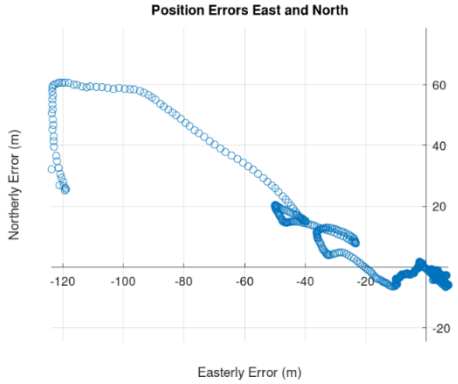
Dataset II

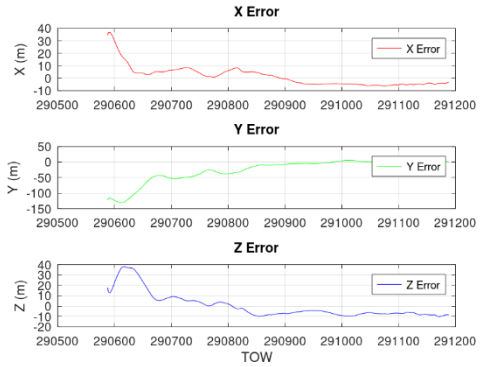






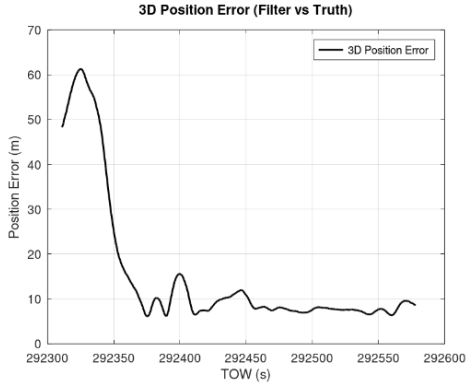


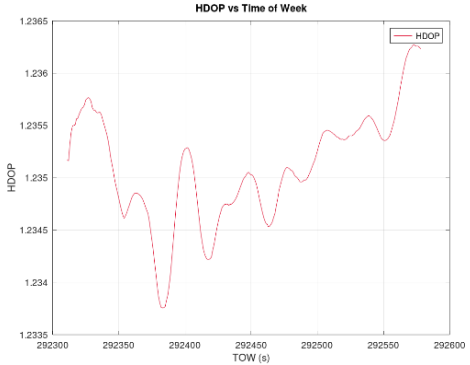


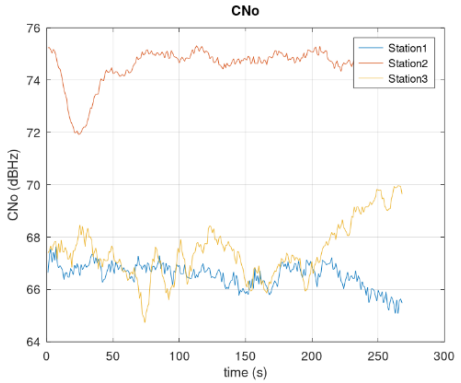


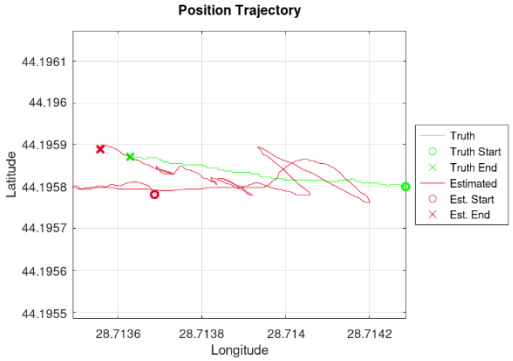
VDES-R performance in nominal conditions

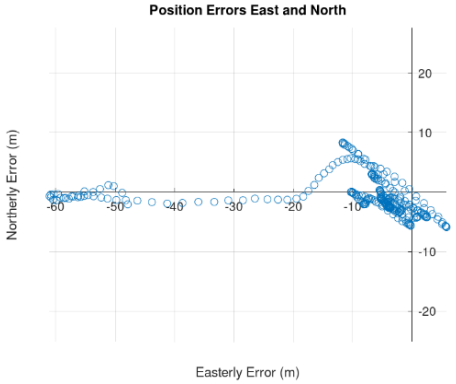
Dataset III

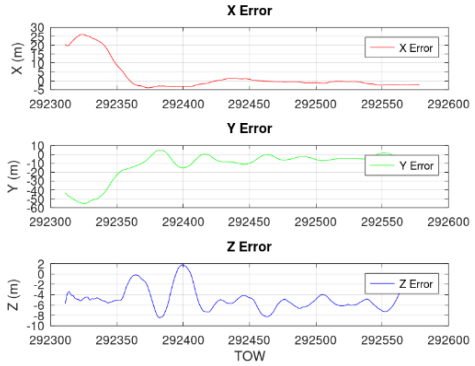








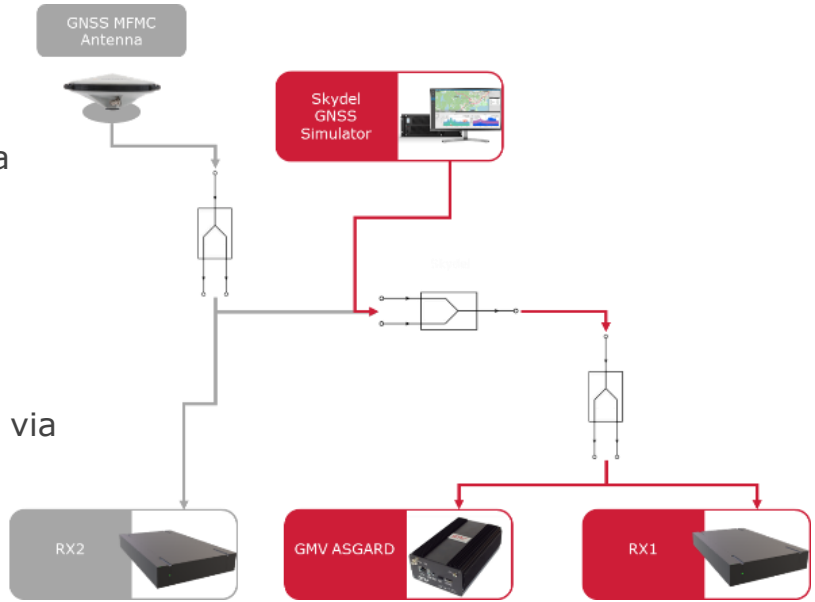




Emulated GNSS RFI Conditions

Test setup

- GNSS MFMC Antenna to collect SiS
- RX2 used as clean GNSS reference
- RX1 and Asgard subjected to spoofing (cable connection) via Skydel GSG-8
- VDES-R assumed fault-free (only GNSS is affected)



Scenario 1 – Localized degradation

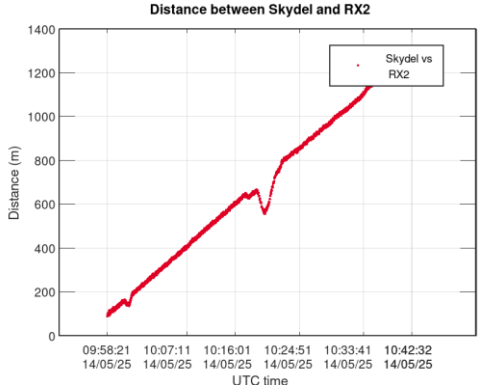
- Both Asgard and RX1 are forced to be degraded by spoofing via cable connection
- No interference detected at CPF
- System required to react autonomously at user level

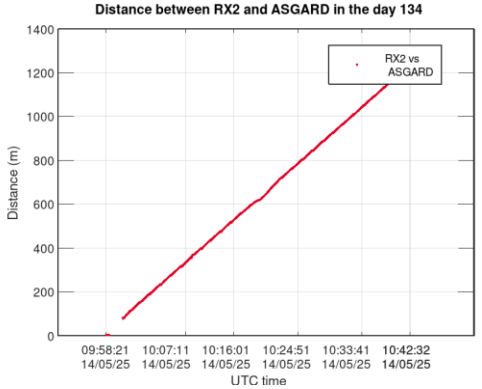
Scenario 2 – Coordinated attack

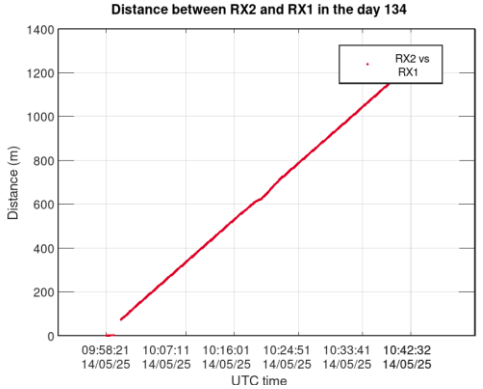
- Both GNSS receivers and CPF impacted simultaneously
- Tests system-wide resilience with CPF + UPF coordination

Emulated GNSS RFI Conditions

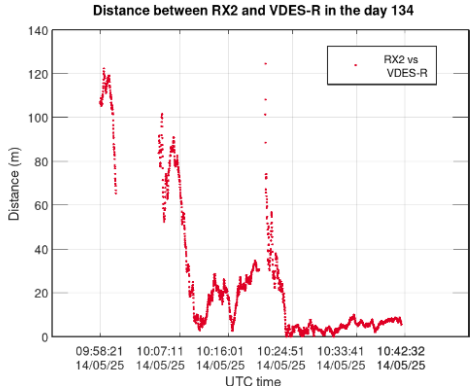
Spoofing impact on GNSS receivers

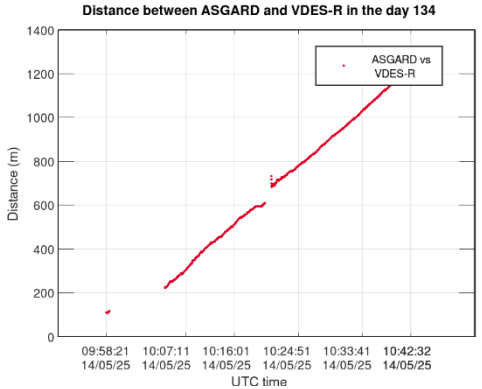


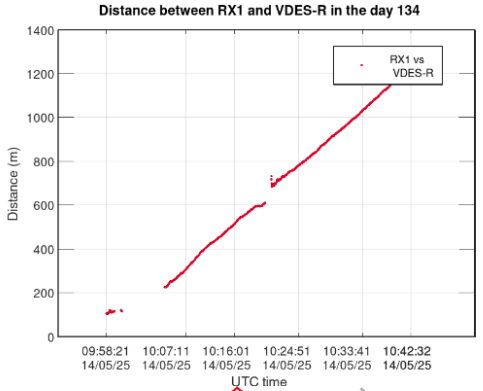




GNSS Spoofing Detection based on VDES-R







Monitor & Protect Response

UPF Cross-checks

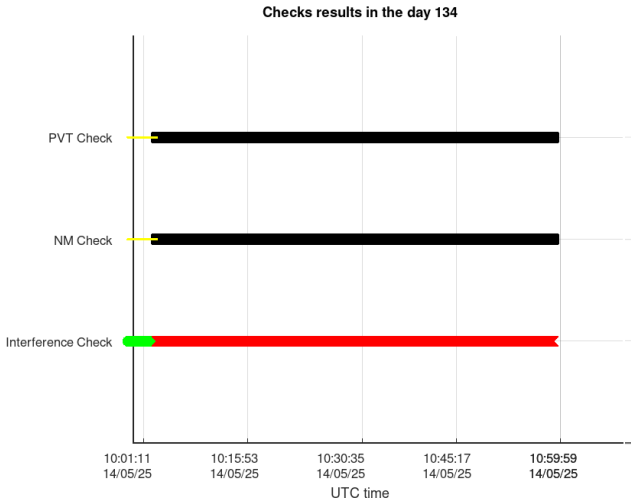
In nominal GNSS and VDES-R conditions, all the checks performed by the UPF – Interference Check, NM Check and PVT Check – are successfully computed and marked with **green**.

The results of a check may be:

- **Not performed** – the check was not performed due to an issue with the input data
- **Continue** – the check was performed and the result did not indicate any issue
- **Stop** – the check was performed and the result indicates a high risk of being under spoofing
- **Warning** – the check was performed and the result indicates a low/moderate risk of being under spoofing

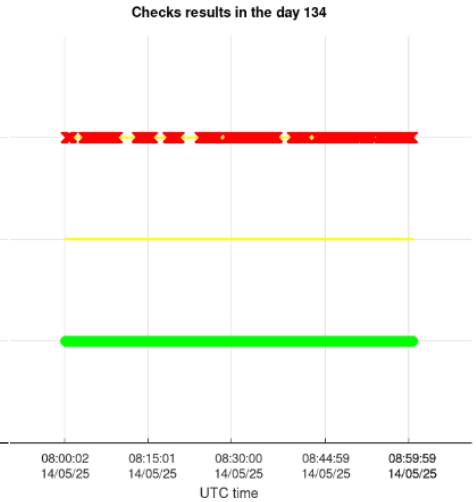
Scenario 2

Coordinated attack



Scenario 1

Localized degradation



Live demonstration events

The consortium organized live demonstration events to showcase the capability of the RIPTIDE Demonstrator in the Black Sea waters.

ESA, **ROSA** and **RNA** joined the live demonstration events onboard **MHD**'s Ocean 2 vessel.

Live GNSS Jamming and Spoofing conditions were encountered during one of these events, corresponding to a **Localized Degradation Scenario** as defined in the previous slides.

The demonstrator detected and mitigated the threats thanks to its **Alternative PNT capability.**

The **VDES-R / R-Mode** system consistently delivered accurate position fixes, with errors remaining below 10 meters in the conditions of strong **GNSS** interference and very poor visibility.

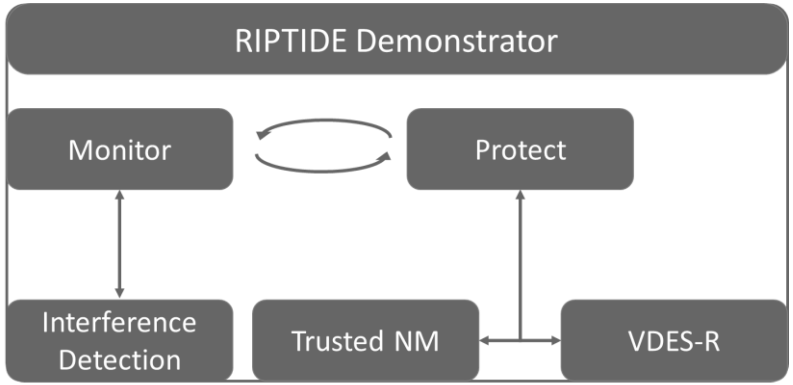
Future RIPTIDE Phases

RIPTIDE Demonstrator Review

Demonstrator implementation was considered compliant to all RIPTIDE Phase 2 requirements following the test and verification activities, including laboratory and sea trials.

Achieved Technology Readiness Level: 6.

Key benefits:
Enhanced situational awareness
Increased operational resilience
Improved positioning accuracy in coastal areas



Future RIPTIDE Phases

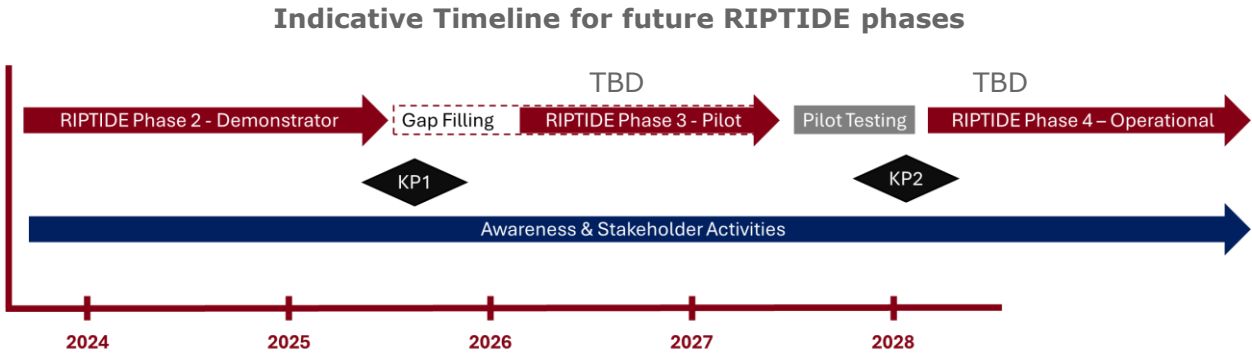
RIPTIDE Phased Approach:

Phase 1 – Study project

Phase 2 – Demonstrator

Phase 3 – Pilot

Phase 4 – Operational



KP 1 – After Phase 2 - Refine Pilot Phase scale and specific objectives.
KP 2 – After Phase 3 – Decide on the scaling up and adaptations needed for operational.

RIPTIDE Pilot Phase

Pilot Design Overview

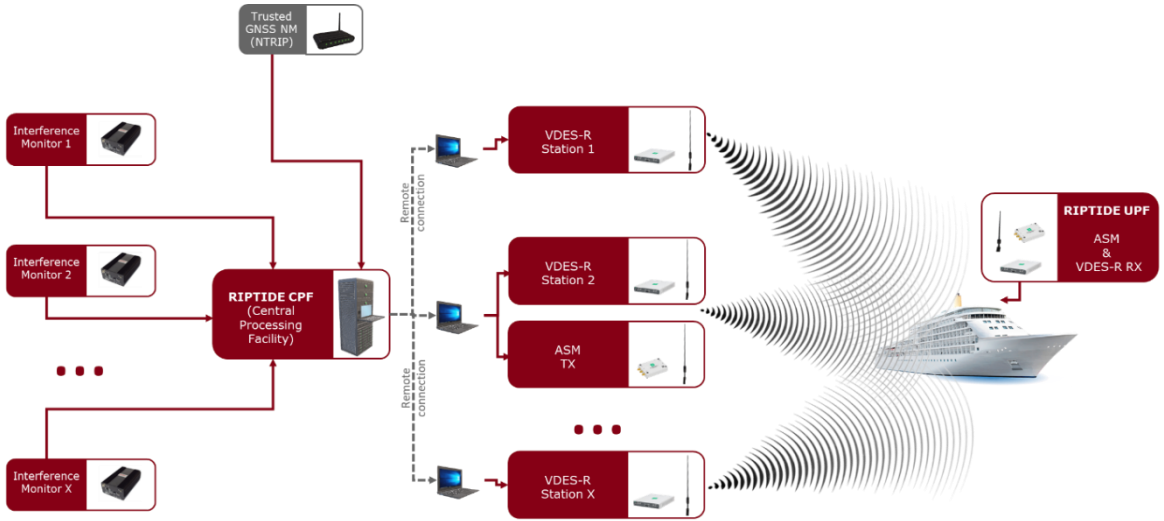
The RIPTIDE Pilot will be developed to validate the Monitor and Protect approach for resilient maritime PNT. The system architecture builds on the following complementary technological pillars, integrated into a coherent ground–user framework:

Monitor

- Spectrum Monitoring – detection and classification of GNSS interference and alert generation and broadcast

Protect

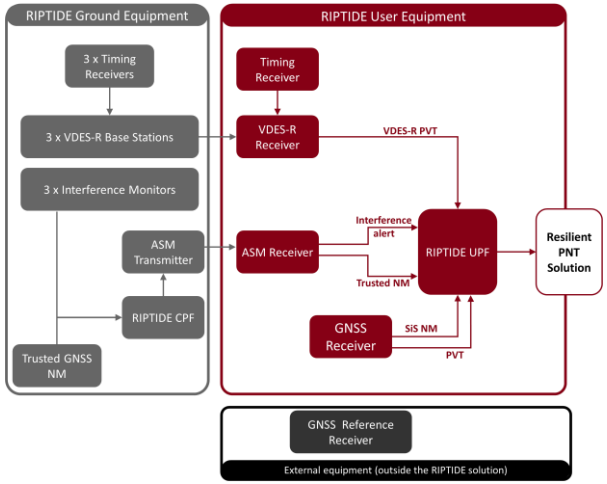
- Alternative Ranging Signals – provision of alternative PNT capability using VDES-R/R-Mode.
- Trusted NM Distribution – secure dissemination of GNSS nav data using AIS/VDES ASM.



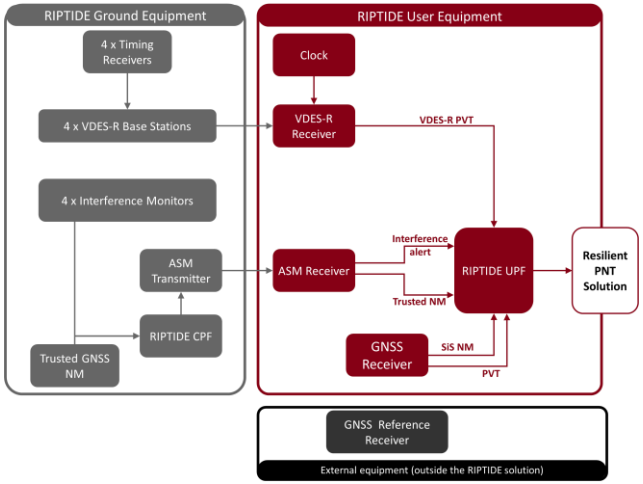
Pilot Implementation Overview

Three implementation variants have been defined for the RIPTIDE Pilot targeting flexibility in design definition. Each version maintains the same Monitor and Protect principles, the same data workflows, and the same user-side processing logic.
The variants differ in the scale of deployment and the level of timing and infrastructure integration as well as achievable performance and resilience.

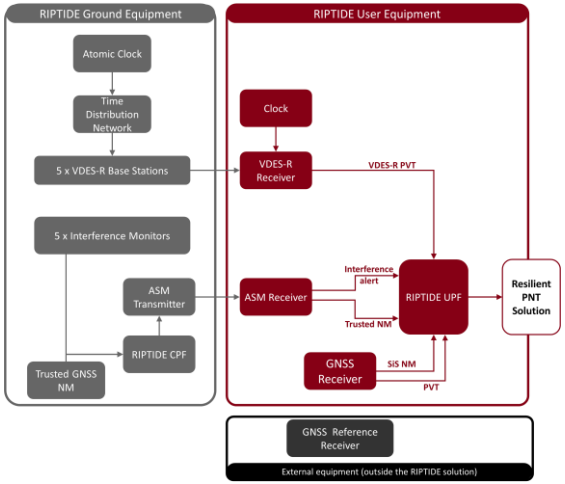
Light Architecture



Intermediate Architecture



Advanced Architecture

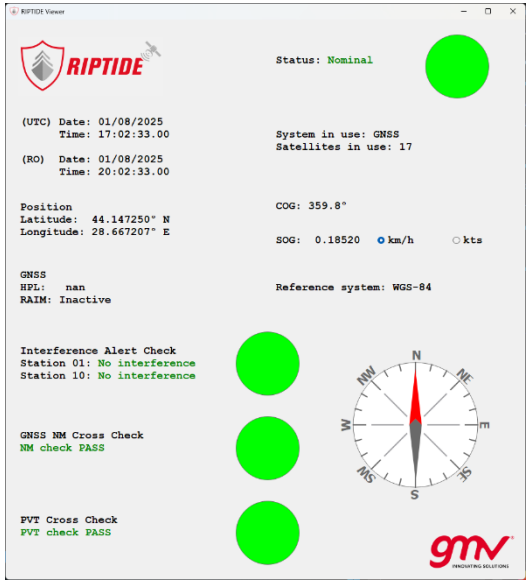


Guideline for Pilot CONOPS

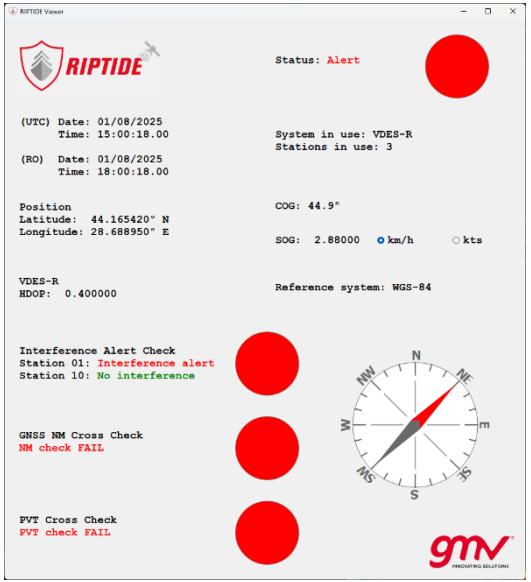
The RIPTIDE Pilot operates in distinct modes depending on the availability and trustworthiness of GNSS signals.

Depending on these modes the user and the authority are both alerted through their respective interfaces, being able to react according to each situation.

Nominal Mode



Degraded/Denied GNSS Mode



Transversal Application Assessment

Transversal Application Assessment

The analysis looks at results of the technology and possible use in other domains assessment based on the results and performance analyzed in the project.

Area	Applicability of RIPTIDE functions	Constraints / Considerations	Priority for resilience
Search & Rescue / Emergency Management	Direct applicability of Monitor/Protect and R-Mode for continuity under GNSS disruption	Operational integration with SAR systems	HIGH
Aviation & Drones	Potential for UAV traffic management, resilience in GNSS-challenged airspace	Requires certification, regulatory adaptation	MEDIUM-HIGH
Road transport	Timing, road user charging, connected & automated driving support	Integration with national ITS frameworks	MEDIUM
Rail transport	Trackside personnel protection, signalling timing support	Legacy system compatibility, regulatory pathways	MEDIUM

The RIPTIDE activity has been carried out
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For more information on the programme visit navisp.esa.int

Thank you!

RIPTIDE Phase 2 Team