Moon Testbed - MOOD

NAVISP EL2 – 081

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Teleconference

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Agenda

1. Introduction & Project Overview
2. Overview of QA707
3. Moon Testbed (QA707 v2.0)
4. Verification & Validation
5. Key Achievements
6. Conclusions and Next Steps

1. Introduction & Project Overview

Scope of the project

- The aim of the MOOD (***MOO**n testbe**D***) project is the development of a testbed for new PNT applications and technologies targeting space-scenarios, such as (but not limited to) satellites orbiting around the Moon and receivers located on the Moon surface.

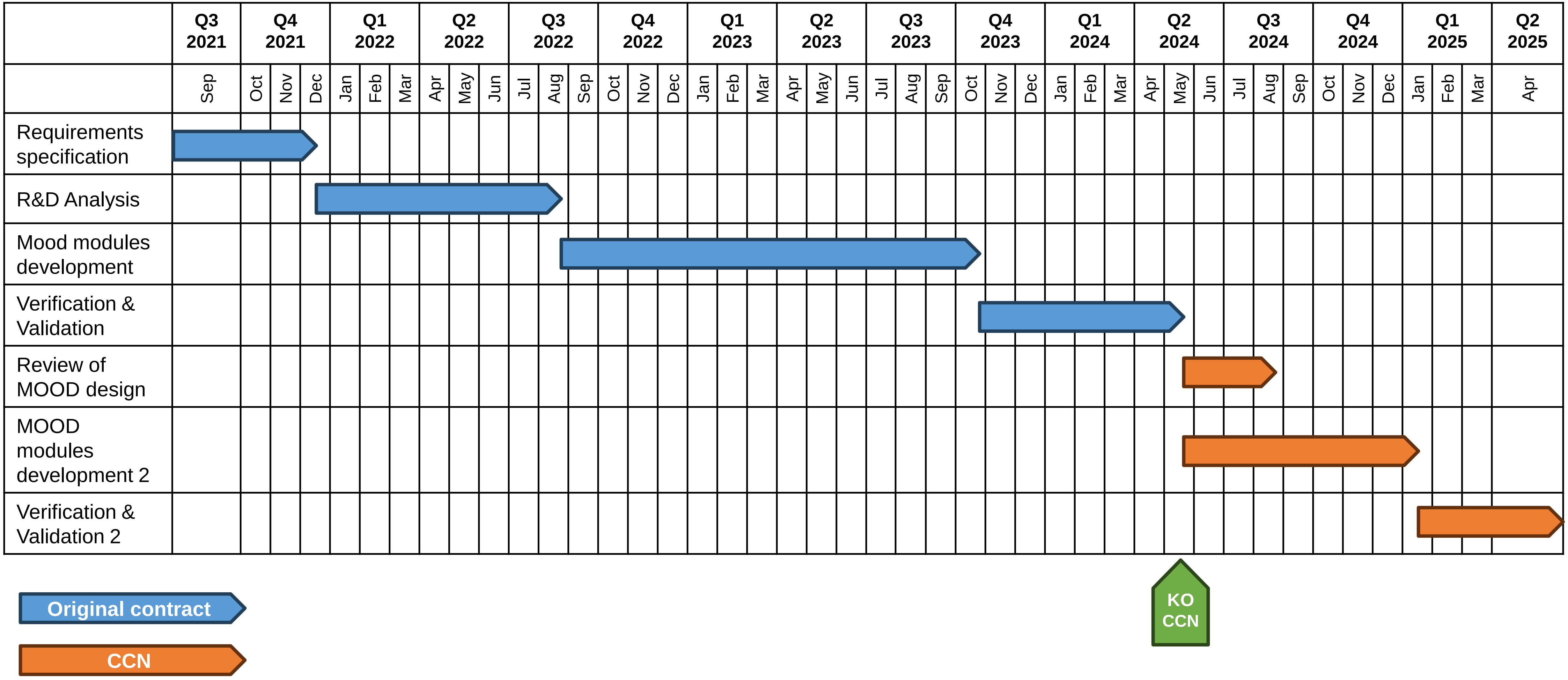
- The testbed is conceived as a fully software GNSS signals simulator, with performances like hardware-based simulators, which can be run on a laptop, enabling a fast assessment of PNT technologies either implemented as software or as HW devices.

- MOOD software has been designed as an upgrade to the former Qascom GNSS simulator named QA707.

- MOOD software is a new product that has replaced the previous version of QA707, in other words, latest release of QA707, i.e., v2.0.0, is the MOOD software which superseded v1.6.5.

- While primary focus of the latest release of QA707 (v1.6.5) is to simulate GNSS interferences, allowing the testing of GNSS authentication schemes in the receivers, with QA707 v2.0.0 the user can test all the features available with v1.6.5 and new features specifically targeting space-scenarios.

Project phases – Timeline



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Project phases – Original Contract

- The main activities carried on during the MOOD project can be divided into three categories:
  - R&D Analysis
  - Testbed development
  - Validation and Verification & test equipment development

- The R&D Analysis dealt with the investigation and engineering tasks focused on designing the features and the application contexts required by a moon/space-scenario testbed.

- In particular:
  - Design of a ranging strategy for lunar-scenarios
  - Design of the software refactoring of Qascom’s earth-bound GNSS simulator software (QA707) to integrate the new features of MOOD.
  - Investigate what Coordinate Reference Systems (CRS) are required, which conversions, and what 3rd party tool may bring these features to the testbed (i.e., NASA SPICE library)
  - Investigate what technology (i.e., GODOT engine) is the most suitable to enhance QA707 GUI with 3D animations capabilities to support the visual feedback of the simulated space-environment (3D-Viewer component).

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Project phases – CCN

- Close to the end to the original contract, the *Testbed development* and *Validation & Verification* activities have been modified introducing additional tasks not initially foreseen that have been identified during the first and second part of the project (design phase and initial implementation).

- For this reason, on May 2024 a CCN has been kicked off thus extending the duration of the activities up to April 2025.

- The main activities (now accounting for both the original contract and CCN) are the following:
  - Major refactor of QA707 software architecture to enable the integration of space-scenario features
  - Implement the BeiDou constellation and B1C signal generation
  - Implement multi-frequency simulation (limited to when signal is output to binary file)
  - Implement multi-antenna receivers (only one receiver is simulated at a time)
  - Development of a new visibility strategy based on signal Line-of-Sight occultation
  - Develop a fully customizable signal source for GNSS and non-GNSS signals (i.e., *custom transmitters* component)
  - Develop of an Inertial Measurement Unit (IMU) simulator that works for space-scenarios
  - Implement a dedicated ranging strategy for lunar-space scenarios
  - Implement the support to Digital Elevation Model (DEM) to compute signal occultation and for positioning purposes
  - Implement the first release of the LunaNet Signal-In-Space ICD
  - Implement a 3D Viewer tool providing feedback and control to the space scene during the simulation

- The activities carried on during the Validation and Verification phase (both original contract and CCN) are:
  - Investigate and then use an open-source Matlab receiver to compute PVT with BeiDou B1C signal (since no COTS receivers were available)
  - Implement a tool to parallel stream the baseband IQ signal generated by QA707 for two different frequency bands
  - Develop a patched version of GNSS-SDR to acquire, track and demodulate data on LunaNet AFS signals
  - Run the validation plan for all the new features implemented.

2. Overview of QA707

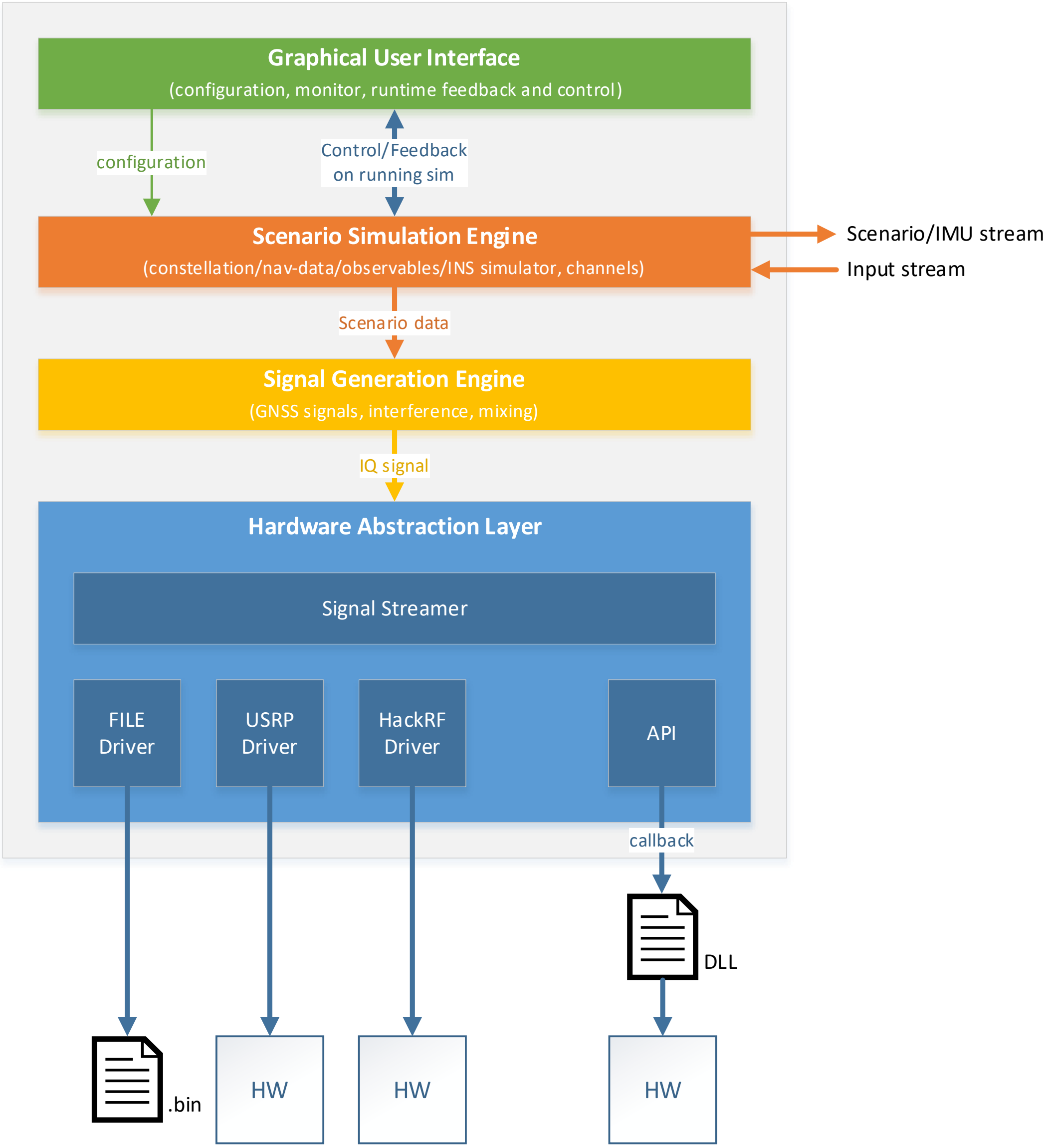
Introduction

- QA707 is a real time RF GNSS multi-constellation simulator with extended interference generation capabilities. QA707 is able to simulate a wide range of jamming and spoofing events, as well as to integrate an additional tool named QA601 to support the Galileo OS Navigation Message Authentication (OSNMA) service.

- The following is a list of the main features of the simulator:
  - GPS L1 C/A signal
  - GPS L5 OS signal
  - GALILEO E1BC signals
  - GALILEO E5a signal
  - SBAS L1 and L5
  - Configurable user trajectories.
  - Configurable channel models
  - Advanced jamming attacks
  - Advanced spoofing attacks
  - GNSS Integrity failures simulation.

- The simulator is software based, and it supports the generation at RF by means of RF upconverters and Software Defined Radio (SDR) platforms.

Components



GUI	Graphical User Interface (GUI) that eases the configuration of the signal generation engine, named QA707-Core. The signal generation logic is made of the SSE, SGE and HAL components. GUI also receives the data generated and streamed by the QA707-Core and renders it to provide feedback to the user.
Scenario Processor (SSE)	One of the main signal generation components being in charge of generating the observables data (pseudorange, doppler, and signal power) for each simulated signal. If necessary, it also generates the navigation messages of data signals.
Signal Processor (SGE)	The signal generation component in charge of converting the observables data (and data messages) in independent signal contribution aligned in time and phase and also to merge the contributions together to obtain the overall baseband signal (IQ samples) that repreresents the signal at the output of the receiver frontend.
HAL	Receives the overall baseband signal envelop from SGE and dispatch it to the correct output target: • HW platforms: USRP, HackRF, Custom HW • SW: Binary File, Custom SW

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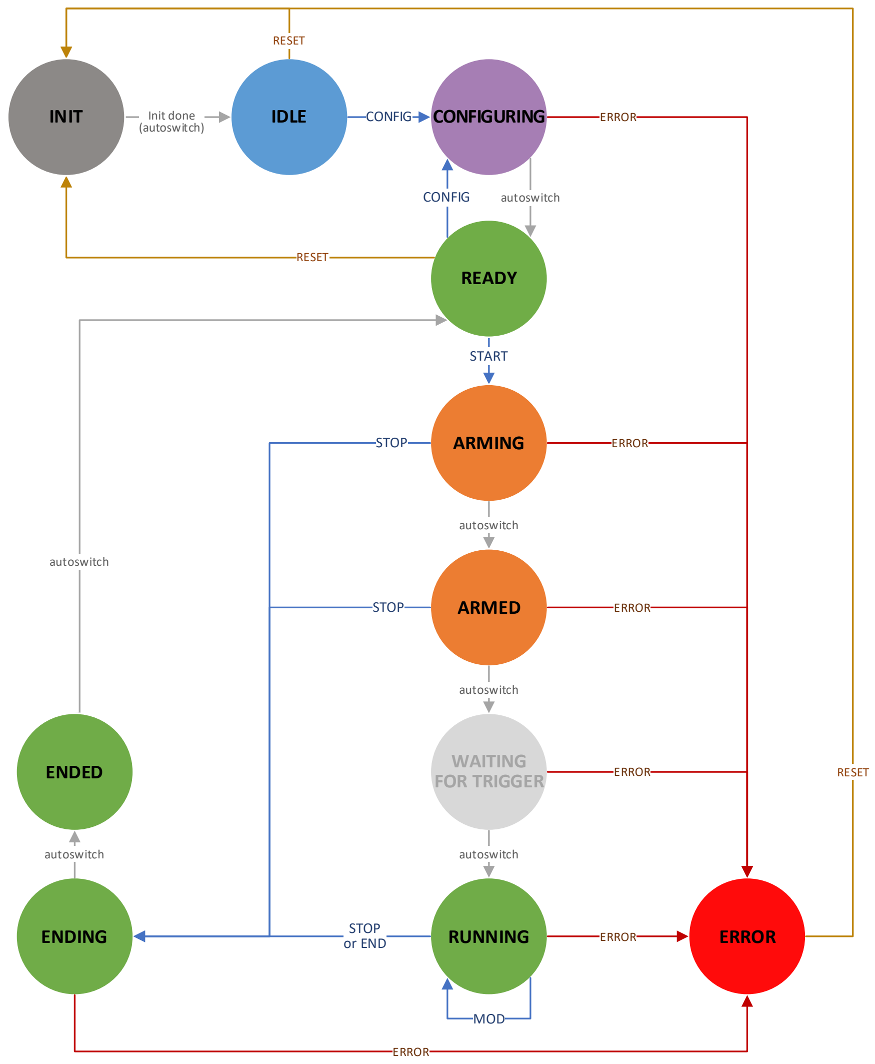
State machine



0	INIT	Entry point. Reached at start-up and after Reset.
1	IDLE	Initialized and waiting for configuration. Configuration is accepted in this state.
2	CONFIGURING	Setting or updating signal generation logic. Cannot accept any command in this state.
3	READY	Configured and ready to start the simulation. Configuration can be updated in this state. Reached also after STOP command received, or at simulation end (automatic STOP)
4	ARMING	Temporarily preparing the application for RUNNING. Transition state automatically left once completed the initialization of the simulation.
5	ARMED	All the structures have been instantiated, the simulation initialized and the buffers have been filled with the data that corresponds to the initial instants of simulation. The software is idle and ready to stream. No data has been pushed to the target platform yet (upconverter or file).
6	WAITING FOR TRIGGER	In this state, the system (software and hardware) is waiting for an external trigger to start the generation. It is allowed only if an RF device is used. Automatically skipped if streaming to file. IQ samples have been pushed to the RF device, but the RF generation is still not active: the hardware is waiting for the hardware trigger to start. Not accessible in the current version of the product.
7	RUNNING	Simulation is ongoing and the output is generated either at RF level or dumped to file. A set of MOD commands are accepted, for runtime updates.
8	ENDING	Clearing all the simulation data to close the simulation in a clean and safe way. Cannot accept any command in this state.
9	ENDED	The simulation is ended, and the supporting structures have been cleared successfully (i.e., restored to their initial READY state). Cannot accept any command in this state.
10	ERROR	Blocking status reached after an unexpected error. RESET is the only command accepted in this state.

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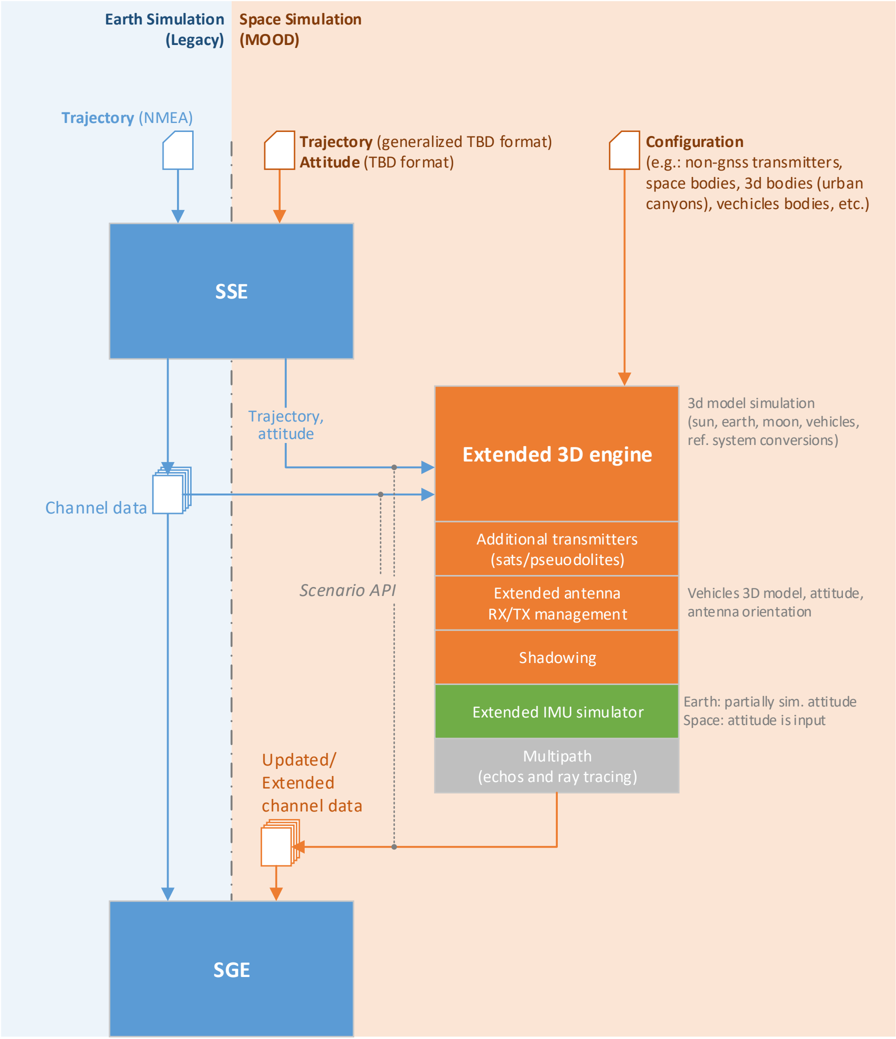
3. Moon Testbed

Overview of new features

- The new features planned from both the original contract and CCN of the MOOD project are designed as extensions to the latest version of QA707 software:
  - Ranging strategy specific for Moon scenarios
  - Support all relevant coordinate reference systems (CRS) (e.g., Geodetic LLA, ECEF, ECI, Moon-PA, LCI, etc.) necessary for space-applications
    - and related conversions
  - Fully user-defined *custom transmitters*
    - additional signal sources (transmitters) such as new satellites orbiting around the Moon or pseudolites on the Moon surface
    - additional user-defined GNSS-like signals
  - LunaNet AFS signals (from first release of the LunaNet SIS-ICD)
  - BeiDou constellation and B1C signals
  - Extended Inertial Measurement Unit (IMU) for space-scenarios (developed by POLIMI)
    - i.e., IMU that considers the gravity interactions of the space bodies (e.g., Earth and Moon)
  - Simulation of the attitude of either vehicle/receiver and any transmitting or receiving antennas
  - Arbitrary vehicle trajectories and attitudes from several different inputs:
    - 3rd-party Navigation Scenarios for Earth and space applications, e.g., NASA GMAT
    - Comma Separated Values (CSV) files
    - CCSDS Orbit Ephemeris Message (OEM)
    - Keplerian Parameters (also selecting around which celestial body the transmitter orbits around)
  - Support obscuration of the signal line-of-sight (LoS)
    - as an alternative visibility strategy compared to the more common “Elevation Mask” visibility strategy which is not available for space-scenarios
  - Import and manage a Digital Elevation Model (DEM) for the Moon
    - Simulate LoS occulation due to the local DEM
    - Define vehicle/receiver altitude (i.e., position/trajectory) with data from the local DEM
  - Graphical tool to visualize trajectory, attitude and all the relevant 3D elements of the simulated space environment (***3D Viewer***)
  - Implement multi-frequency simulation (when signal is output to binary file)
    - Generate an independent IQ samples file for each simulated signal bandwidth
  - Implement multi-antenna receivers
    - Only one receiver
    - Only one antenna is enabled at a time

Original contract design

- The state machine and the baseline layered structure of QA707-Core (i.e., SSE+SGE+HAL) is left untouched.
- The original design proposal, and in particular the initial development phase, plan to place the logic of all the new features within a single tool named ***Extended 3D Engine*** (E3E) expected to talk with the legacy QA707-Core through a new dedicated interface (*Scenario API*).
- E3E is designed as a Dynamic Link Library (DLL) such that the only planned modification to the previous version of QA707-Core is the implementation of the new interface, *Scenario API*.
- In practice all the efforts are focused on the development of E3E tool which is expected to spill the observables data from SSE, make modifications to it, and provide it back to the SGE.
- In this way, for SSE and SGE the modification would be transparent.
- The first version of MOOD which implements this concept has been released at the end of the original contract (May 2024).



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CCN contract design

- With CCN we reworked the design to allow a smooth integration of the C*ustom Transmitters* feature as well as the LunaNet constellation within the QA707-Core.

- All the features being part of E3E have been integrated to SSE. For this reason the concept of a *Scenario Api* has been dropped.

- QA707 maintan a backward compatibility of all its features for Earth-bound scenarios, since Space-scenario support is enabled just at license level. In other words, a specific license module may enable/disable specific sections of QA707, e.g., Custom-transmitters, DEM, LunaNet, etc.

- That is why at the end of CCN activities the new MOOD software has definitively replaced the previous version of QA707.

- The latest version of MOOD (QA707 v2.0) has been released at the FR milestone planned for the CCN (Apr-May 2025).

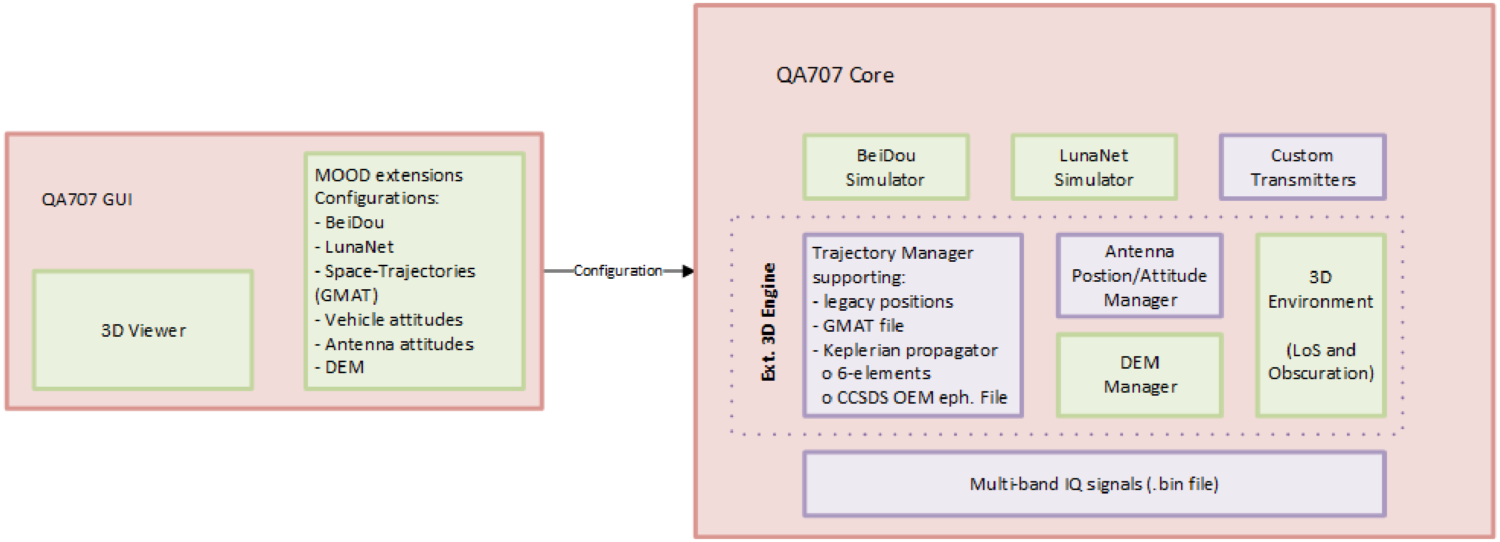
QA707 v2.0

- All the features have been categorized in:
  - New Components
  - New feature for an existing component

- New features of the QA707-Core required the implementation of new configuration forms at the GUI.

- The main existing components that have been enhaced with new features are:
  - **Trajectory Manager**: adding new trajecoty/attitude provisioning types
  - **Antenna Manager**: improved the management of attitude, and the description of its position w.r.t. the body axis of receiver/transmitter
  - **HAL**: support write to multiple files at the same time
  - And of course the ***QA707-Core scenario parser*** which has been enhanced to support the new configurations.

- Brand new components are:
  - BeiDou constellation and signal generation
  - LunaNet Simulator
  - Custom Transmitters
  - Digital Elevation Model (DEM) Manager
  - 3D Environment Manager
  - 3D Viewer (impacting in particular the GUI)



- 3D Viewer characteristics:
  - Independent tool
  - Integrated within the QA707-GUI window
  - Interfaced via log-files and UDP packets with QA707-Core

Focus on space-scenarios – Moon-PA ranging strategy (1/2)

- With range strategy we define the approach used to emulate the pseudorange measures as they were measured from the point of view of the receiver.

- The common approach to pseudorange computation follows by this definitions:

1. ***Pseudorange is a measure of time*** represented as a distance. In particular, the pseudorange is the distance traveled by the signal transmitted from the signal source (e.g., the GNSS satellite) to the receiver.

2. Pseudorange is expressed as the distance between the position of the phase center of the transmitter antenna ***at the time of signal emission*** and the phase center of the receiving antenna ***at the time of signal reception***.

- In other words, let adopt the following notation:
  - *tx*: time of signal emission
  - *rx*: time of signal reception
  - T_t: the position of the transmitter in WGS84 (ECEF) at time *t*
  - R_t: the position of the receiver in WGS84 (ECEF) at time *t*

- The pseudorange is given by:

$$\rho = \|T_{tx} - R_{rx}\|$$

- Since ECEF is a non-inertial CRS, the computation of ρ has to deal with the «Sagnac Effect» that accounts for the Earth rotation during the signal travel

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Focus on space-scenarios – Moon-PA ranging strategy (2/2)

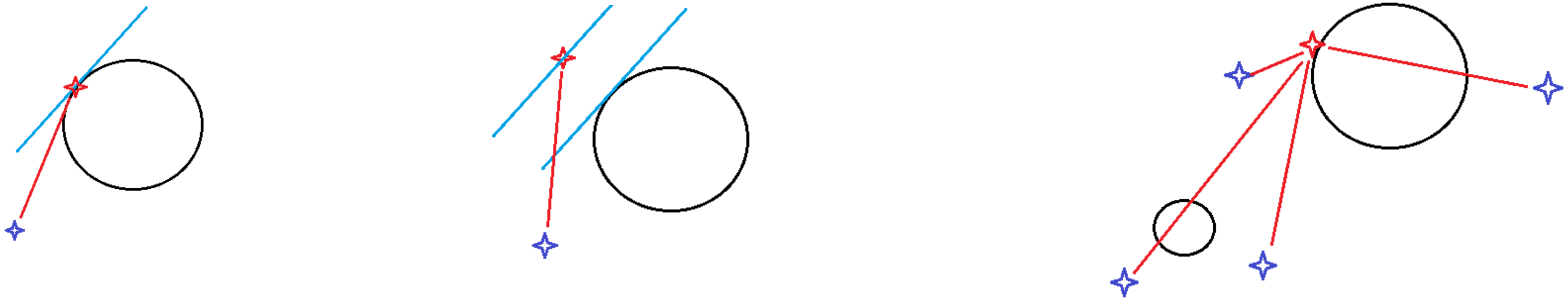
- On the Moon surface, where the position of either the transmitter, or the receiver, or both, are expressed in Moon-PA (Moon Principal Axis), the problem to emulate the «Sagnac Effect» is similar to an Earth-bound scenario, but in this case the rotation that must be compensated is the ***Moon rotation around its axis*** (slower w.r.t. the Earth).

- The approach to pseudorange computation remains the same once the Earth rotation rate is replaced with the Moon rotation rate, and the ECEF positions of transmitter and receiver are replaced with Moon-PA positions.

- Hence, depending on the scenario, QA707-Core shall select the proper ranging strategy based on which CRS has been used to feed the trajectories of the receiver and the ranging signals transmitters.

Focus on space-scenarios – LoS visibility strategy

- When a transmitter is far from the Earth/Moon surface, the commonly used "Elevation Mask" visibility strategy is not the proper way to compute the occultation effects.



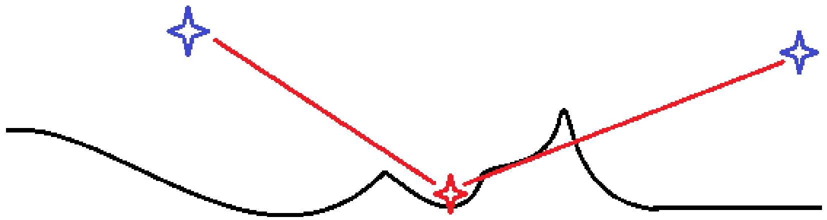
- With "elevation mask" strategy the approach is to compute the angle of LoS (between transmitter and receiver) with respect to the horizon line. The transmitter is considered not-in-view if the angle is below a given threshold.

- However, in Lunar-space scenarios, a visibility strategy based only on **elevation** fails for two reasons:
  1. Negative elevations may prevent the visibility of channels that are in view (not really obscured by the physical horizon)
  2. Positive elevations put in visibility transmitters that actually are obscured by the 3D environment (Earth and Moon bodies).

- In this context the physical transmitter obscuration is better to consider the ***intersection of the LoS with the sphere/geoid*** that represents a specific celestial object (i.e., Earth and Moon).

Focus on space-scenarios – Digital Elevation Model (DEM)

- Signal occultation may account also for the terrain data provided by Digital Elevation Model (DEM) files.



- This effect adds to the LoS obscuration effect.

- It is worth to note that the visibility changes due to the DEM are much faster than what happen considering just the geometric occulation of the LoS by the celestial bodies.

Focus on space-scenarios – Custom-Tx and LunaNet

- *Custom transmitters* is a new features not actually targeting space-scenarios but very useful to start developing new GNSS-like signals like LunaNet.

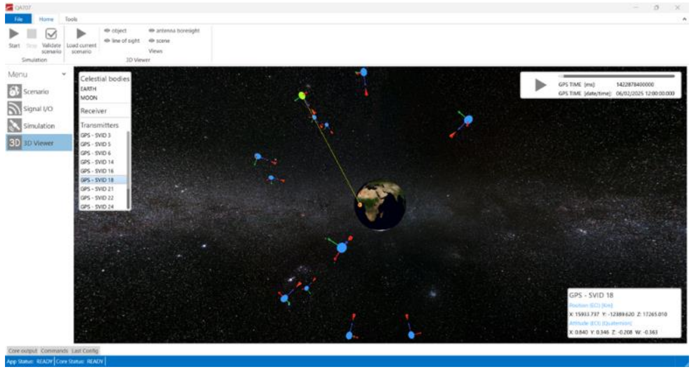
- *Custom transmitters* component provides an interface to the user to define a fully-customized signal source in terms of:
  - Trajectory and attitude (with all variants foreseen for the vehicle carrying the receiver)
  - Carrier frequency (could be either any of the GNSS or a fully custom frequency band)
  - Antenna pattern
  - Signal components (pilot and/or data)
  - Spreading codes
  - Data messages
  - Coding rate
  - Symbol rate
  - Modulation (BPSK / BOC)

- In the context of MOOD, LunaNet is seen as a constellation made of custom transmitters (i.e., individual user-configurable signal sources).

- Each LunaNet signal source defines a specific satellite following an ELFO orbit and broadcasting both components of the Augmented Forward Signal (AFS), Pilot and Data.

Focus on space-scenarios – 3D Viewer

- *3D Viewer* is a graphical component that interact with QA707 to show the position, trajectory, attitude and relative movements of all the objects that build the space scenario, i.e.:
  - ☐ Celestial objects: Earth, Moon, and Sun
  - ☐ GNSS satellites: GPS, Galileo, BeiDou, etc.
  - ☐ Custom transmitters:
    - LunaNet Satellites
    - Beacon/Pseudolite signals
    - Any other exploiting the *Custom-Tx* interface



- *3D Viewer* is in charge to provide feeback to the user but also some degree of control on what is shown.

- The user can move the scene forward or backward in time, freeze the scene while the simulation is running, load a previous scenario to replay the space scene.

4. Verification & Validation

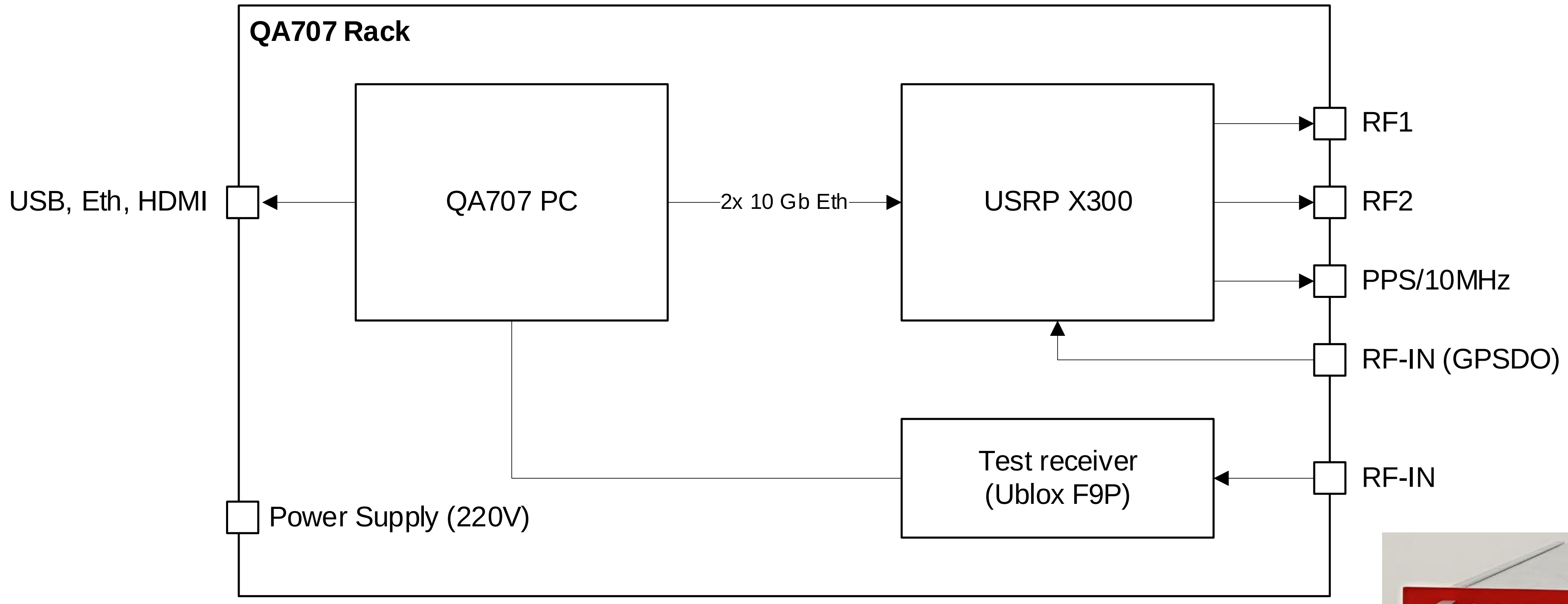
Verification & Validation Approach – QA707 v1.X (pre-MOOD)

- Before the start of MOOD project the QA707 software has already a dedicated suite of verification & validation tests.
- In particular, individual features that are part of QA707 are verified through unit-testing
- Unit tests are small tests involving single components or even single functions of a component that are stimulated with different configurations and whose outputs are compared against reference results.
- Validation of the software, on the other hand, involves the execution of integration tests between the components.
- For this purpose, the release candidates were manually configured by the tester from a set of pre-defined configurations, and checking the behaviour of a receiver (either HW or SW) that process the signal generated by the QA707 SW.

Verification & Validation Approach – QA707 v2.0 (MOOD)

- Created a suite to automate the unit-tests and also the validation tests
- Based on the Continuous-Integration (CI) feature of Gitlab.
- Unit-tests have been ported to Gtest (Google Test framework)
  - Automatically run every new commit in the QA707-Core repository
- Validation tests involve a predefined set of QA707-Core configurations prepared using the latest version of the GUI
  - The configurations are an enhanced set of integration test
  - Every new feature/component is added a new configuration is added to the suite
  - When the GUI is updated the configurations are updated as well
- Validation tests have been divided in two categories:
  - ***Without hardware***: automated by Python scripting
    - Automatically run every new commit in the QA707-Core repository (if all Unit-tests succeded)
  - ***With hardware***: automated by Python scripting,
    - Manually launched by the tester once the release candidate (RC) has been built
    - Build of RC is done automatically by the CI every new Merge Request (MR) is approved and feature is merged to the master branch
- Several different HW setup have been configured to cover all validation tests with hardware
  - SW based: Matlab SW receiver, GNSS-SDR
  - HW based: GNSS-SDR + USRP x300, Ublox-F9P receiver, Septentio PolaRx5

Simulator - QA707 Rack version Scheme



- Test signal is generated by a rack-mount device composed of:
  - Host PC (Intel i7 – quad-core) where QA707 v2.0 run,
  - USRP x300 with double daugtherboard (UBX-160) to test also dual-band configurations (not natively supported by QA707-Core)
  - Internal receiver (Ublox-F9P) used for configurations not involving either GNSS-SDR or PolaRx5 receivers.

5. Key Achievements

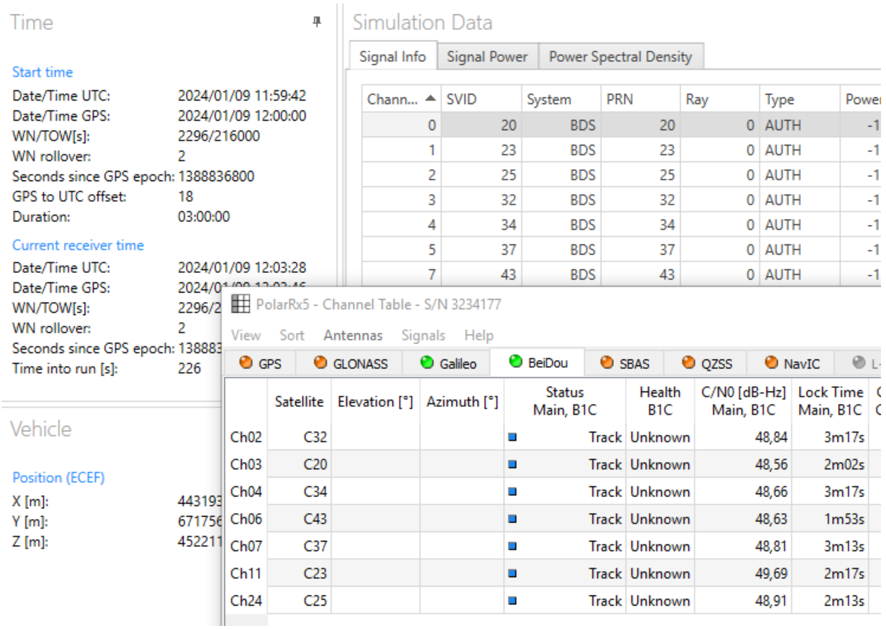
BeiDou B1C Signal Validation

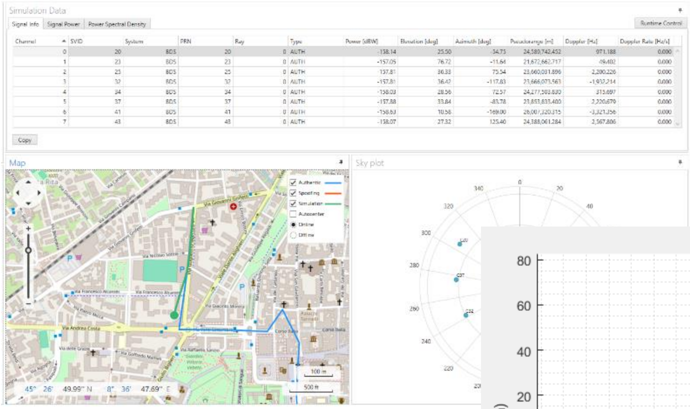
- In the context of the MOOD project a dedicated testbed validates the correct implementation of the BeiDou B1C signal.

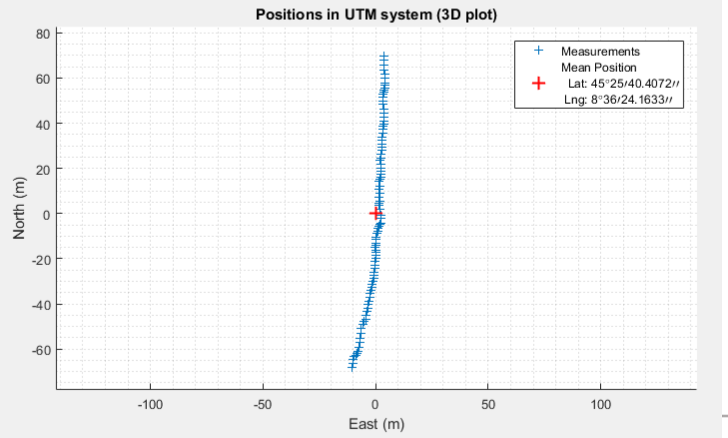
- This testbed includes a PC running QA707 v2.0, an USRP x300 connected to the PC with 1Gb ethernet connection, and a COTS receiver supporting BeiDou B1C signal.

- Regarding the receiver, the best choice among the ones available at Qascom has been the Septentrio PolaRx5.
  - Though it supports B1C signal only for acquisition and tracking since it does not decode the ephemeris data and thus it is not able to compute the PVT.

- Since Septentrio PolaRx5 does not support decoding of BeiDou BCNAV1 navigation data, the PVT solution is tested using a Matlab open-source B1C SDR receiver presented in “*Li, Y., Shivaramaiah, N.C. & Akos, D.M. Design and implementation of an open-source BDS-3 B1C/B2a SDR receiver. GPS Solut 23, 60 (2019)*”







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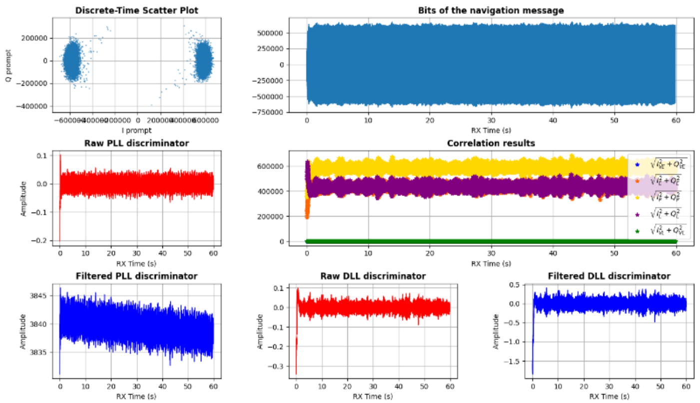
LunaNet AFS Signal reception and validation

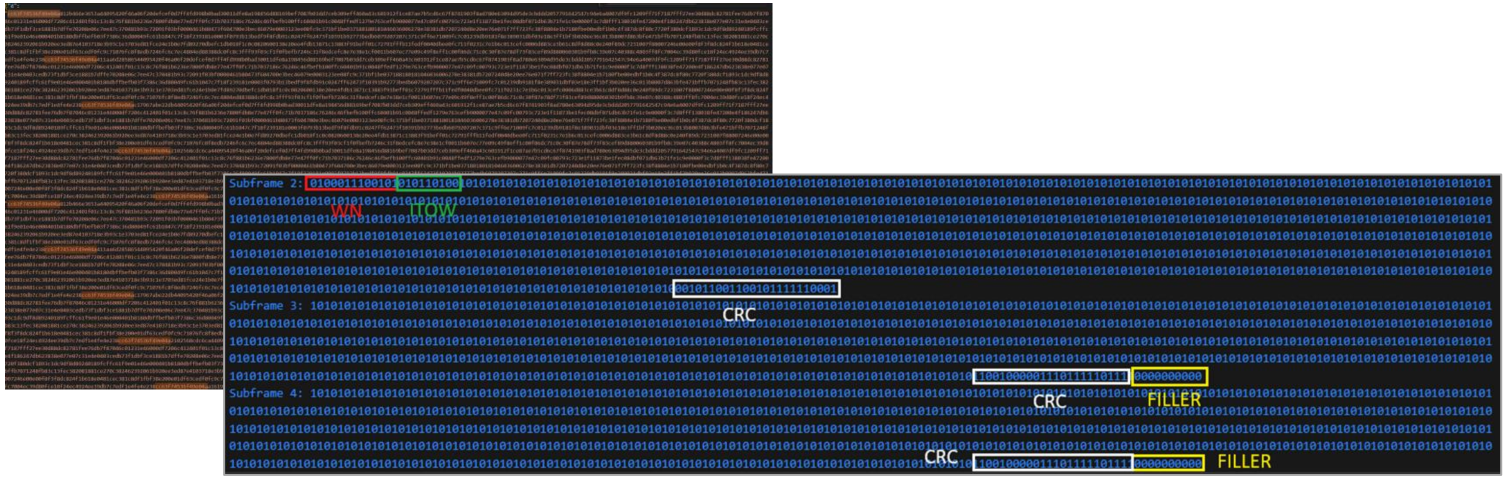
- In the context of the MOOD project a dedicated testbed validates the correct implementation of the LunaNet AFS signal.

- This testbed includes one PC running QA707 v2.0, one PC running a patched version of GNSS-SDR software that enables acquisition and tracking of the AFS signal, and two USRP x300 connected to both PCs with 10Gb ethernet connection (one for streaming and one for receiving).

- The processing results obtained from GNSS-SDR analyzing each of the simulated signals show that the in-phase component is correctly retrieved and the PLL is locked, and tracking is performed consistently with the estimated doppler coherent with values generated by QA707 (dumped to log files).

- Moreover, the navigation message bits have been correctly retrieved and post-processed to detect all fields that build the navigation message.
  - Analysis of the navigation message symbols is performed via Python script.





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PVT with LunaNet signals and Moon-PA ranging validation

- In the context of ESA DEMOS-1 project (***NAVISP-EL1-062***) the Moon-PA range strategy and LunaNet signal generation have been cross-validated since QA707 has been used to perform validation tests for the Qascom QN400 receiver (modified to support tracking of the LunaNet AFS signal)
- The Navigation engine developed in the scope of DEMOS-1 project has been used also to compute the PVT result from a LunaNet constalltion of 4 satellites. The results validate the correct implementation of the Moon-PA range strategy and make possible to evaluate the accuracy of PVT results obtained from signals generated by QA707
- Results are coherent with the scenario configurations (having just 4 signals/satellites available)

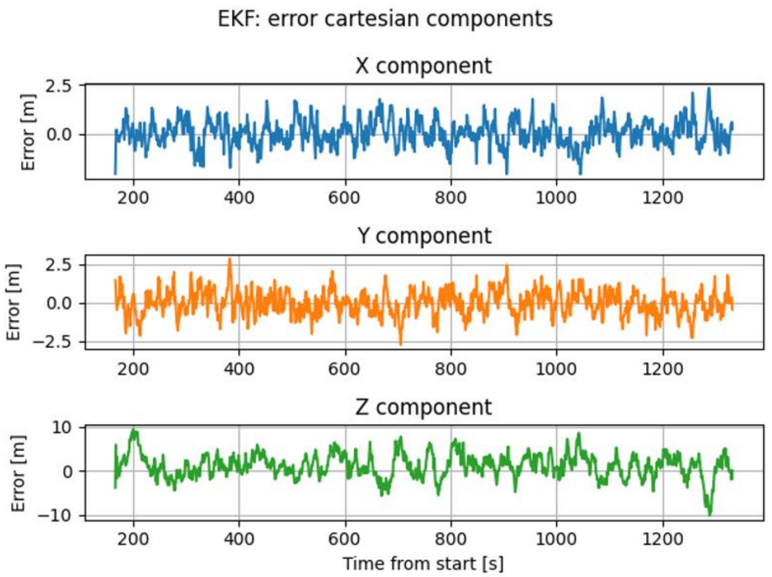


Figure 4-48: XYZ position error

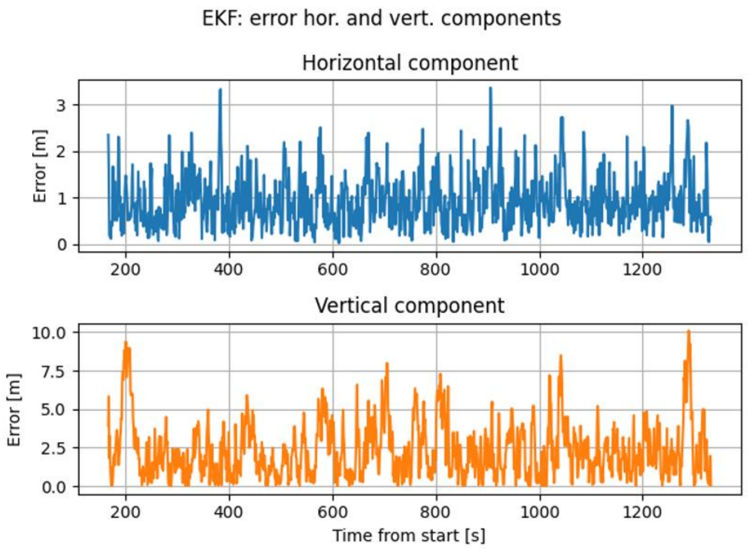


Figure 4-49: Positioning error on the horizontal and vertical components.

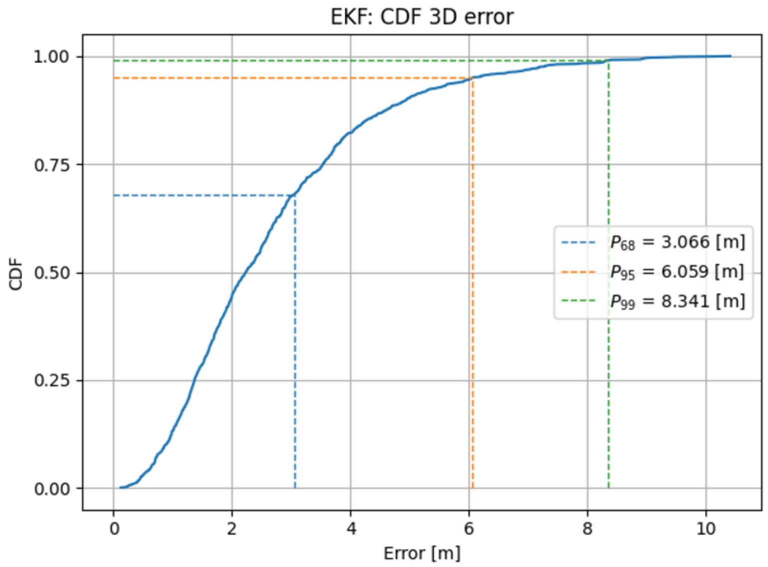
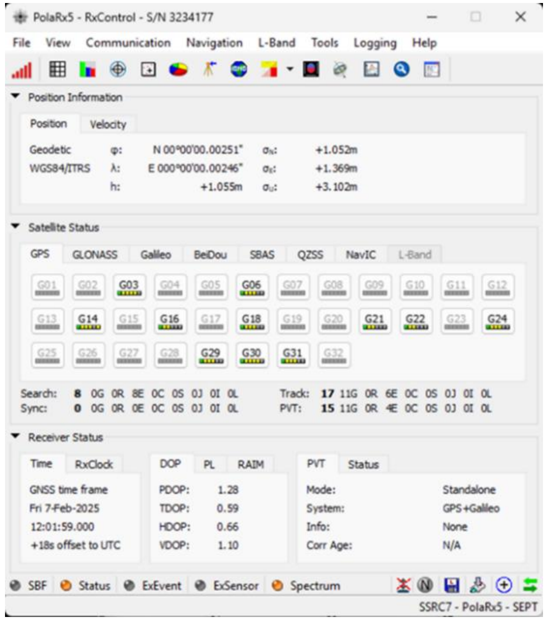


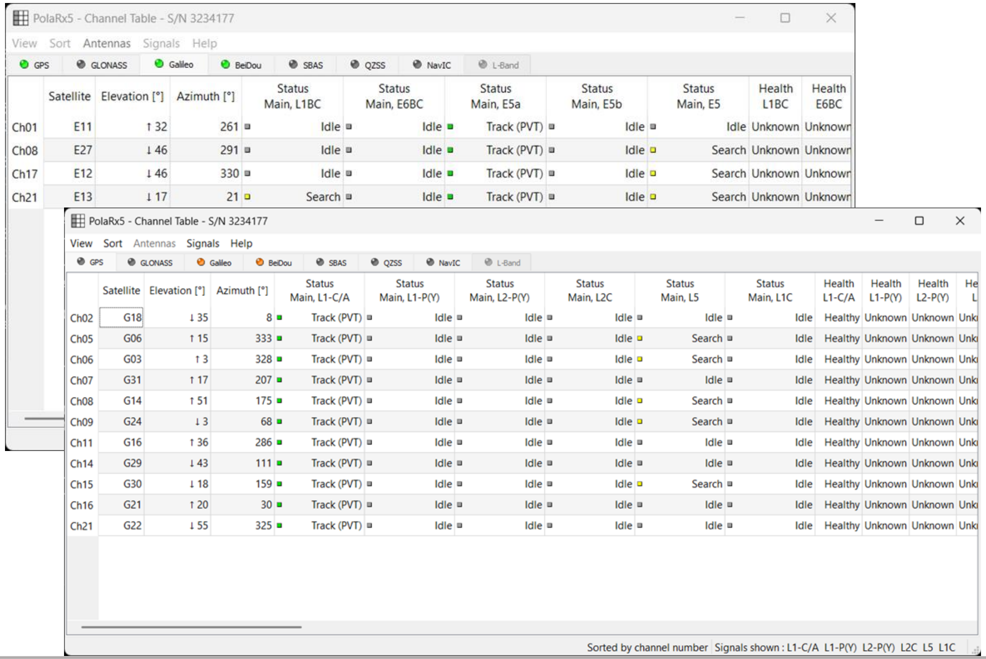
Figure 4-50: Cumulative Distribution Function of the 3D positioning error.

KEY ACHIEVEMENTS

Dual-Frequency RF Stream

- The original version of QA707 is single-band, whereas during the MOOD project QA707 has been enhanced to generate multiple IQ Baseband signals (one per frequency band) at the same time.
- QA707 was not expected to directly output the RF signal from multi-frequency bands generated in parallel, hence the parallel RF streaming has been implemented with a dedicated tool that supports an SDR with two RF channels.
- Dual-frequency RF signal generation has been verified through a dedicated testbed.
- The testbed included a dual-frontend USRP x300, a PC running both QA707 v2.0 and the tool for parallel streaming, and a COTS multi-frequency receiver (Septentrio PolaRx5).
- Each stream of IQ samples generated by QA707 is dumped to an independent, though time and phase aligned, binary file. In other words, a binary file is generated per each carrier frequency, one for L1 (1.57542 GHz), and one for L5 (1.17645 GHz).
- PVT accuracy is comparable to the one obtained in single frequency mode, where the pseudorange residuals are below 0.5m.





PolaRx5 - Channel Table - S/N 3234177

	Satellite	Elevation [°]	Azimuth [°]	Status Main, L1BC	Status Main, E6BC	Status Main, E5a	Status Main, E5b	Status Main, E5	Health L1BC	Health E6BC
Ch01	E11	↑32	261	Idle	Idle	Track (PVT)	Idle	Idle	Unknown	Unknowr
Ch08	E27	↓46	291	Idle	Idle	Track (PVT)	Idle	Search	Unknown	Unknowr
Ch17	E12	↓46	330	Idle	Idle	Track (PVT)	Idle	Search	Unknown	Unknowr
Ch21	E13	↓17	21	Search	Idle	Track (PVT)	Idle	Search	Unknown	Unknowr

PolaRx5 - Channel Table - S/N 3234177

	Satellite	Elevation [°]	Azimuth [°]	Status Main, L1-C/A	Status Main, L1-P(Y)	Status Main, L2-P(Y)	Status Main, L2C	Status Main, L5	Status Main, L1C	Health L1-C/A	Health L1-P(Y)	Health L2-P(Y)	He
Ch02	G18	↓35	8	Track (PVT)	Idle	Idle	Idle	Idle	Idle	Healthy	Unknown	Unknown	Unk
Ch05	G06	↑15	333	Track (PVT)	Idle	Idle	Idle	Search	Idle	Healthy	Unknown	Unknown	Unk
Ch06	G03	↑3	328	Track (PVT)	Idle	Idle	Idle	Search	Idle	Healthy	Unknown	Unknown	Unk
Ch07	G31	↑17	207	Track (PVT)	Idle	Idle	Idle	Idle	Idle	Healthy	Unknown	Unknown	Unk
Ch08	G14	↑51	175	Track (PVT)	Idle	Idle	Idle	Search	Idle	Healthy	Unknown	Unknown	Unk
Ch09	G24	↓3	68	Track (PVT)	Idle	Idle	Idle	Search	Idle	Healthy	Unknown	Unknown	Unk
Ch11	G16	↑36	286	Track (PVT)	Idle	Idle	Idle	Idle	Idle	Healthy	Unknown	Unknown	Unk
Ch14	G29	↓43	111	Track (PVT)	Idle	Idle	Idle	Idle	Idle	Healthy	Unknown	Unknown	Unk
Ch15	G30	↓18	159	Track (PVT)	Idle	Idle	Idle	Search	Idle	Healthy	Unknown	Unknown	Unk
Ch16	G21	↑20	30	Track (PVT)	Idle	Idle	Idle	Idle	Idle	Healthy	Unknown	Unknown	Unk
Ch21	G22	↑55	325	Track (PVT)	Idle	Idle	Idle	Idle	Idle	Healthy	Unknown	Unknown	Unk

Sorted by channel number Signals shown : L1-C/A L1-P(Y) L2-P(Y) L2C L5 L1C

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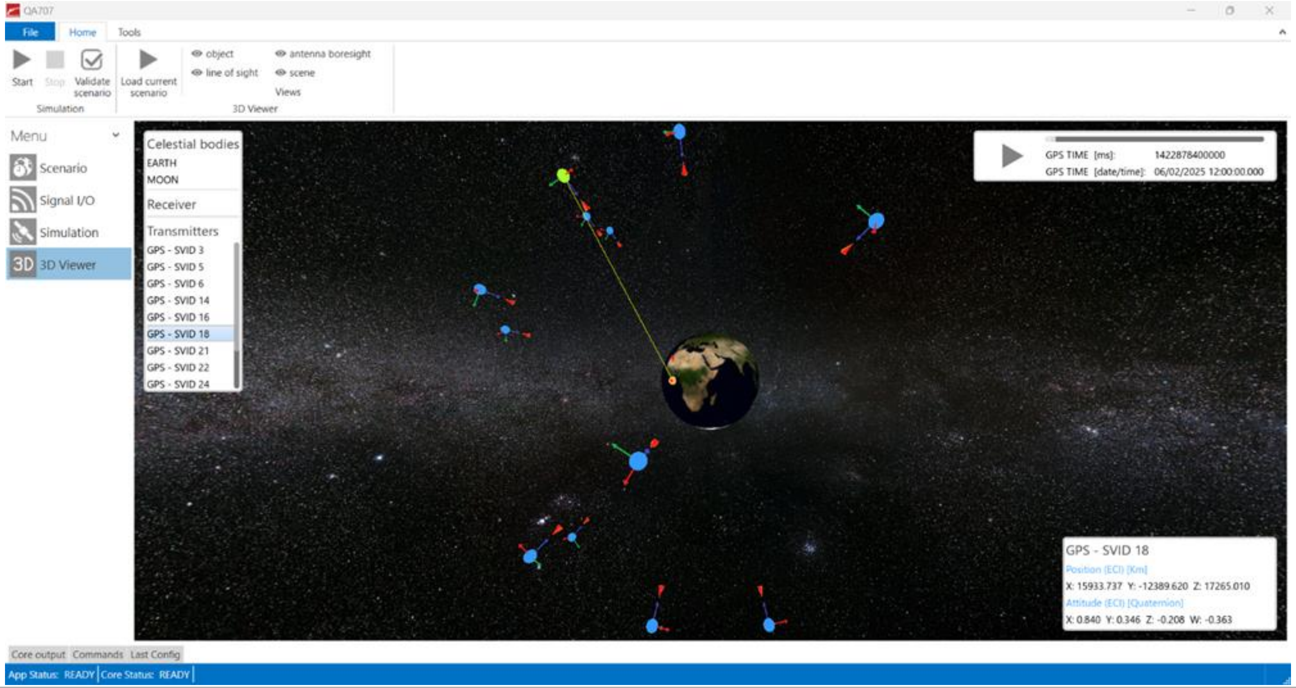
3D Viewer

- 3D Viewer is a visualization tool that provides feedback about the 3D space scenario simulated by QA707.
- This tool is designed to read the 3D information about the scenario both receiving an UDP stream directly from QA707 or reading the log which is generated by a previous simulation run.
- This tool includes a GUI that is embedded with the QA707 GUI.
  - The GUI is developed around the Godot framework, being an open-source 3D game engine.
- The viewer main characteristics are:
  - visualization of the trajectory and attitude of target vehicle/receiver and transmitters
  - Visualization of antenna attitude, boresight, and radiation cone
  - Visualization of LoS for all (Tx-Rx) pairs
  - Store the history of the simulation and makes possible through dedicated controls to move forward/backward the simulation time
  - Control the point of view of the user



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6. Conclusion & Next Steps

Conclusions and wrap-up

- The activities concluded in time with the project schedule.
- The SW has already been used to support the test campaign of the DEMOS-1 project (*NAVISP-EL1-062*), and other internal projects in QASCOM.
- The MOOD testbed has definitively replaced the previous version of QA707, and now it is the only GNSS simulator product on the market from QASCOM.

- Next Steps:
  - Onging development activities focus on:
    - Supporting dual-frequency RF signal generation directly from QA707
    - Support integration with dedicated SDR hardware (e.g., JNRS project *NAVISP-EL2-090*)

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Qascom thanks NAVISP for the opportunity to work on MOOD!

SEE YOU @ ION 2025, Baltimore MD, USA