PERENA

Real Time PPP demonstrator for geomatics applications

Final Presentation Meeting

gmv INNOVATING SOLUTIONS

Agenda

Project Presentation
Overview of Activities
Development Outcomes
Uses Cases Definition
Testing and Verification Results
Conclusions and Future Work
Q&A Session

Project Presentation

PERENA - Overall context and objective

- Currently, the PPP-RTK is still in early stages for large scale adoption in the **geomatics** domain, where RTK is still the main approach used.
- PPP is at the moment targeting more mass market or safety-related markets, but it is steadily entering other ones
- RTK is extensively used in geomatics but has its drawbacks on both end-user as well as service provider level
- GMV is a known PPP service provider with high experience especially in the automotive domain
- GMV is looking to adapt and extend the service to other markets

*The objective of PERENA is to **develop and validate a new functionality** to complement the GMV's PPP Correction Service, **which will adapt the service corrections for dedicated use in the geomatics sector.***

PERENA – Benefits

Adapt the PPP streams in a flexible approach to make it easily ingested by regional service providers (managing regional / local RTK networks) and redistribute it further to their end users

BENEFITS

- **For GMV**
  - Further expand the already existing PPP services provision schemes to adjacent markets
  - Solidify the position of PPP service provider at EU level
  - Develop new business opportunities
- **For SysCAD and other 3rd party redistributors**
  - Provide the end-users with alternative positioning solutions
  - Cover areas where current RTK services are not covering the targeted territory
  - Opportunities to reduce costs with current infrastructure and maintenance operations
  - Better planning of future evolution of the infrastructure / optimization
- **For end-users of the services**
  - Back-up solutions in areas where current RTK services fail
  - Reduce dependence on local infrastructure
  - Continuous operations and availability to obtain high accuracy solutions even in more challenging environments

PERENA - Consortium

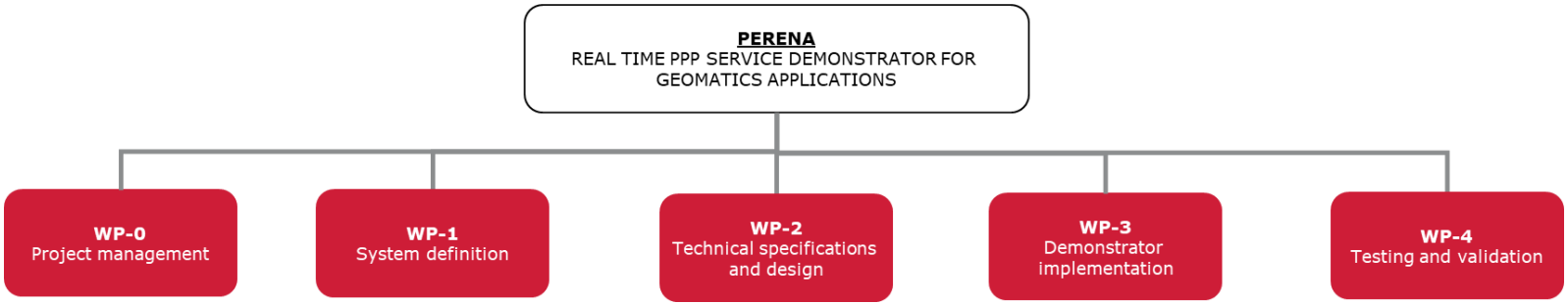
GMV Romania - prime contractor for PERENA – will be responsible for all activities related to the development of the new component to adapt the current Correction Service for geomatics applications

GMV is a privately owned technological business group with an international presence. Founded in 1984, GMV offers its solutions, services and products in very diverse sectors: Aeronautics, Banking and Finances, Space, Defense, Health, Cybersecurity, Intelligent Transportation Systems, Automotive, Telecommunications, and Information Technology for Public Administration and large corporations.

SysCAD Solutions S.R.L. is a private company, founded with the desire to offer to all those who work in the field of terrestrial measurements and computer-aided design quality solutions and services, recognized on the world market, at affordable prices. Our company provides the necessary consultancy for the implementation of solutions in the field of CAD, GIS, topography and cadaster, being an authorized distributor.

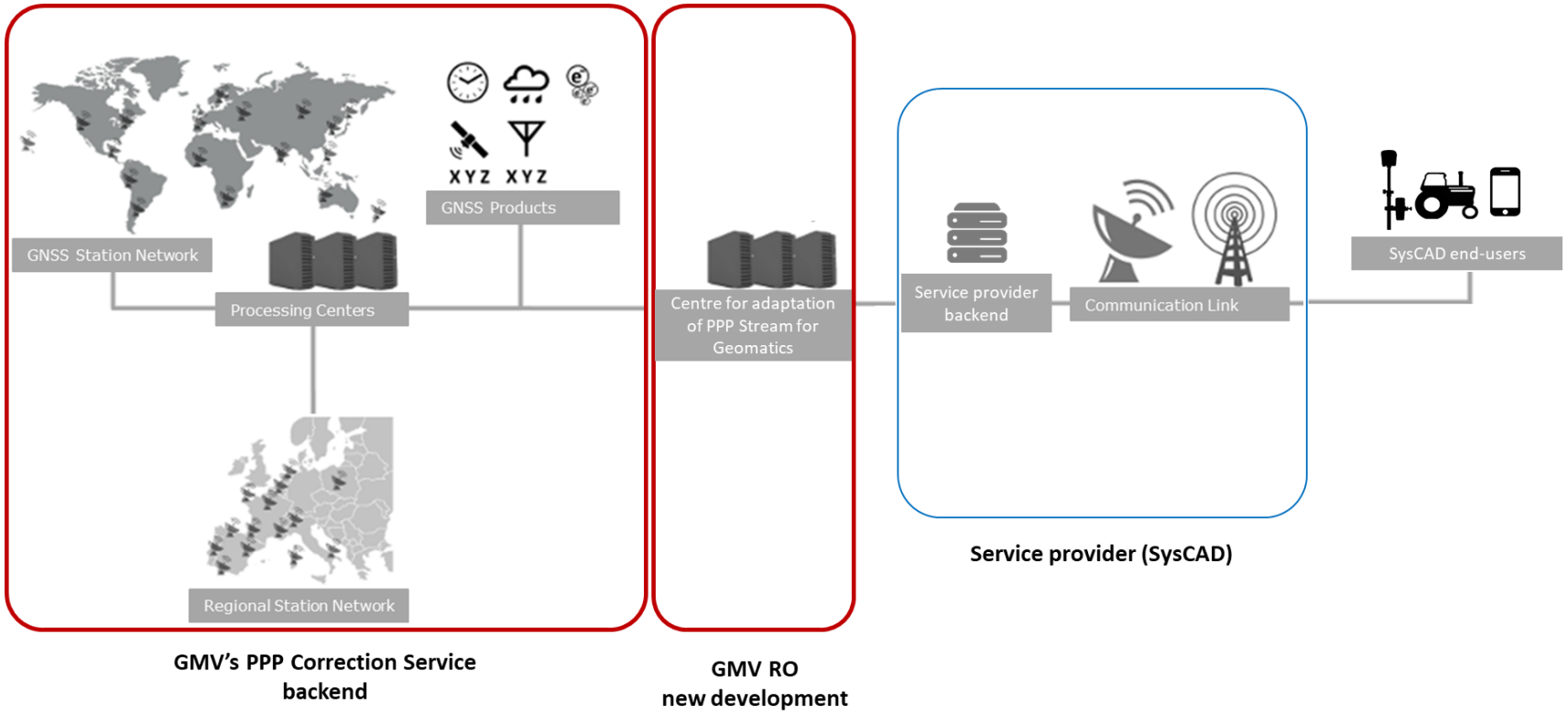
SysCAD manages in Romania its own CORS RTK network, providing RTK services to users from geomatics, agriculture, construction works machinery and others.

PERENA– Work Breakdown Structure



Overview of Activities

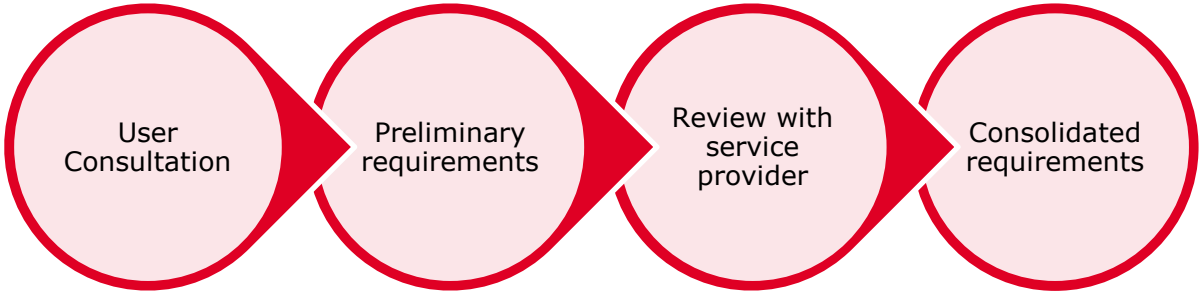
PERENA Development Integration



Addressed Needs and Competitive Characteristics

Addressed needs /customer benefits	Product Innovative Characteristics
Need for alternative positioning solutions to RTK at a national level for surveying, cadastral applications, etc. with similar performance, and minimizing the dependence on the infrastructure.	By ingesting the PPP-RTK stream and redistribute it towards the users via the same infrastructure, the user has alternative solutions, even in cases where the local RTK solution is failing.
From the service redistributor needs, the new service should be as much as possible independent of the existing network, and with immediate availability.	The PERENA service only depends on stations already available in the GMV global and regional CORS network, data provided through the Correction Service. The service redistributor has a very high degree of flexibility in the infrastructure design and maintenance.
Users will rely on the already installed base of receivers, and don't want to change it, but rather include additional services with similar performance.	The inclusion of the service is seamless for the users and allows for easy change between all available services in operations.
The adaptation should be very flexible in terms of reference frames to which the OSR corrections are provided, as this will allow for a quick scalability and implementations to other regions / countries.	The reference conversion module included is adaptable and allows reuse and scalability.

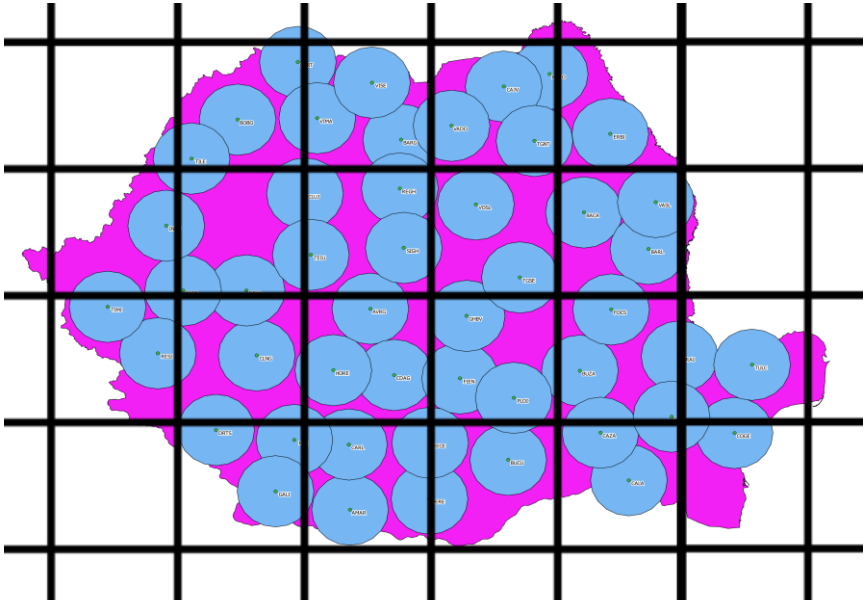
Requirements Definition Process



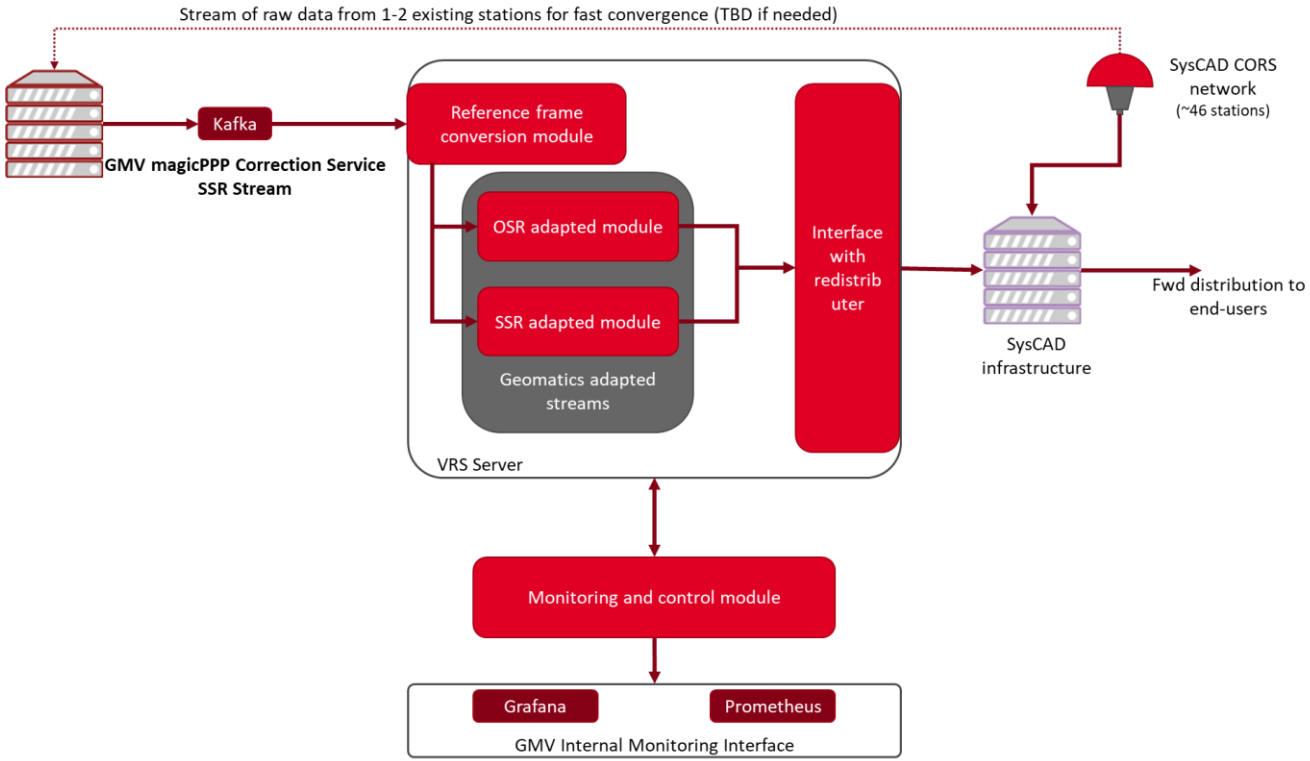
PERENA VRS approach

- **Current coverage through SysCAD infrastructure: ~70% of the Romanian territory**

- **2 possibilities of enhancing the service:**
  - Complete grid layout of VRS stations
  - Auxiliary layout to fill the areas without coverage of the current RTK solution
- **Implemented solution: Complete grid layout**



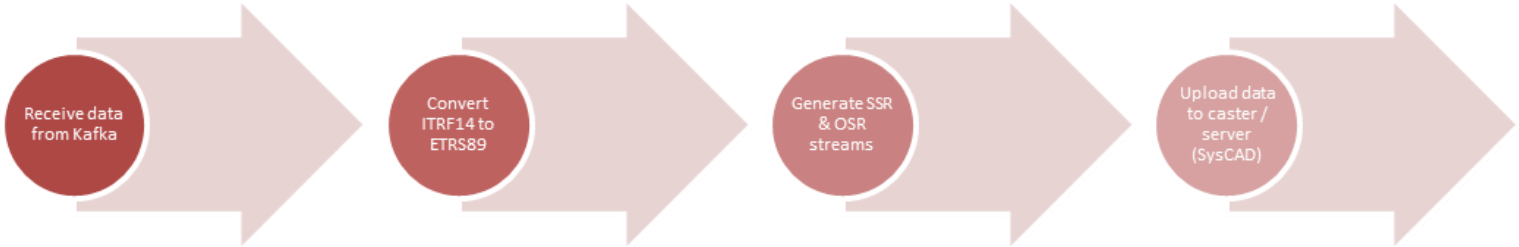
Architecture Review



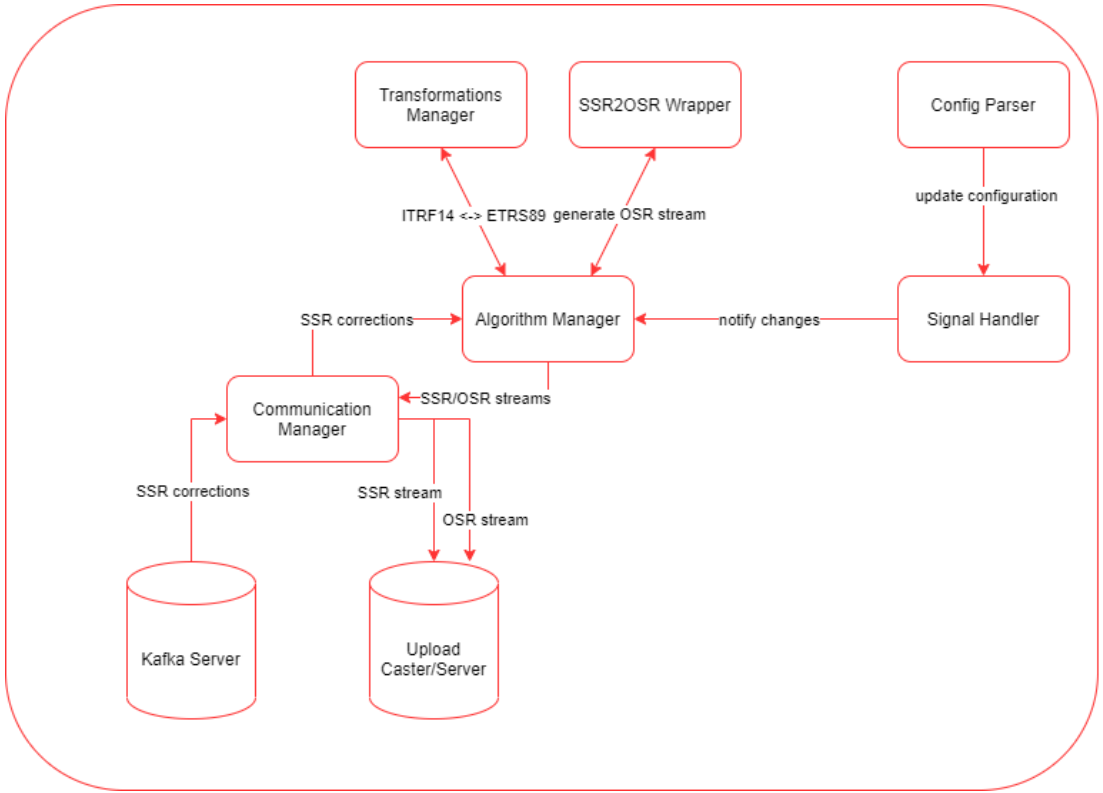
High level data flow of the system

The **high level data flow** of the PERENA Demonstrator will be as follows:

- The program receives corrections from the PPP corrections server by connecting to a Kafka streamer.
- The reference frame conversion is applied to the data.
- The OSR stream is generated by using the internal SSR2OSR library.
- The data streams are uploaded to SysCAD.



Low level VRS server modules



Development Outcomes

Newly developed modules and COTS

- **The reference frame conversion** module performs the transformation from ITRF14 reference frame to the ETRS89 reference frame.
- **The SSR adapted module** uses GMV's magicPPP Correction Service and a Kafka server connection to retrieve the corrections for the demonstrator. The Kafka server is an intermediary system that streams data from the magicPPP Correction Service subscribing users via an NTRIP connection. The demonstrator subscribes to topics to retrieve the appropriate corrections for each station.
- **The OSR adapted module** uses the SSR corrections previously retrieved from the Kafka server and transforms them into OSR corrections (Observation-State Representation) via a proprietary library called SSR2OSR.
- **The interfacing module** with the redistributor is designed to connect to SysCAD's infrastructure via NTRIP and broadcast the adapted data streams.

Demonstrator module	New development	Reused and adapted
Reference frame conversion module	✓	
OSR adapted module	✓	
SSR adapted module	✓	
Interface with redistributor	✓	
Monitoring and control module		✓

Newly developed modules and COTS

GMV Proprietary COTS:

- ***magicPPP* library** provides a framework for the development of server-like architectures working with the GMV *magicPPP* Correction Service.
- **SSR2OSR library** is a GMV developed library meant to transform the State Space Representation (SSR) corrections stream into an Observation State Representation (OSR) one.

3rd Party COTS:

- **Apache Kafka** is a distributed event streaming platform used for retrieving the satellite corrections stream.
- **Prometheus** is a monitoring system used to efficiently monitor different metrics such as number of satellites used, time since last solution, etc.
- **Grafana** is an analytics and monitoring solution for every database, used to output statistics in a more graphical manner, such as dashboards.

Reused and adapted modules

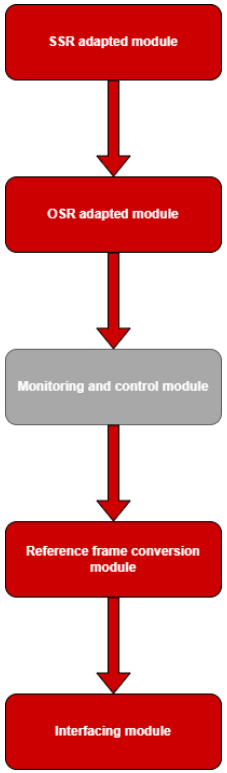
- The development team of PERENA performed several adaptations of the reused framework provided by the *magicPPP* library and of GMV's PPP Monitor Server

- The **PPP Monitor Server** is one of the components of the monitoring and control module. It receives corrections from the VRS Server, then runs RTK's based on these corrections and on the ones received from rovers and compares the computed position with the real known position of the rovers to assess the quality of the corrections used.

- Another important aspect of the monitoring and control module is represented by the computed **metrics** of the demonstrator, that are uploaded to a Prometheus and Grafana server.

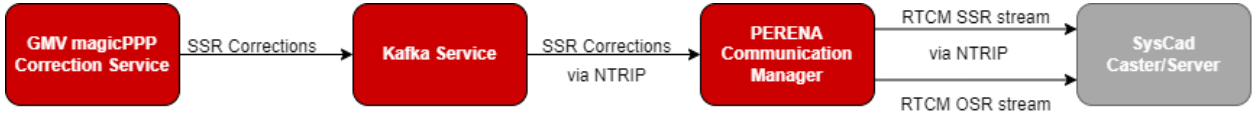
```
magicgnss@magicgnss-v7:~/git/perena$ curl localhost:10091/metrics
# HELP exposer_transferred_bytes_total Transferred bytes to metrics services
# TYPE exposer_transferred_bytes_total counter
exposer_transferred_bytes_total 47138.00000000000000000
# HELP exposer_scrapes_total Number of times metrics were scraped
# TYPE exposer_scrapes_total counter
exposer_scrapes_total 13.00000000000000000
# HELP exposer_request_latencies Latencies of serving scrape requests, in microseconds
# TYPE exposer_request_latencies summary
exposer_request_latencies_count 13
exposer_request_latencies_sum 6583.00000000000000000
exposer_request_latencies{quantile="0.5000000000000000"} 422.00000000000000000
exposer_request_latencies{quantile="0.9000000000000002"} 584.00000000000000000
exposer_request_latencies{quantile="0.98999999999999999"} 712.00000000000000000
# HELP vrs_corrected_corrections_num_messages_total Number of correction messages
# TYPE vrs_corrected_corrections_num_messages_total counter
vrs_corrected_corrections_num_messages_total{Topic="PECS_EU_L11_000011010010000"} 4.00000000000000000
# HELP vrs_corrected_corrections_num_bytes_total Number of correction bytes send
# TYPE vrs_corrected_corrections_num_bytes_total counter
vrs_corrected_corrections_num_bytes_total{Topic="PECS_EU_L11_000011010010000"} 7120.00000000000000000
# HELP vrs_stations_num_messages_total Number of messages send per VRS station
# TYPE vrs_stations_num_messages_total counter
vrs_stations_num_messages_total{Id="Munich"} 20.00000000000000000
vrs_stations_num_messages_total{Id="Frankfurt"} 20.00000000000000000
vrs_stations_num_messages_total{Id="Bucharest"} 20.00000000000000000
# HELP vrs_stations_num_bytes_total Number of bytes send per VRS station
# TYPE vrs_stations_num_bytes_total counter
vrs_stations_num_bytes_total{Id="Munich"} 5645.00000000000000000
vrs_stations_num_bytes_total{Id="Frankfurt"} 5645.00000000000000000
vrs_stations_num_bytes_total{Id="Bucharest"} 5420.00000000000000000
# HELP vrs_corrections_num_messages_total Number of corrections received per topic
# TYPE vrs_corrections_num_messages_total counter
vrs_corrections_num_messages_total{Topic="PECS_EU_L11_000011010000100"} 5.00000000000000000
```

Implementation Process Flow



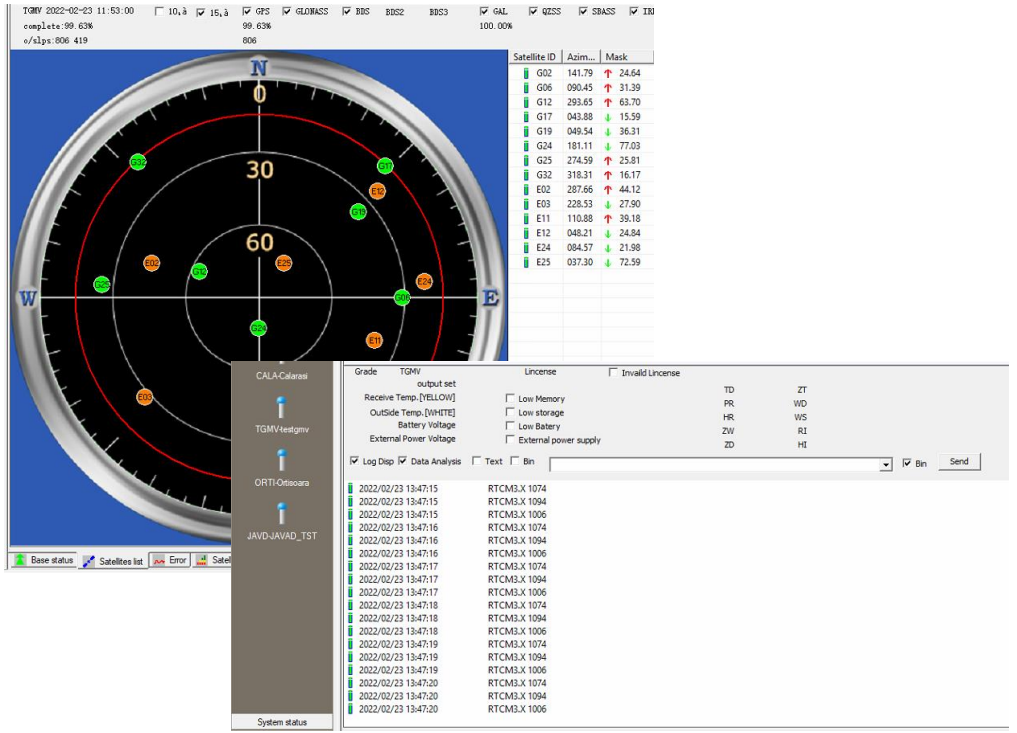
Modules	Functions/Features	Description
SSR adapted module	Ensure the appropriate handling and forwarding of SSR service.	This module takes the SSR corrections from the Reference Frame Conversion Module which received them from the Correction Service. The SSR adapted module then forwards the data to the interfacing module.
OSR adapted module	Ensure the proper conversion of SSR to OSR (based on existing COTS library). Handle the nodes of the grid for OSR streams generation.	Based on existing COTS (the SSR2OSR library already existing and provided by GMV AD), this module ensures the conversion of the SSR streams into OSR ones. Furthermore it optimizes and handles the grid points where these streams will be generated.
Monitoring and control module	Monitor the service. Modify and control the service provision. Generate and allow for analysis of metrics through Prometheus and Grafana.	This module serves for managing the service distribution. It provides the ability for the service administrator at GMV to monitor the service, modify and control the provision and compute and analyse the KPIs.
Reference frame conversion module	Translate the correction streams reference frame in different alternative ones.	This module takes care of the conversion needed for different reference frames of the CS streams. The reference frame transformation for PERENA is ITRF14-ETRS89.
Interface with redistributor	Wrapper for interfacing with redistributor.	This module ensures the provision of the SSR streams adapted to the redistributor's needs and in accordance with the agreed formats. GMV broadcasts the data through NTRIP, which is based on TCP/IP. The data stream is be formatted respecting RTCM MSM4/MSM7 standards.

Demonstrator interfacing



- The demonstrator retrieves corrections in SSR format from a Kafka server via Kafka queue.
- The adapted data stream is broadcast via NTRIP.
- The adapted data stream meets the RTCM standards and respects the MSM4 message structure.

- The ***magicPPP*** **library** functions for NTRIP connections were used in the Communication Manager class of the VRS Server in order to connect to a server or caster.
- The **SSR2OSR library** was adapted in order to meet the specific constraints of PERENA. By default, the library would convert the SSR stream into an OSR stream with MSM7 message resolution. However, SysCAD's system is not able to handle MSM7 messages, therefore a down-conversion of the data-stream to the MSM4 standard was agreed.



Use Cases Definition

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After some initial tests were done obtaining some conclusions about the configuration of the VRS Server that was needed, two main cases are included in the final results, being considered as the conclusive ones.

From the initial tests mentioned, the next key aspects in the VRS Server configuration was found. These **two variables** were key in the final RTK performances.

Possible use cases	Verification condition	Short description of the conditions	Elements to be analysed w.r.t. to the demonstrator
Cadastral activities	**Open sky with ideal conditions**	Verifications will take place in the urban outskirts, with a mix of houses and blocks and obstructions considered as **low.**	Accuracy Type of solutions obtained
Infrastructure mapping			
GIS			
Constructions activities			
Fleet monitoring			
Cadastral activities	**Open sky with nominal conditions**	Verifications will take place in the urban outskirts, with a mix of houses and blocks and obstructions considered as **low.**	Number of satellites observed Stability of the solutions
Infrastructure mapping			
GIS			
Constructions activities			
Fleet monitoring			

Use Cases Definition

Two key aspects:

1) Distance between the regional stations and the virtual station. Regional stations are used to compute the ionospheric slant delays. In order to ensure a good performance of the transformation from SSR to OSR corrections, the distance between the different regional stations used by the GMV CS and the Virtual Reference Station (VRS) needs to be considered.

Use Cases Definition

CS Regional stations

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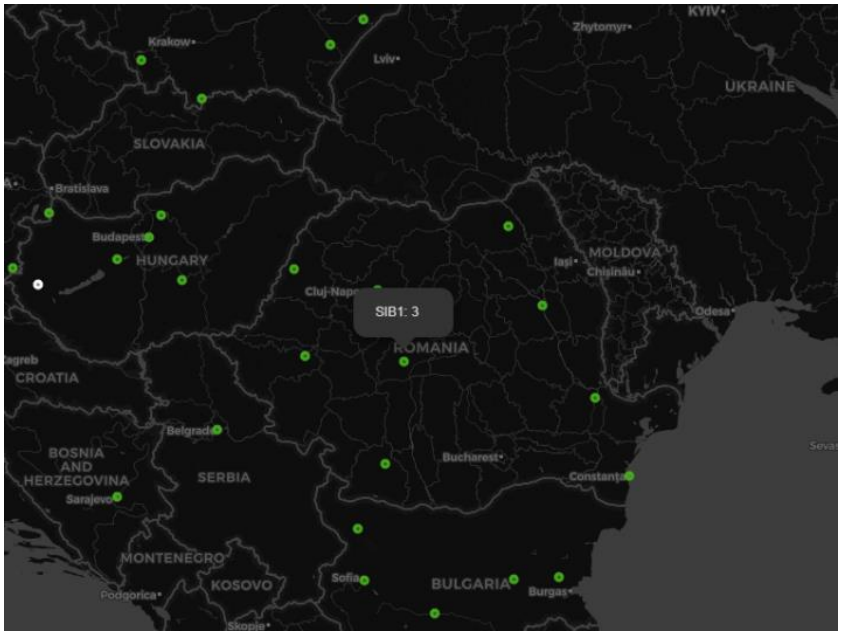

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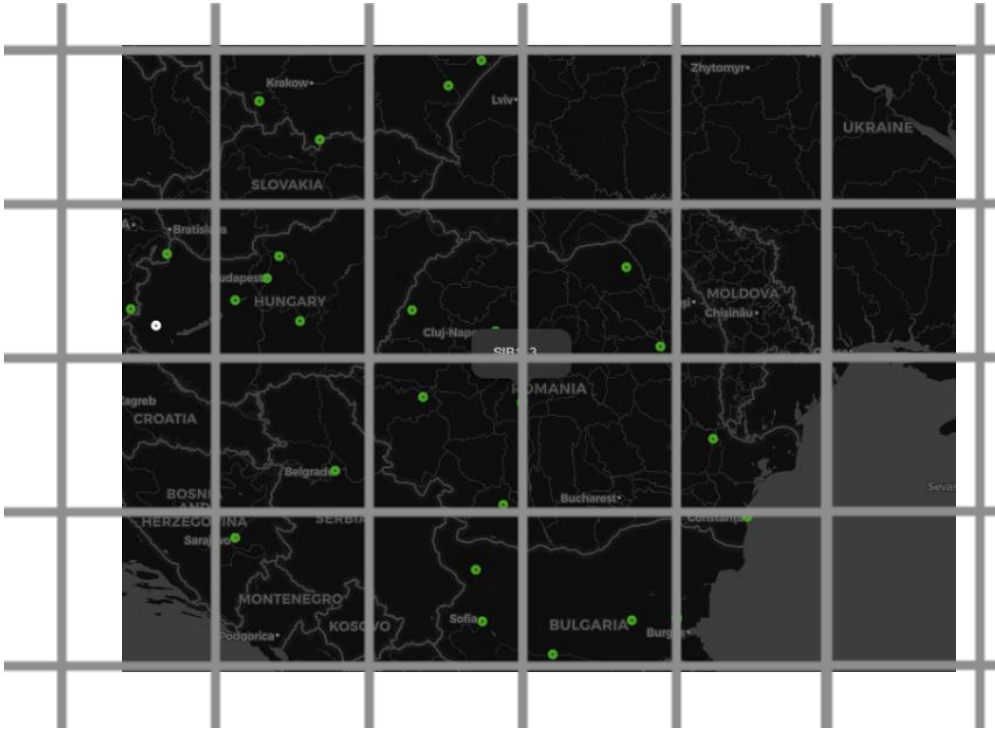

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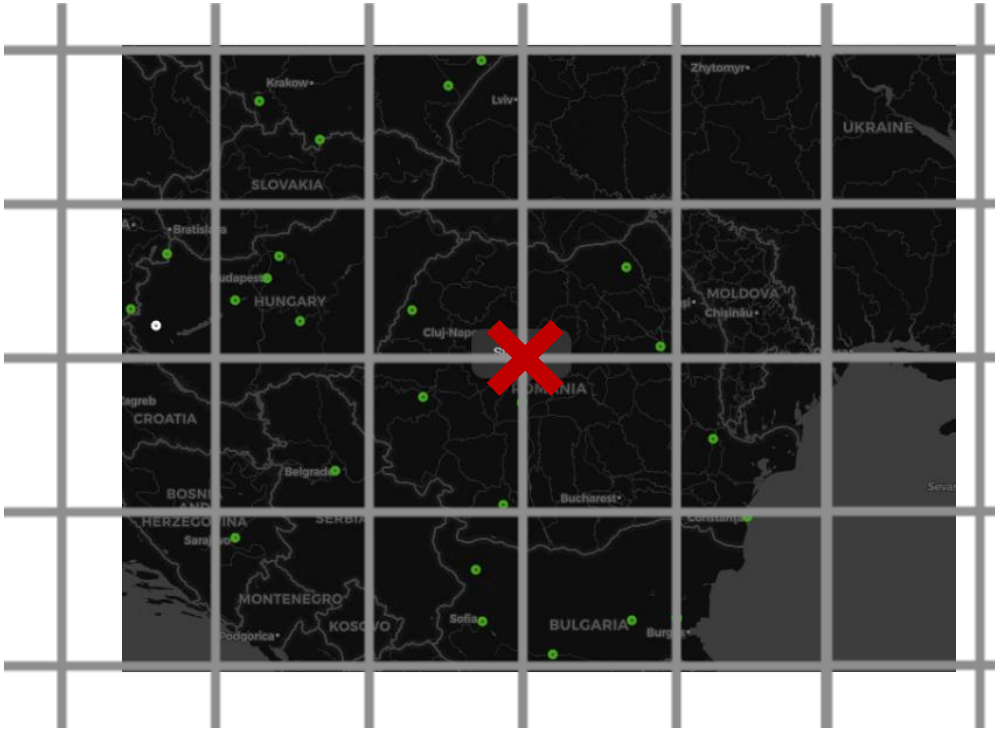

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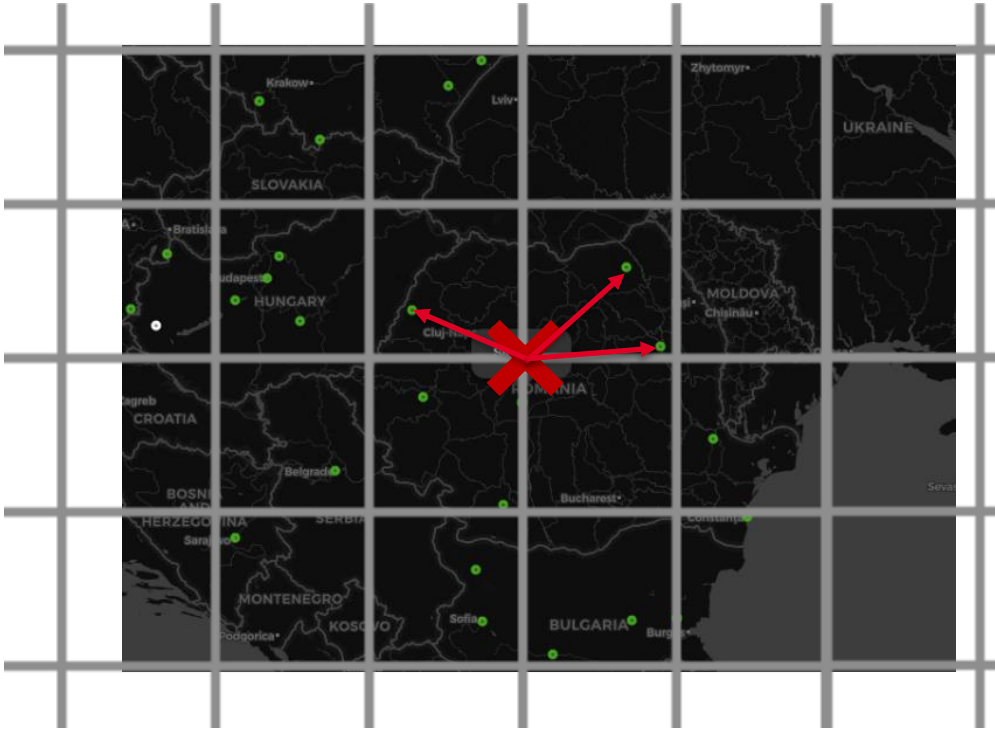

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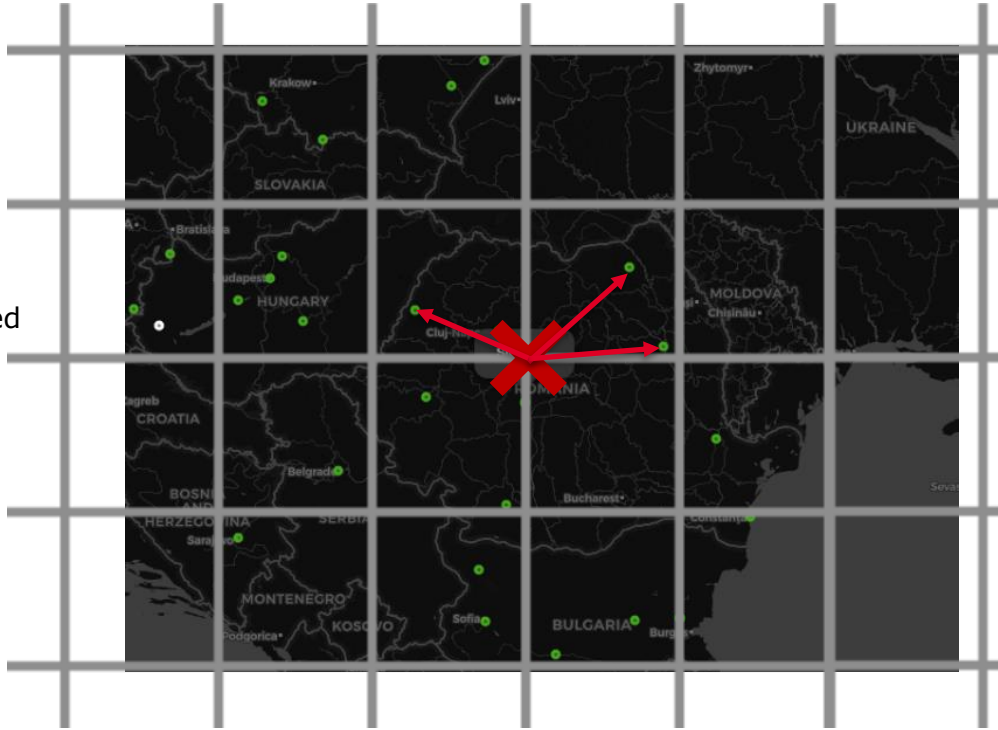

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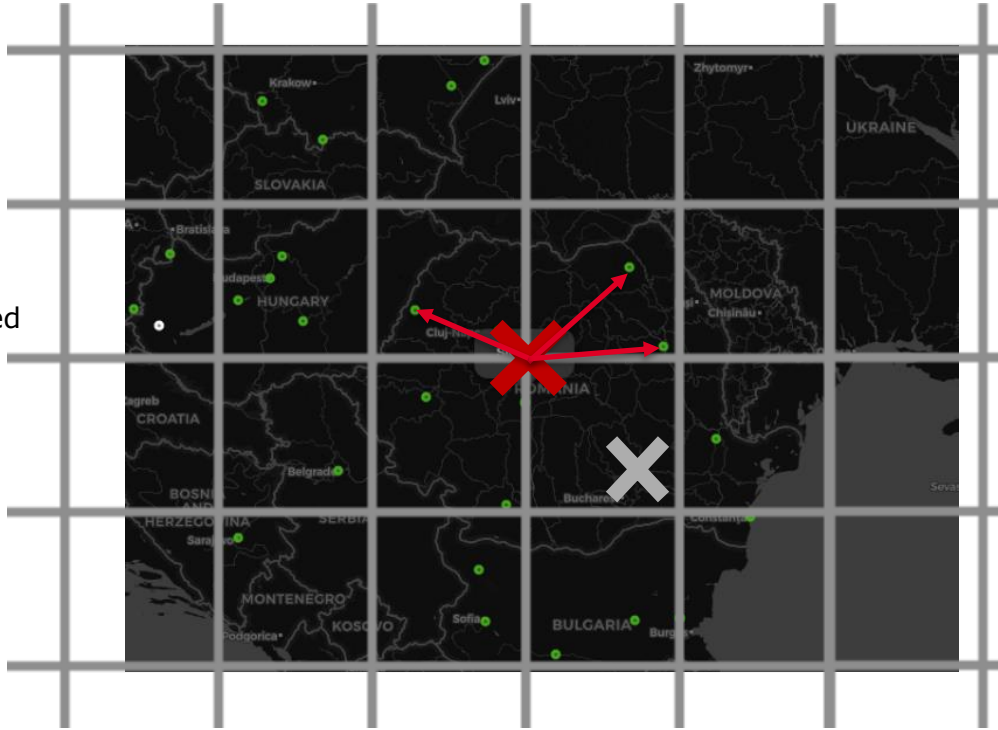

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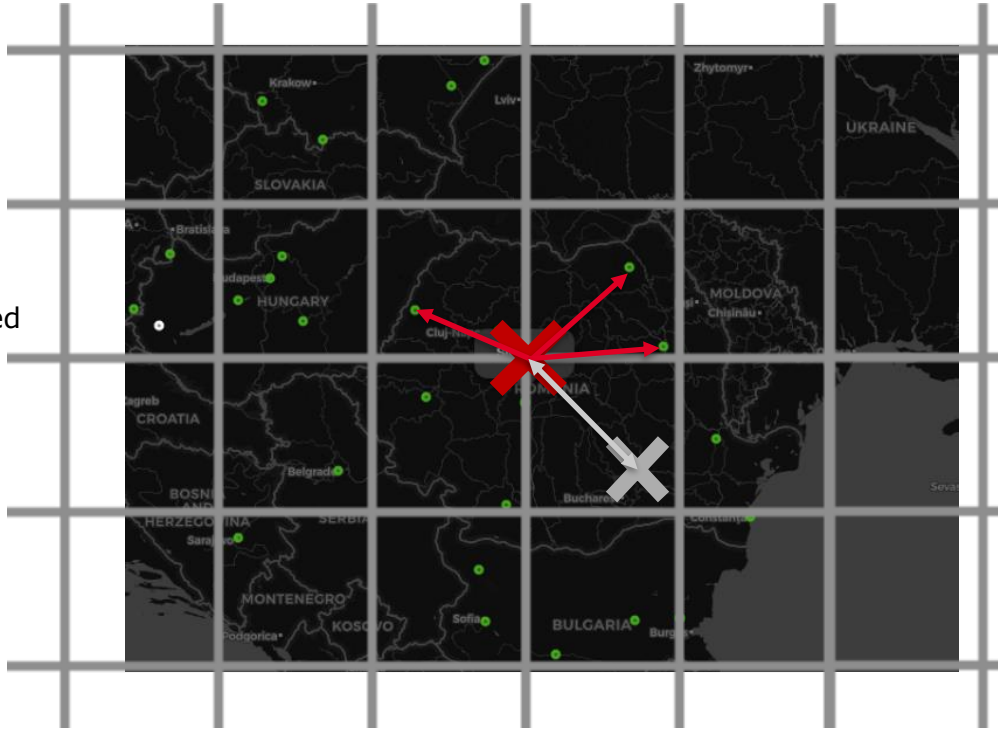

Use Cases Definition

OPEN SKY SCENARIO WITH IDEAL CONDITIONS

- A virtual station has been set up on the same position of a regional station (SIB).
- The virtual stations coordinates are the same that those of SIB. In order to 'create' the virtual station, the VRS Server has been used, which takes the SSR corrections given by the GMV CS and transforms them into OSR messages, casted following the RTCM standard.
- To validate the accuracy of the measurements, an RTK has been run from the exact same coordinates.

OPEN SKY SCENARIO WITH NOMINAL CONDITIONS

- A virtual station has been set up some kilometers away from Sibiu, (the city where SIB is placed). In this case, the virtual station has been set on a nearby town called Ocna.
- Distance between the virtual station and SIB is 12 kilometers.
- RTK has been run using the virtual station as a base and SIB as rover.

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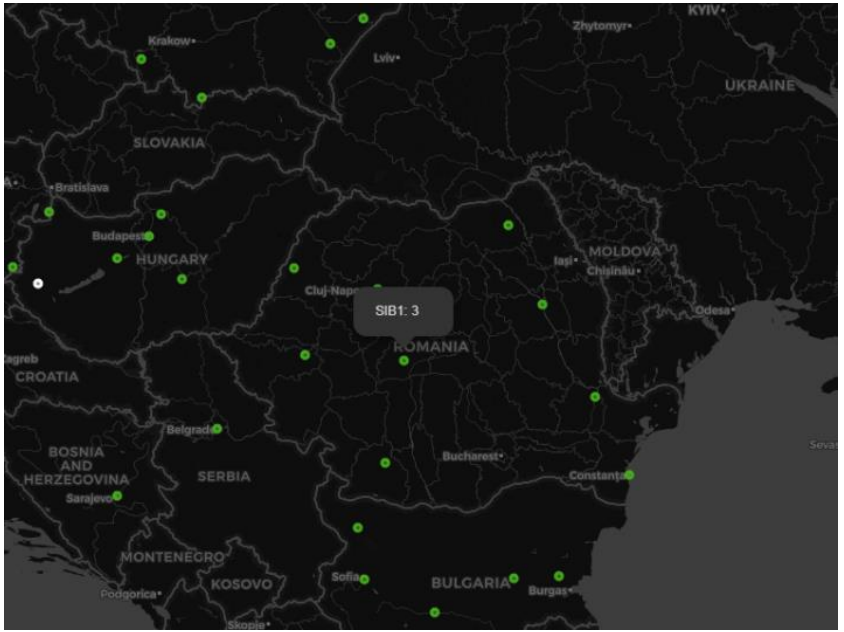

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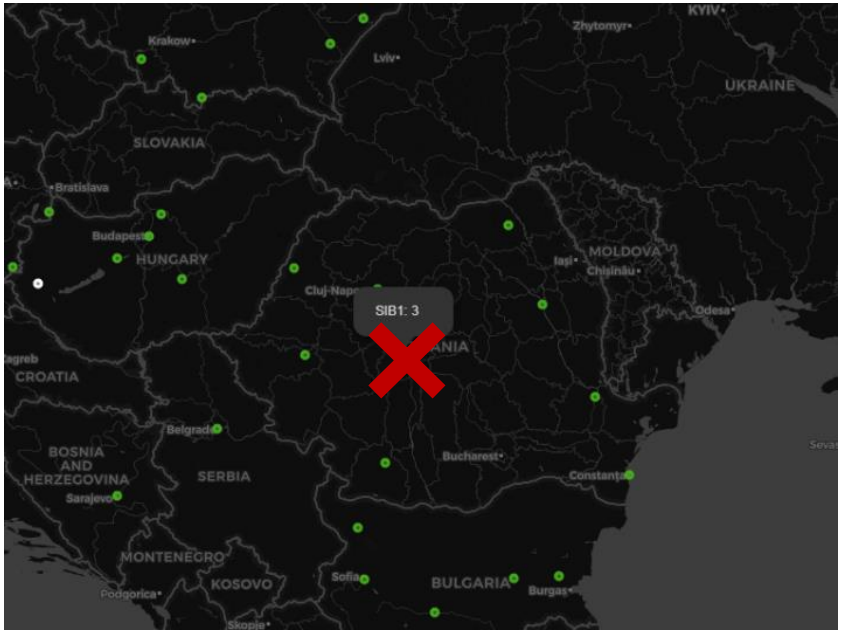

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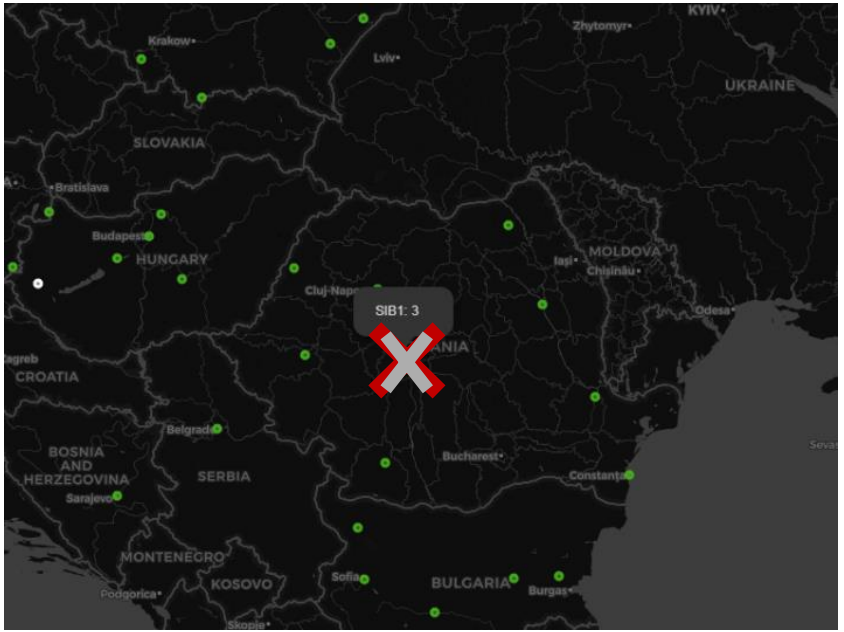

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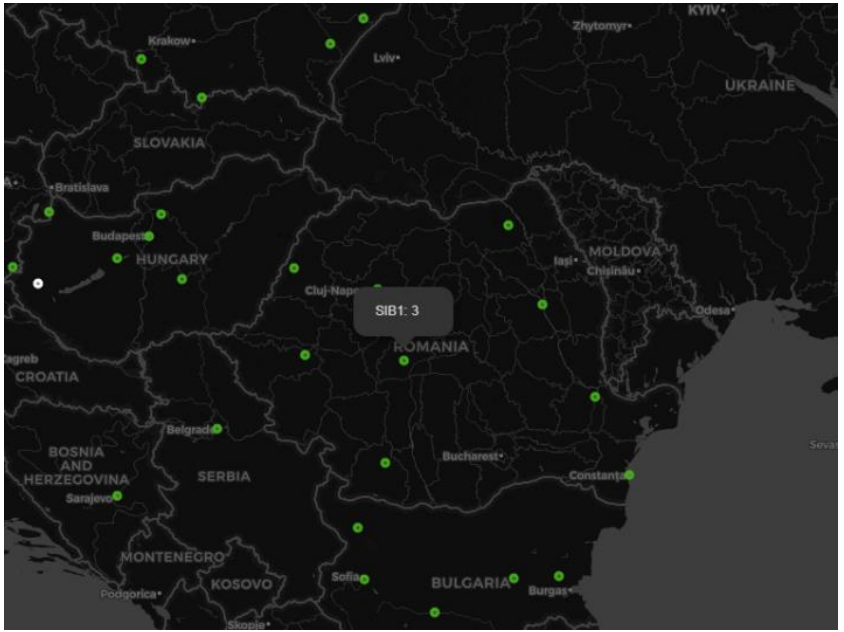

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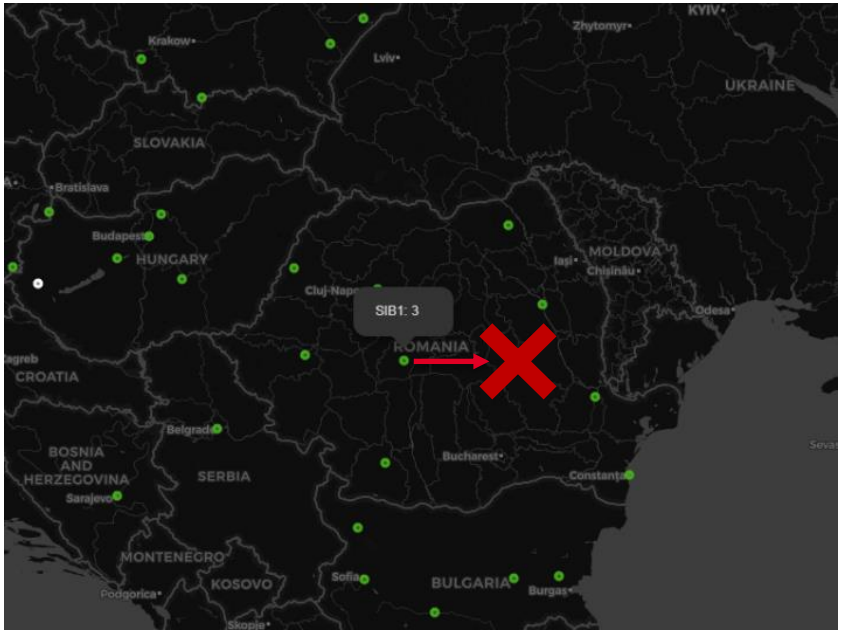
- RTK has been run using the virtual station as a base and SIB as rover.

CS Regional stations
VRS (RTK base station)
RTK Rover station



Use Cases Definition

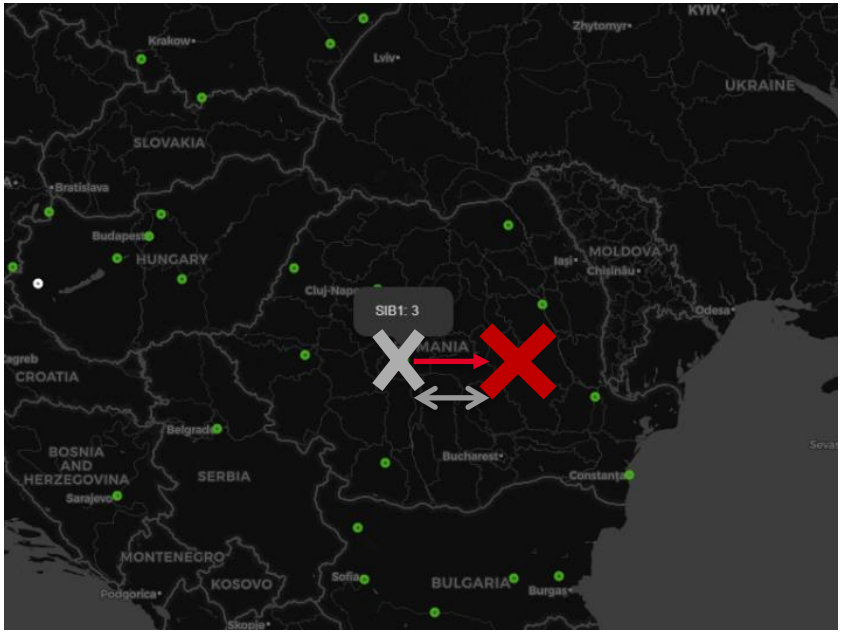
OPEN SKY SCENARIO WITH IDEAL CONDITIONS

- A virtual station has been set up on the same position of a regional station (SIB).
- The virtual stations coordinates are the same that those of SIB. In order to 'create' the virtual station, the VRS Server has been used, which takes the SSR corrections given by the GMV CS and transforms them into OSR messages, casted following the RTCM standard.
- To validate the accuracy of the measurements, an RTK has been run from the exact same coordinates.

OPEN SKY SCENARIO WITH NOMINAL CONDITIONS

- A virtual station has been set up some kilometers away from Sibiu, (the city where SIB is placed). In this case, the virtual station has been set on a nearby town called Ocna.
- Distance between the virtual station and SIB is 12 kilometers.
- RTK has been run using the virtual station as a base and SIB as rover.

CS Regional stations
VRS (RTK base station)
RTK Rover station



Testing and Verification Results

Summary Test Report

Several tests have been executed in order to validate the different requirements: **functional and performance**.

A **summary** of the requirements to be covered is:

- Constellations supported: GPS (L1/L2) and Galileo (E1/E5).
- Reference frame conversion.
- Provision of SSR corrections through a NTRIP Caster.
- Provision of OSR corrections through a NTRIP Caster.
- Area coverage.
- Performance requirements:
    - Horizontal accuracy better than 10cm (1-sigma) in nominal conditions.
    - Vertical accuracy better than 20cm (1-sigma) in nominal conditions.

Summary Test Report

Several tests have been executed in order to validate the different requirements: **functional and performance**.

A **summary** of the requirements to be covered is:

- Constellations supported: GPS (L1/L2) and Galileo (E1/E5).

```
magicgnss@magicgnss-v7:~/git/perena$ /home/magicgnss/git/vrs_server/build_test_rtk/test_RTCM_stream/test_RTCM_stream 18
        CORRECTIONS_PERENA
2022/06/20 09:55:31.574580 [Info   ] [Main functions   ] Client started
2022/06/20 09:55:32.735355 [Info   ] [Comm. manager    ] Connection established
2022/06/20 09:55:33.638815 [Info   ] [Comm. manager    ] RTCM message received. Code: 1094
2022/06/20 09:55:33.654893 [Info   ] [Comm. manager    ] RTCM observation message received:  E02( 1C 7Q)  E15( 1C 7Q)  E30( 1C 7Q)  E36( 1C 7Q)
2022/06/20 09:55:33.655473 [Info   ] [Comm. manager    ] RTCM message received. Code: 1006
 Antenna Reference.
       Station id: 0
       GPS supported: true
       GLONASS supported: false
       GALILEO supported: true
       Physical station: true
       Single oscillator: false
       ARP (4113107.640300,1997216.904200,4432114.708400). Height:0.000000
2022/06/20 09:55:33.655699 [Info   ] [Comm. manager    ] RTCM antenna reference message received
2022/06/20 09:55:33.737062 [Info   ] [Comm. manager    ] RTCM message received. Code: 1074
2022/06/20 09:55:33.737681 [Info   ] [Comm. manager    ] RTCM message received. Code: 1094
2022/06/20 09:55:33.737929 [Info   ] [Comm. manager    ] RTCM observation message received:  G10( 1C 2W)  G16( 1C 2W)  G18( 1C 2W)  G23( 1C 2W)  G26
( 1C 2W)  G27( 1C 2W)  G29( 1C 2W)  E02( 1C 7Q)  E15( 1C 7Q)  E30( 1C 7Q)  E36( 1C 7Q)
2022/06/20 09:55:33.738028 [Info   ] [Comm. manager    ] RTCM message received. Code: 1006
 Antenna Reference.
       Station id: 0
       GPS supported: true
       GLONASS supported: false
       GALILEO supported: true
       Physical station: true
```

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- Reference frame conversion.

```
:47.265886 [Info    ] [SSR2OSR Library  ] Station Bucharest position: X: 4100058.259700 Y: 2011045.193300 Z: 4437694.143100 Height: 0.000000
:46.330315 [Info    ] [SSR2OSR Library  ] Station Bucharest position: X: 4100058.941400 Y: 2011044.668300 Z: 4437693.761100 Height: 0.000000
```

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- Constellations supported: GPS (L1/L2) and Galileo (E1/E5).
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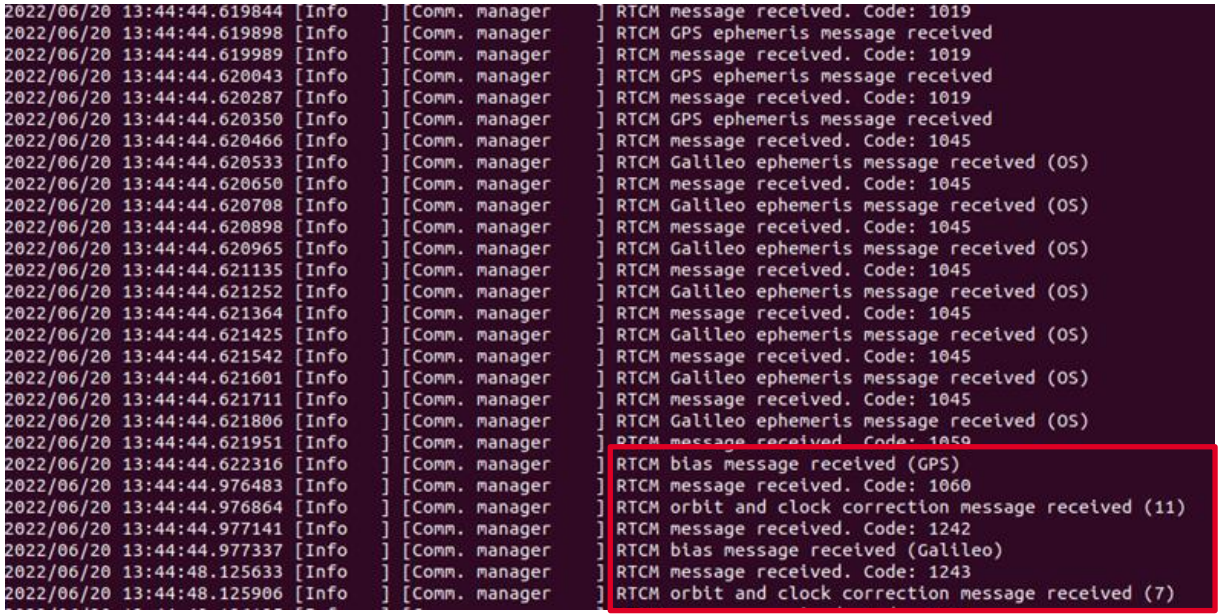

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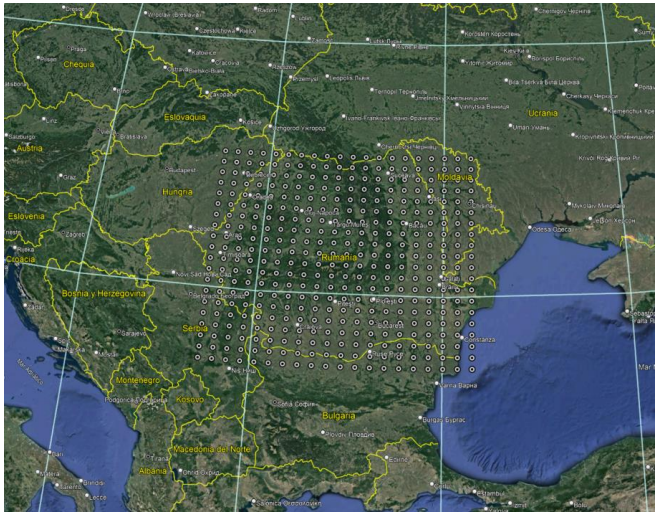
- Provision of OSR corrections through a NTRIP Caster.
- Area coverage.

VRS_288	3522	97.80616495417794
VRS_267	3522	97.80616495417794
VRS_289	3522	97.80616495417794
VRS_258	3522	97.80616495417794
VRS_290	3522	97.80616495417794
VRS_291	3522	97.80616495417794
VRS_282	3522	97.80616495417794
VRS_292	3522	97.80616495417794
VRS_293	3522	97.80616495417794
VRS_297	3522	97.80616495417794
VRS_3	3522	97.80616495417794
VRS_301	3522	97.80616495417794
VRS_76	3522	97.80616495417794
VRS_12	3522	97.80616495417794
VRS_302	3522	97.80616495417794
VRS_311	3522	97.80616495417794
VRS_303	3522	97.80616495417794
VRS_39	3522	97.80616495417794
VRS_130	3522	97.80616495417794
VRS_305	3522	97.80616495417794
VRS_306	3522	97.80616495417794
VRS_248	3522	97.80616495417794
VRS_307	3522	97.80616495417794
VRS_25	3522	97.80616495417794
VRS_134	3522	97.80616495417794
VRS_136	3522	97.80616495417794
VRS_308	3522	97.80616495417794
VRS_314	3522	97.80616495417794
VRS_315	3522	97.80616495417794
VRS_320	3522	97.80616495417794
VRS_323	3522	97.80616495417794
VRS_324	3522	97.80616495417794
VRS_126	3522	97.80616495417794
VRS_326	3522	97.80616495417794

Average system availability for 3600 seconds: 97.80616495417857%



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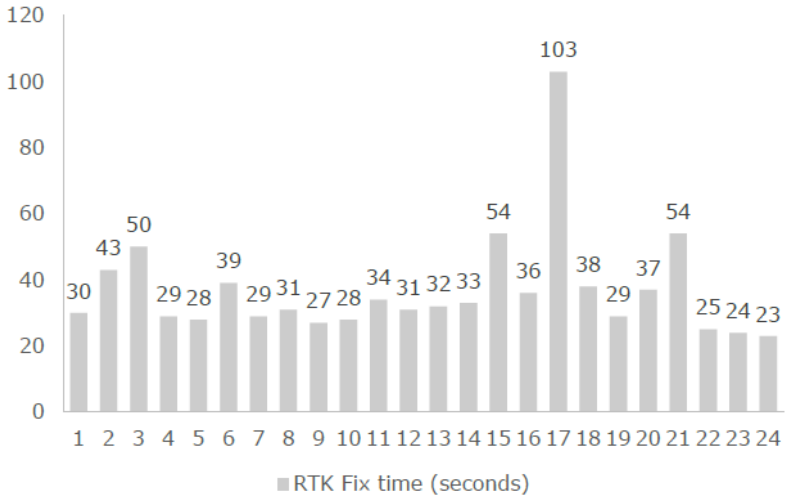
- Performance requirements:
    - Convergence time.



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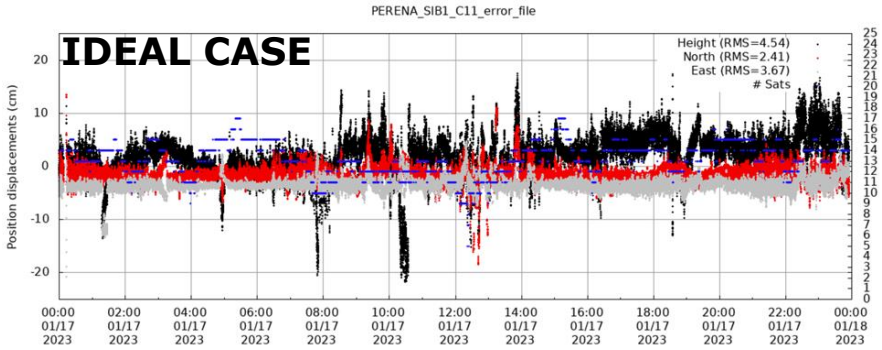
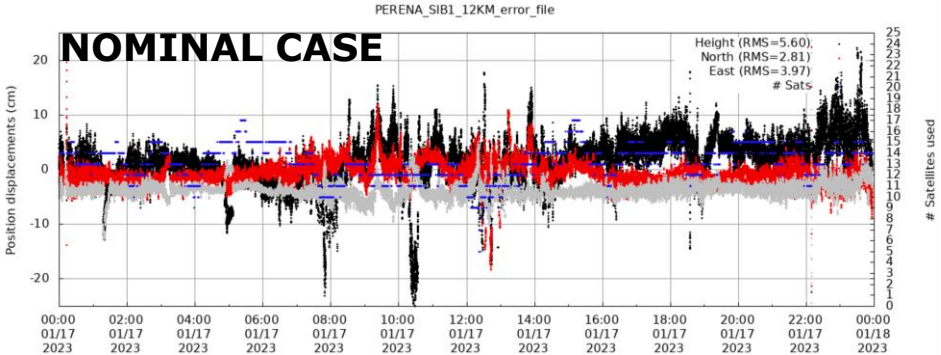
- Performance requirements:
    - Convergence time.
    - Horizontal and vertical accuracy better than 10cm and 20 cm (1-sigma) in nominal conditions, respectively.





Conclusions / Future Work

Conclusions and Future Work

CONCLUSIONS

- Virtual Reference Station Server (VRS Server) has been developed and integrated. Functionalities have been validated (results have been presented).
- Experimentation for the proposed cases have been conducted.
- Key factors in the VRS Server configuration have been identified (especially regarding distances between the different stations: regional, VRS (RTK base) and RTK rover).
- Results are valid for the proposed requirements. Last centimeter shall be achieved with pure RTK but a wide set of use cases can be covered with the proposed VRS service.
- Commercial benefits from PERENA:
  - The number of CORS stations used at the moment for covering a specific territory could be lowered, leading to efficiency in maintenance costs.
  - it also represents an optimum way to provide services in border areas
  - It also represents a key step in a possible extension / deployment of services in new regions.

FUTURE WORK

- Once the limitations are known, tests with different configurations can be done in order to a better performances profiling of the RTK using the Virtual Reference Stations generated by the VRS Server.
- Complete the integration for SSR messages with service providers which might require changes in 3rd party SW under operation.
- Experiment in other areas out of Romania to validate the suitability with other network topologies and base station receivers.

Working with ESA

- The development of PERENA was possible thanks to the support provided by ESA and the NAVISP Element 2 programme.
- ESA has provided valuable technical review and guidance at all stages of the project.
- ESA has provided support in contacting potential partners and clients.
- PERENA gains increased visibility through the ESA NAVISP mechanisms.
- ESA showed understanding with respect to delays that appeared in the project and trusted the consortium's capability to complete the technical challenges that arose in the project.

The consortium would like to thank ESA and the NAVISP team for the ongoing support of PERENA.

Q & A Session

Thank you!

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Laura Martinez Fernandez – lmartinez@gmv.com

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