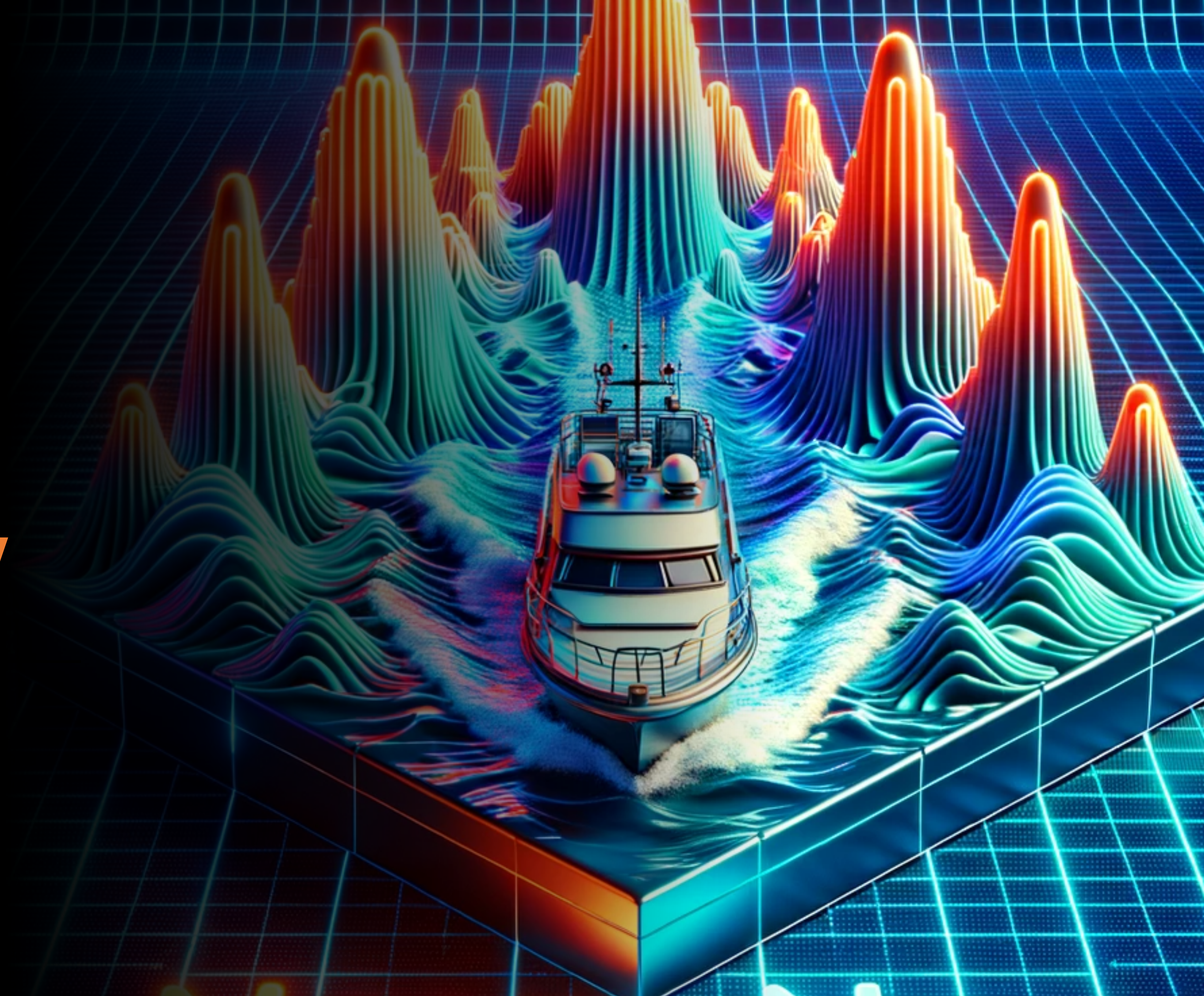
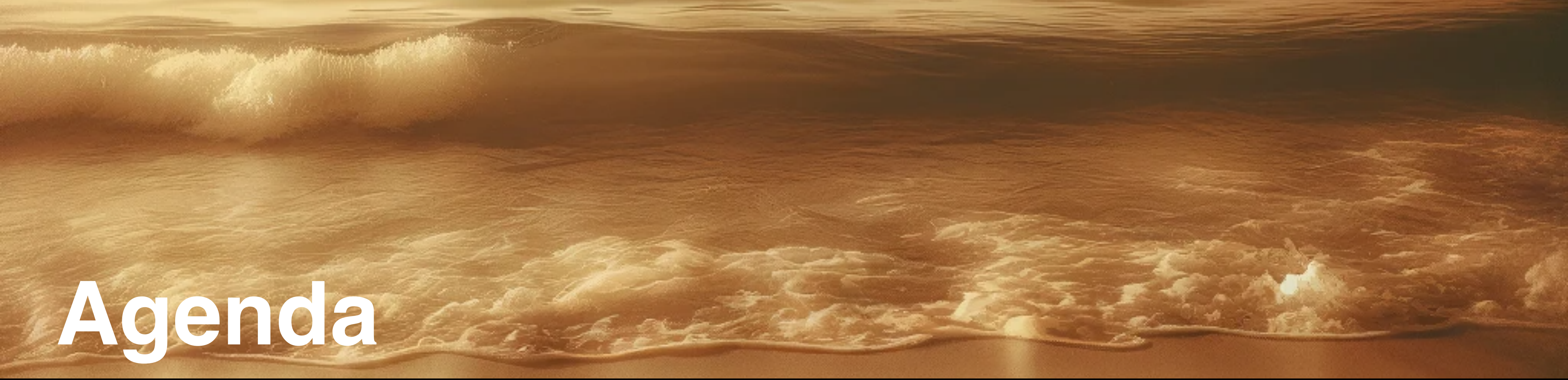
NEURONAV

NAVISP-EL2-154

FINAL PRESENTATION

5th August 2025





Agenda

01

Introduction

- Context and rationale

02

Project outcomes

- Product description
- Testing campaign & results
- Customers needs addressed

03

Product opportunities

- Competitiveness characteristics of the product
- Path to market
- Growth & opportunities of the company

04

Next steps to commercialize

- Future work

05

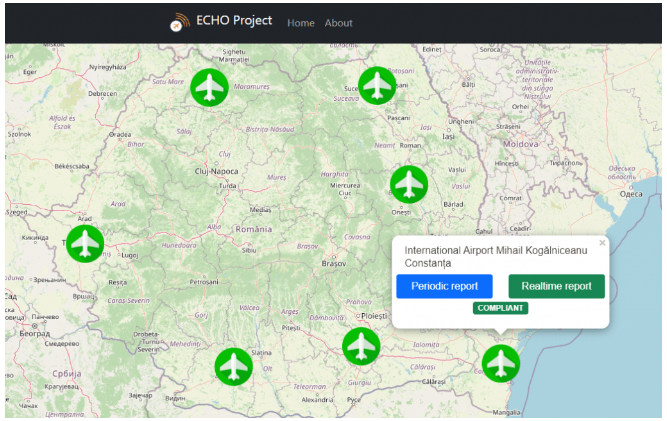
Benefits of working with ESA

1. Introduction

NeuroNav Team

Romanian InSpace Engineering (RISE) – Prime

- Research-oriented company in the space field, addressing also defense and security applications
- Experience with ESA projects, especially in NAVISP (all 3 elements)
- GNSS and precise positioning technologies
- Subsystems for small satellites
- TVAC facilities for environmental testing



rise

NeuroNav Team

Maritime Hydrographic Directorate (MHD) – Subcontractor

- **Hydrographic Data & Survey Management**
  - Conduct surveys (bathymetry, geodesy, geophysics & oceanography) across coastal, seabed, land and submarine areas
- **Official Charting & Publications**
  - Develop, produce and continuously update Romania's official nautical charts, publications, notices to mariners and radio navigation warnings
- **Navigation Equipment Services**
  - Calibrate, compensate, install and maintain shipborne and coastal navigational and hydro-meteorological instruments for military and civilian vessels
- **Research & Development**

Project background and rationale

- Leverage **the experience in the MARGOT** (Maritime GNSS data collection & analysis) and project's outcome

ESA project: → **Know-how:**

ESA project:

- Piggyback and dedicated campaigns on three vessels
- Various navigation types on the Danube, in the Black Sea and in the Aegean Sea
- Operations in four international ports: Constanta, Tulcea, Sulina and Galati
- Analysis
- Derivation & validation of models

Know-how:

- Raw GNSS signal collection
- GNSS performance assessment
- GNSS spectrum analysis
- Interference detection
- Multipath analysis

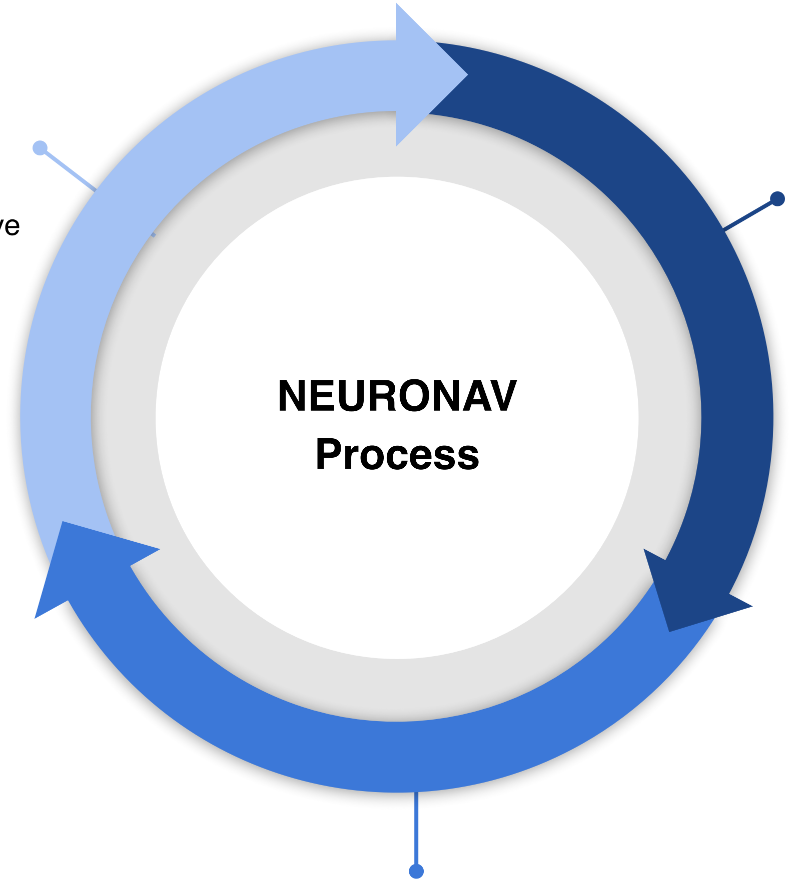
2. Project outcomes

Product description

- NEURONAV is an **AI-augmented positioning system** for **maritime navigation**
- Uses AI to **reduce effects of multipath** by "learning" the **geometry** of the vessel
- **Augmentation** of the GNSS receiver
- Automatic **dataset preparation** and model training & validation

Receiver's output correction (live)

- Uses the estimated position error to improve the accuracy



Data-set preparation

- Data acquisition
- Data processing and formatting
- Data storage

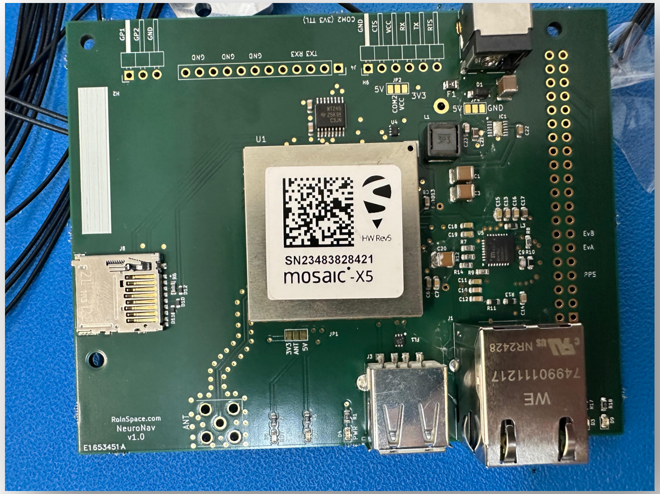
Model training & validation

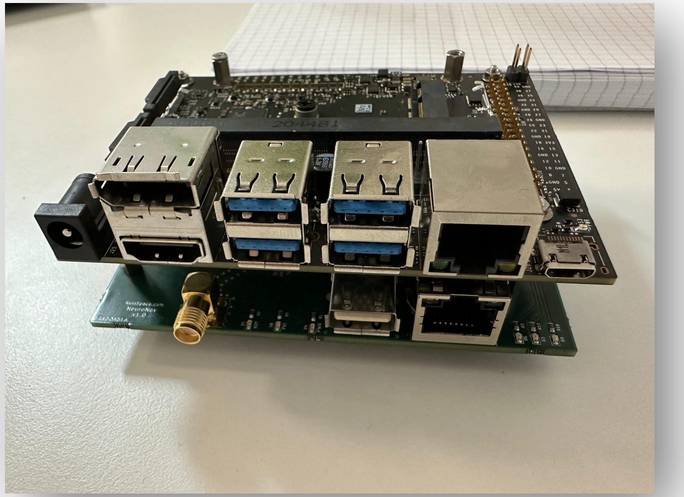
- Train and validate the AI model (locally)
- Evaluates the performance of the model

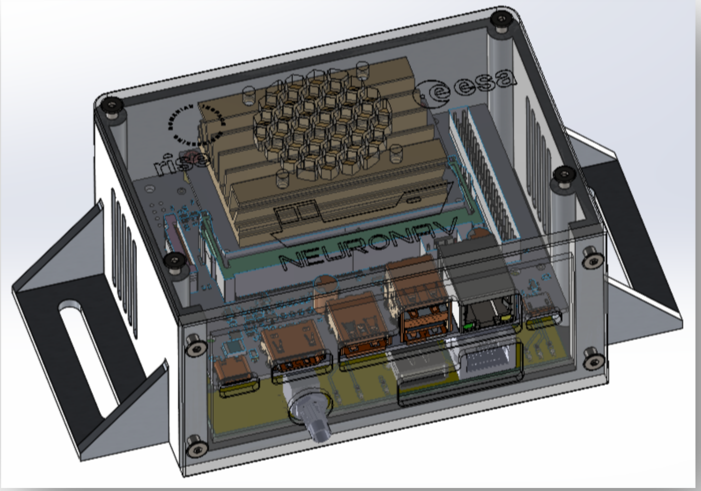
rise

Hardware design

PCB design with the GNSS receiver







GNSS receiver

Septentrio mosaic-X5

- Multi-constellation, multi-frequency
- Interference detection& mitigation

Single-board computer

Jetson Nano

- 4 GB 64-bit LPDDR4
- CUDA 10

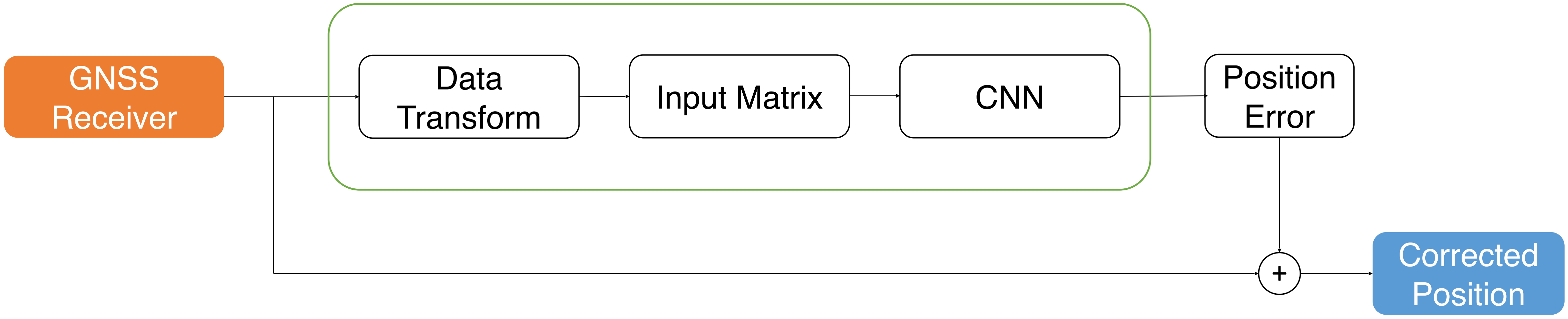
3D printed encasing

Custom box

- Ventilation holes
- Universal mounting brackets

Error prediction

Block diagram



ESA Patent: *Caparra, Gianluca, Zoccarato, Paolo, Melman, Floor, "Machine Learning Correction for Improved PVT Accuracy," Proceedings of the 34th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2021), St. Louis, Missouri, September 2021, pp. 3392-3401. https://doi.org/10.33012/2021.17974*

Error prediction

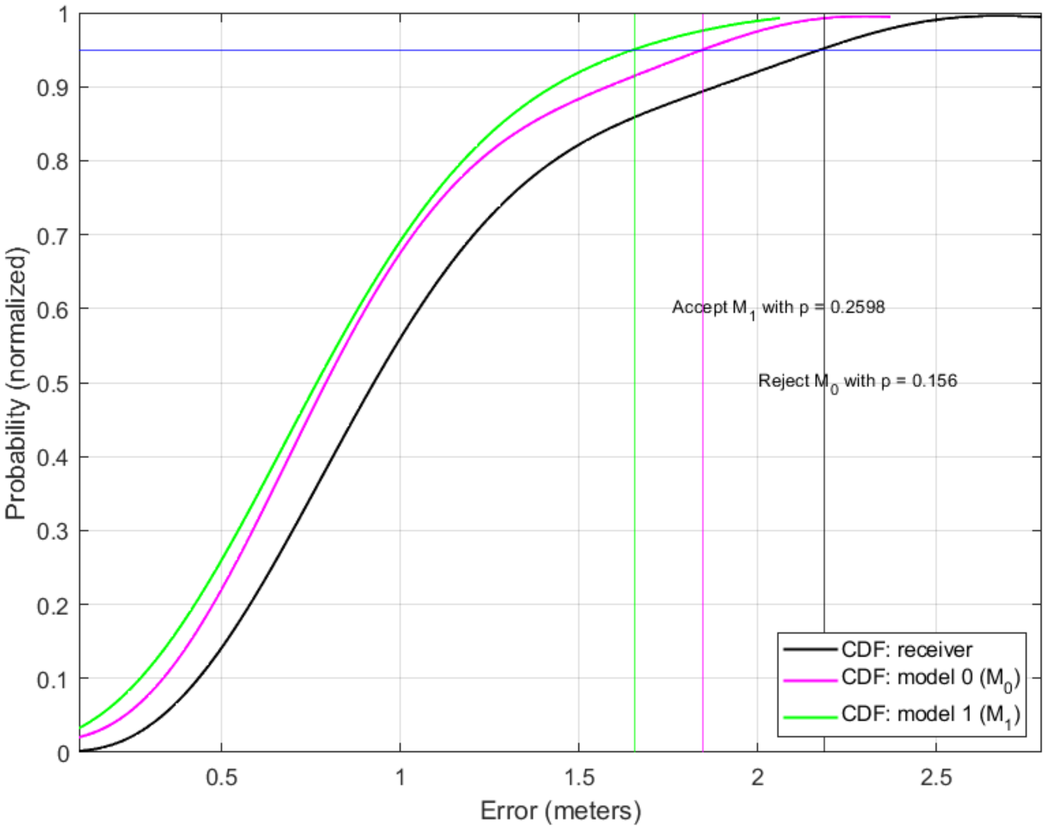
Convolutional Neural Network

The input data consists of **four transformed features** from **satellites** involved in the PVT computation process by the GNSS receiver:

- **Azimuth**, **Elevation** and **C/N0** for each satellite
- **Pseudorange residuals**
- The (residual, Azimuth, Elevation) define **spherical coordinates that can be mapped to the Cartesian error space**

The validation process involves computing correction errors and **comparing CDFs** of receiver vs. corrected errors.

Automatic decision criterion, without human supervision

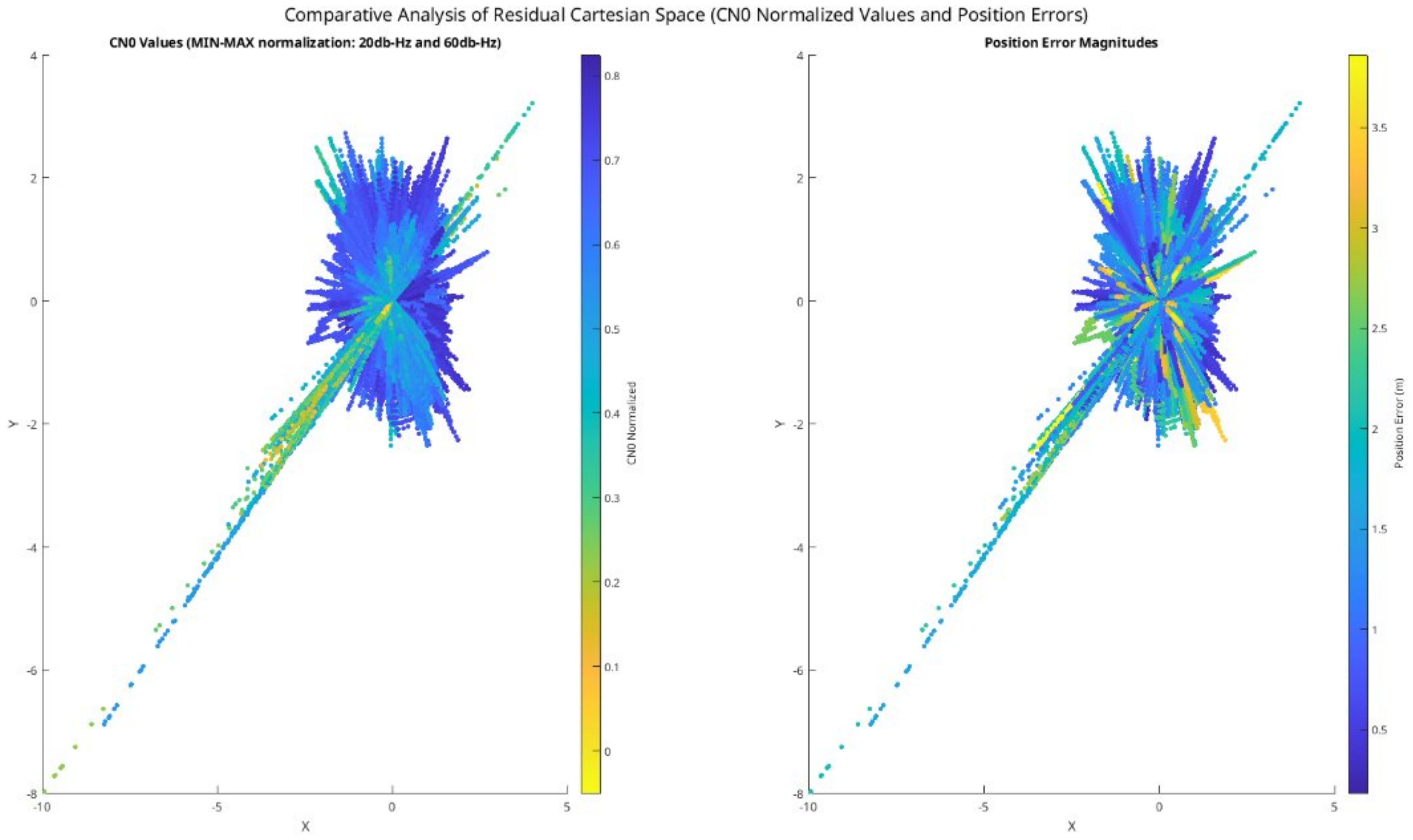


CNN input matrix

rise

Cartesian error space visualization

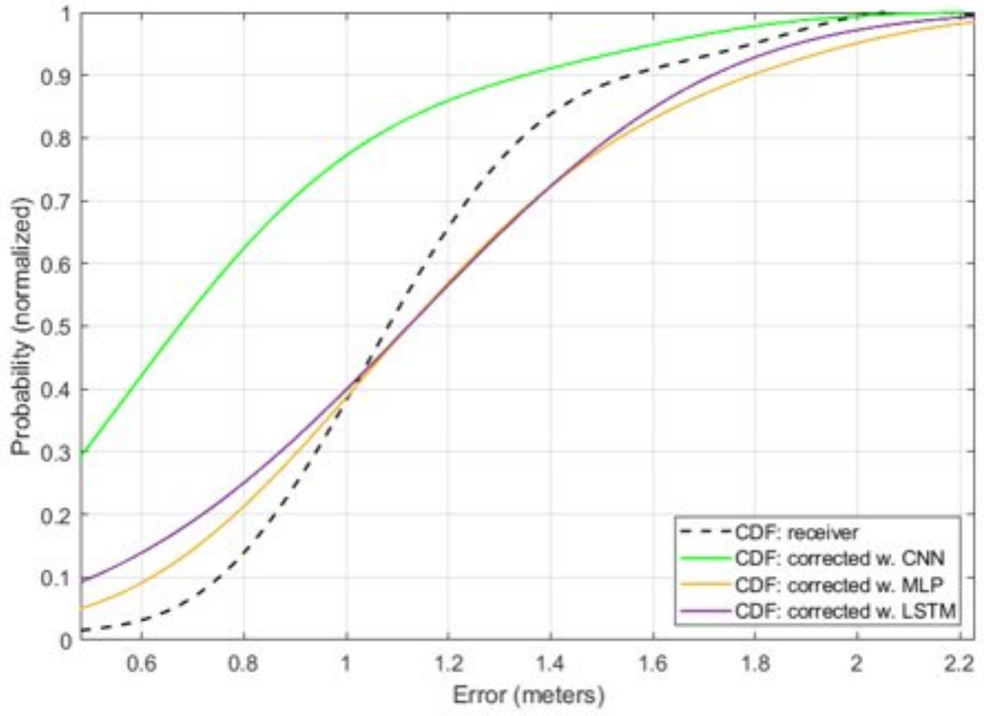
Dual-panel residual scatter: normalized C/N_0 (left) vs. position error (right)



CNN Architecture

Comparison with other architectures
- CNN outperforms other models (MLP, LSTM)

Network's Architecture
- **Input & Pre-processing**
  - Raw tensor (error cartesian space)
  - Dropout (p = 0.2) to regularize
- **Convolutional Feature Extraction**
  - 2D Convolution
  - 2D Max Pooling + ReLU
  - 2D Convolution
  - 2D Max Pooling + ReLU
  - Flatten → 256 features
- **6 Fully Connected Regression Layers**
- **Output Layer:**
  - Predicted X, Y, Z errors

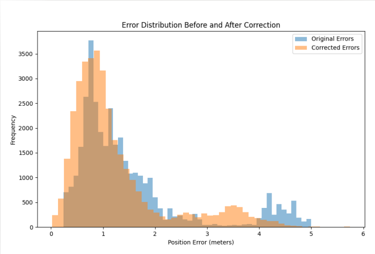


Source: ESA Patent

Testing campaign

Roadmap

Data Postprocessing



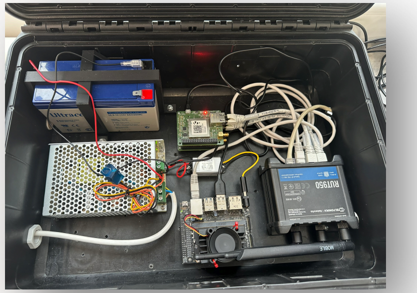
1st Campaign

MHD's Ocean 1
Hydrographic vessel

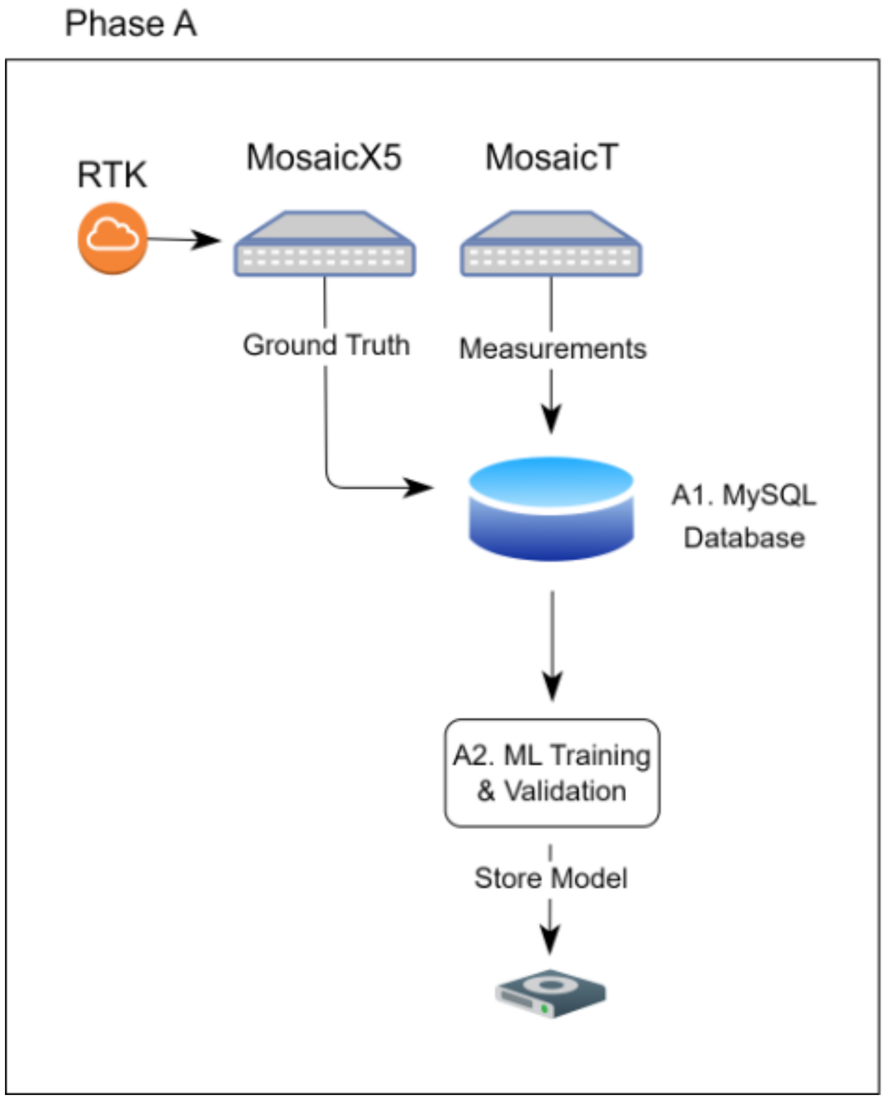
2nd Campaign

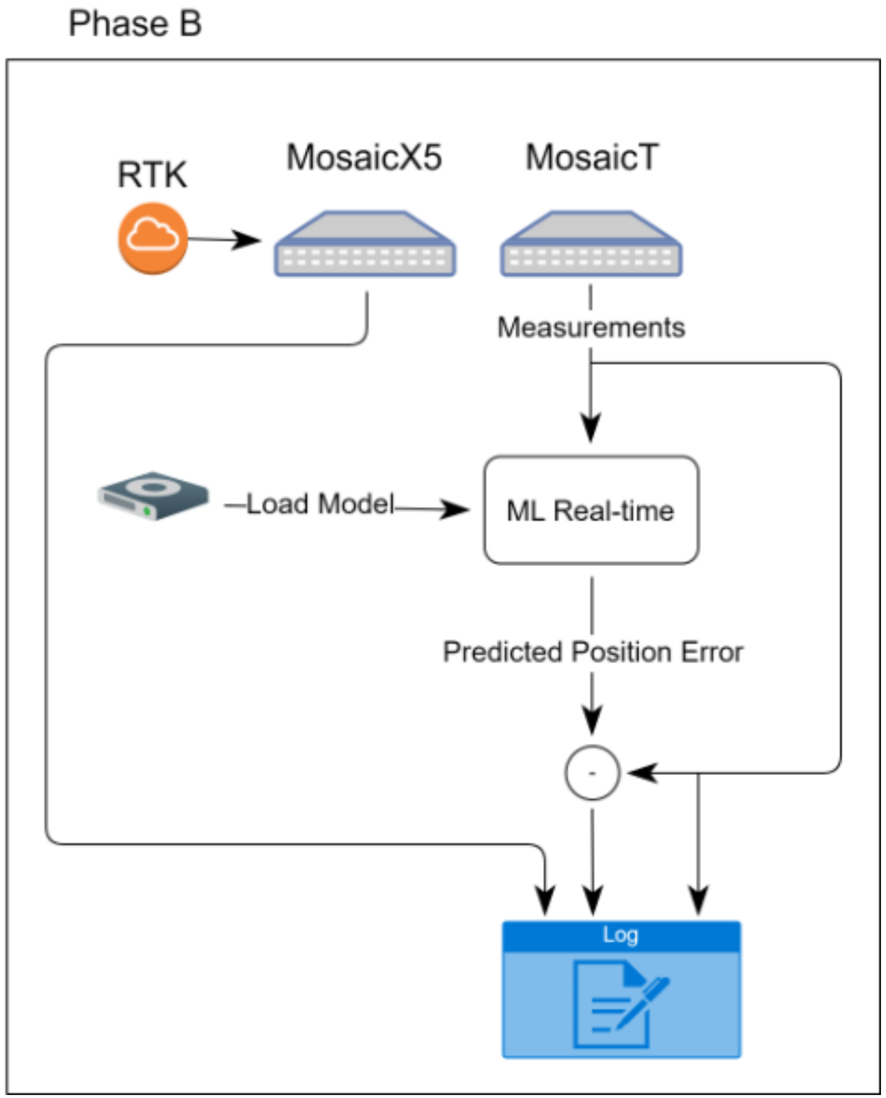
MHD's "Cpt.Cdor. ALEXANDRU CĂTUNEANU"

Testbed TRR



Experiment phases in the testing campaign





Results of the testing campaign

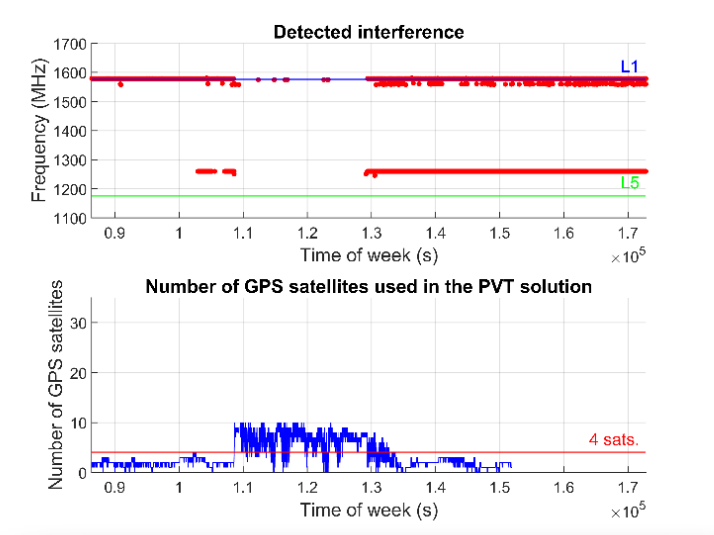
Results consistency

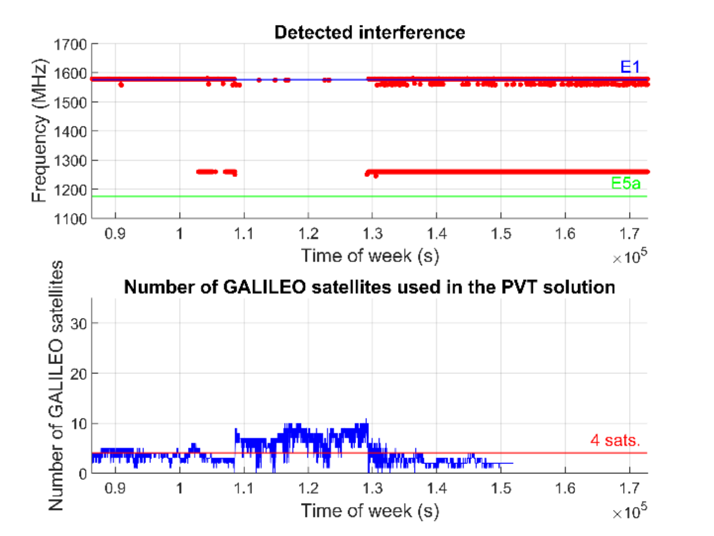
- Findings from both campaigns are similar

Challenges faced

- **Interference Issues**
  - Significant interference reduced data volume, resulting in a smaller dataset for analysis
  - Interferences originate mainly from the conflict in Ukraine

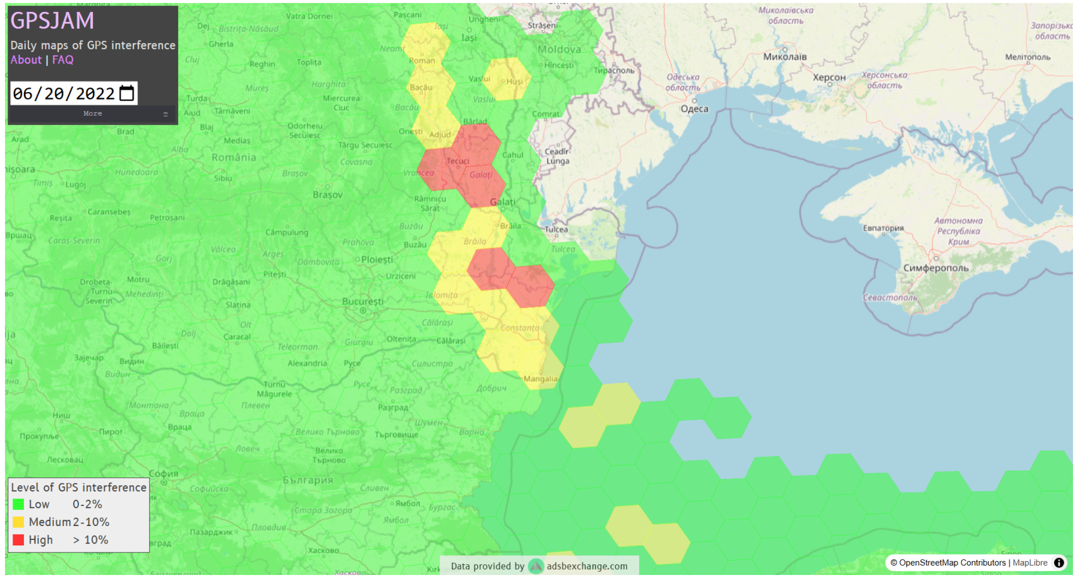
- **RTK coverage limitations**
  - RTK signal loss shortly after departure led to a switch to DGNSS
  - This switch compromised the “ground truth” reliability, impacting model training quality and accuracy



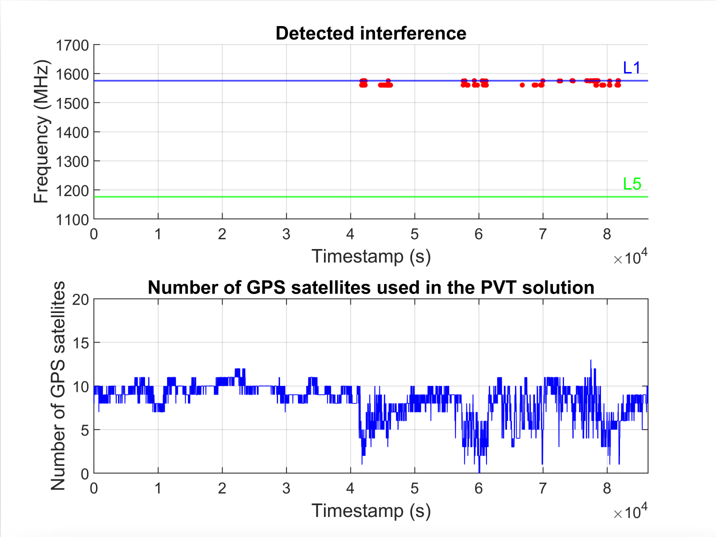


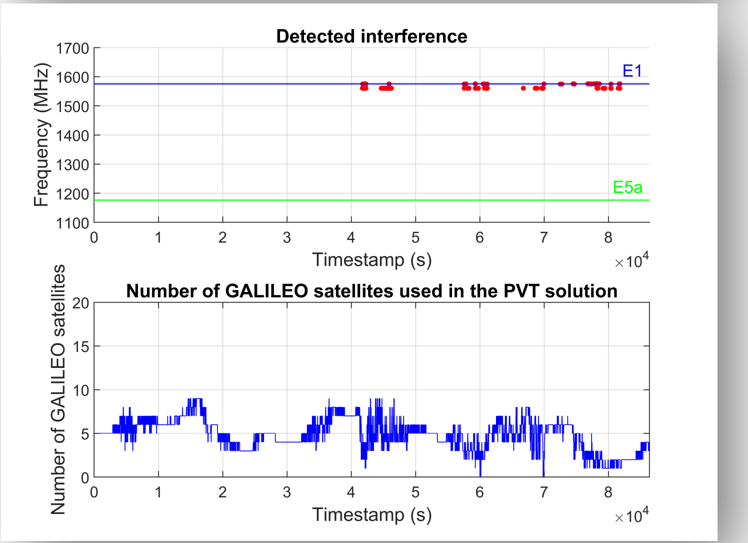
Impact of interferences on the number of satellites used in the PVT solution

20th June 2022 – Black Sea



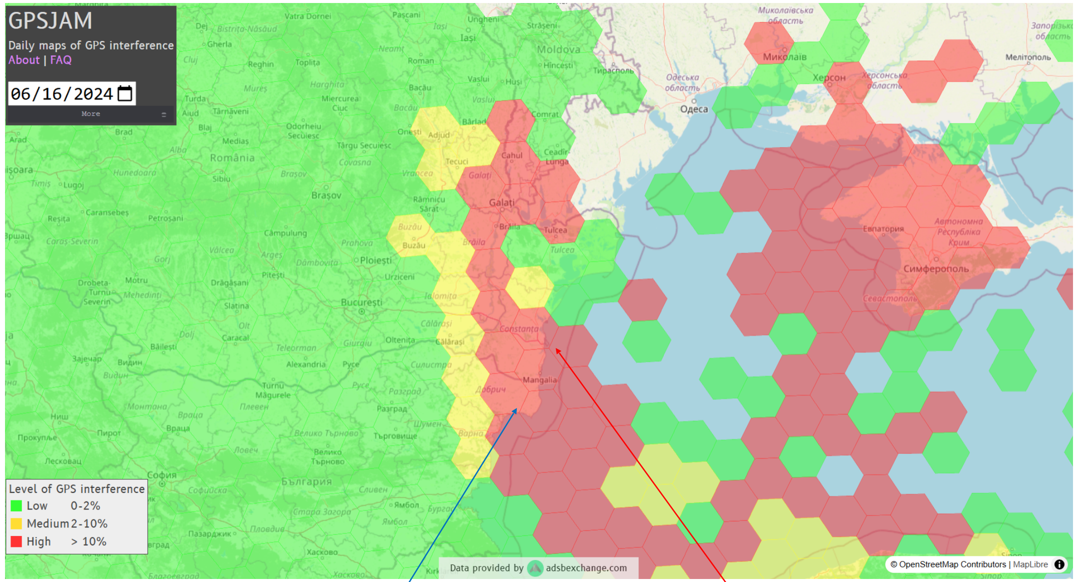
Source: https://gpsjam.org/



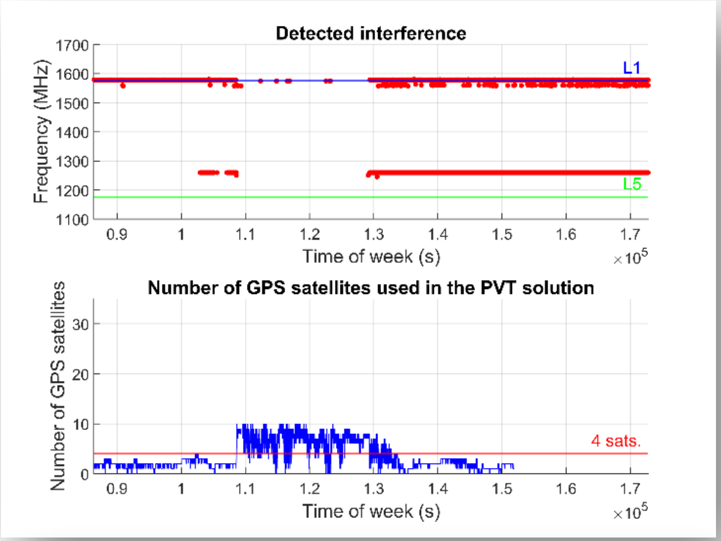


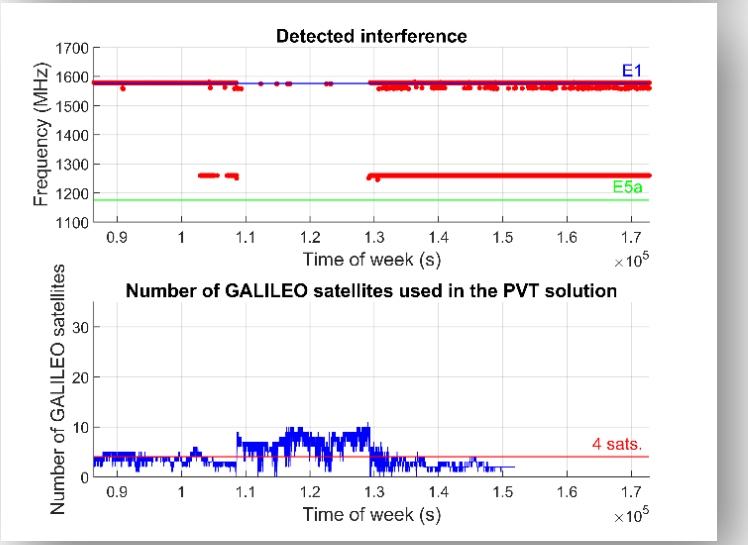
Impact of interferences on the number of satellites used in the PVT solution

16th June 2024 – Black Sea

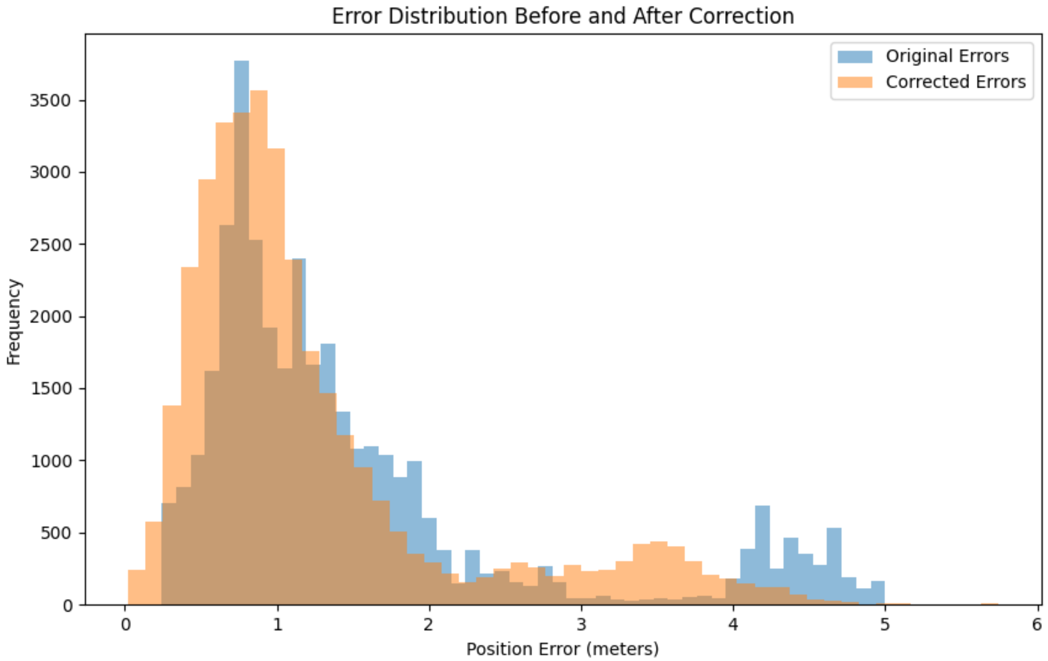


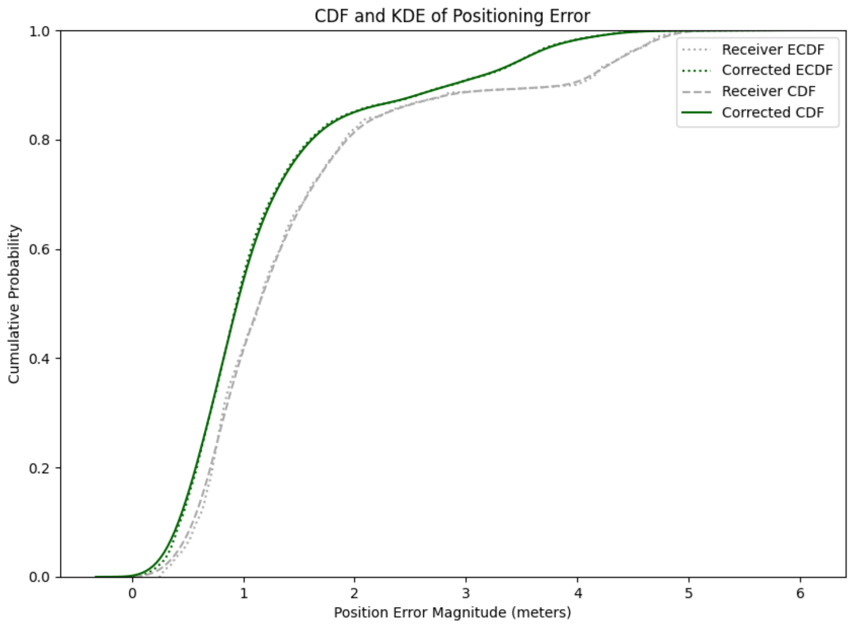
Source: https://gpsjam.org/





Data postprocessing





- **Dataset**
  - **Training**
    - DoYs 232 to 238 (static)
    - Sampling time: 5s
  - **Validation**
    - DoY 244 (kinematic)

- **Mean error**
  - **Receiver** 1.507 m
  - **ML model** 1.268 m
- **Error at 95^{th} percentile**
  - **Receiver** 4.391 m
  - **ML model** 3.259 m
  - **Improv.** 25.78%

Summary of inputs from stakeholders

Stakeholder engagement

- MHD raised specific challenges like **jamming issues** and need for highly **accurate maritime positioning**
- Expressed **strong interest**, detailing questions on functionality, training data sources, validation issues, and performance
- MHD showed potential for future collaboration

Feedback & development areas

- Recommendations include exploring **errors and integrity thresholds**, onboard interface protocols, **GUI development**, and real-time precision within small margins

Conference exposure

- NEURONAV presented at ION GNSS 2024 conference during a session focused on "Marine Applications and Search and Rescue."

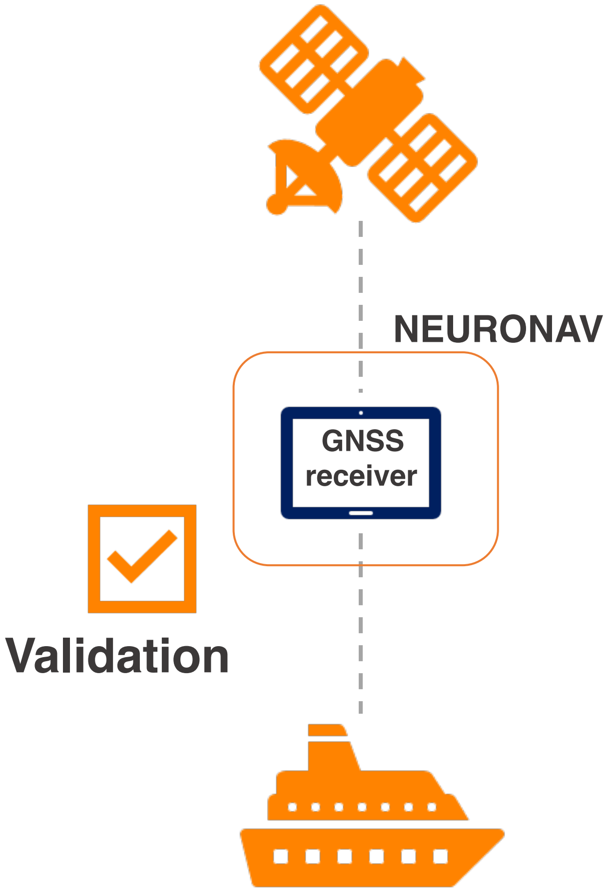
3. Product opportunities

Competitiveness characteristics

AI-Augmented Positioning
Uses ML to reduce multipath errors

Validation
ML model validation

Receiver Augmentation
Is built upon existing receivers – will not affect nominal PVT



Automatic Processing
Dataset preparation

Automatic Training
ML model trains without human supervision

Security
Data is stored & processed on the device

rise

Path to market

Long-Term Objective

- License NEURONAV to GNSS receiver manufacturers for integration and value-added resale
- Build on the commercial agreement with Septentrio for distribution in Romania and Moldova

Short-Term Objective

- Manufacture and market GNSS receivers with NEURONAV via RISE for direct-to-consumer sales
- Leverage maritime web shops to target professional and recreational sectors

Company opportunities

🔧 Development & Technical Innovation

- Extend NEURONAV to mitigate not just multipath, but also **GNSS interference**, **jamming**, and **spoofing**
- Develop a **more robust, real-time AI model** for broader maritime environments
- Explore fusion with other sensors (e.g., inertial, radar) for enhanced resilience

🛡️ Growing Demand in Defense Applications

- Rising need for **resilient navigation** in GNSS-contested environments
- **Potential deployment in military systems**, including **USVs**

ROMANIAN INSPACE ENGINEERING
rise

4. Next steps to commercialize

Next steps

Interference Mitigation

- Ensure reliable data collection and model training in high interference environments

Model Validation

- Store and validate models over extended periods and adverse conditions
- Combine outputs of different models

Data Management

- Introduce thresholds for outlier removal
- Increase dataset size

Software Navigation Filter

- Utilize a robust proprietary navigation filter

5. Benefits of working with ESA

Benefits of working with ESA

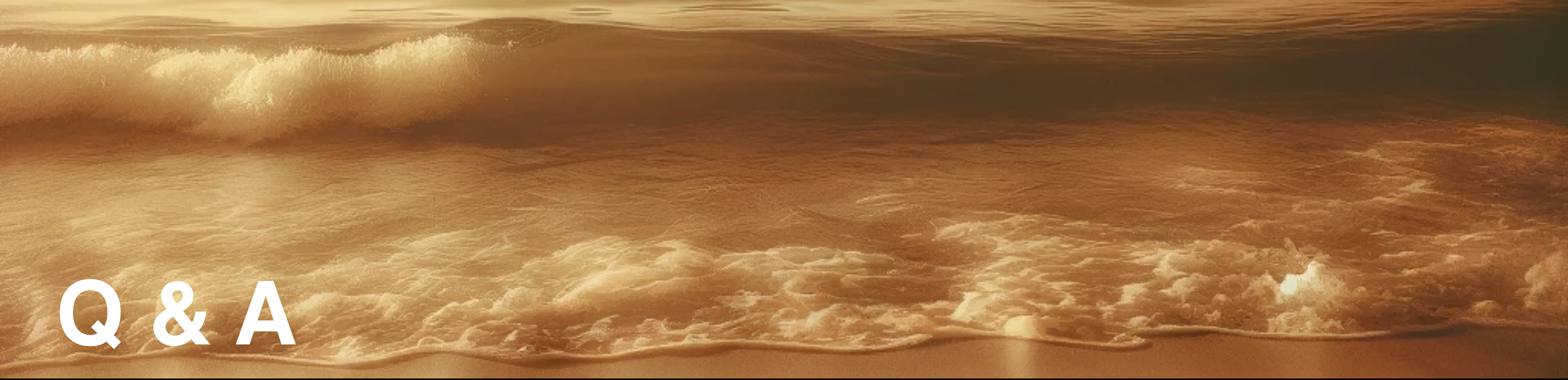
Key projects with ESA

OrbFix – a precise multi-constellation GNSS receiver precise position for small/ micro satellites

Dropcoal – droplets coalescence on the ISS. A high-speed camera records the interaction and mixing process

ECHO & ECHO-NN – GNSS monitoring and RF interference detection; continuous observation and logging of GNSS signals

rise



Q & A

Thank you!

Romanian InSpace Engineering S.R.L.

📩 E-mail: office@roinspace.com

📞 Phone: +40729074993