INSPIRe

D6.1 – RAIM Prototype Report

Prepared for:

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TABLE OF CONTENTS

List of Tables and Figures

1 INTRODUCTION

1.1 Purpose

This document is deliverable D6.1 of the INSPIRe project, titled ‘RAIM Prototype Report’. This deliverable document is one of the main outputs of WP6 and the purpose is to report on the activities that have been completed within WP6, including:

- Requirements for the tool, including an indication of which are applicable for the prototype development in this activity
- Functional design and functional test specification for the prototype tool
- Software design and test specification for the prototype tool
- Verification and validation plan for the prototype tool
- Validation results
- User manual for the tool
- Identification of steps and timescales for development and implementation of an operational tool
- High level estimated cost report (development, implementation and operations), highlighting assumptions and data sources.

1.2 Scope

Following the introduction to the document presented in Section 1, the layout of the remainder of the document is as follows:

- **Section 2** contains a list of applicable and reference documents.
- **Section 3** provides a review and consolidation of the current RAIM Prototype performance prediction tool being developed.
- **Section 4** provides a high-level design for M(G)RAIM Performance Prediction Prototype Tool including an overview of the M(G)RAIM Performance Prediction prototype software design and its test specification.
- **Section 5** presents the validation results from the verification and validation plan.
- **Section 6** contains a brief description of the main prototype features and detailed information about how to use the tool.
- **Section 7** details the roadmap and for the development of an operational M(G)RAIM Performance Prediction tool
- **Section 8** details the estimated operational M(G)RAIM Performance Prediction tool including the development, implementation, and operations, highlighting assumptions and data sources.

1.3 Definitions and Acronyms

1.3.1 Definitions

Concepts and terms used in this document and need defining are included in the following table:

Table 1-1 Definitions

Concept / Term	Definition
MG-RAIM	Maritime General-RAIM: is a chi-squared fault-detection process with simple geometric screening rules to ensure safety
MRAIM	Maritime RAIM: is a maritime-specific implementation of the aviation ARAIM concept and performs a multiple-hypothesis solution-separation process, then computes a protection level and iteratively optimises this PL through re-allocation of integrity risk

1.3.2 Acronyms

Acronyms used in this document and need defining are included in the following table:

Table 1-2 Acronyms

Acronym	Definition
AL	Alert Limits
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
CDF	Cumulative distribution function
DFMC	Dual Frequency Multiconstellation
DGNSS	Differential GNSS
DGPS	Differential GPS
DOP	Dilution of Precision
ECAC	European Civil Aviation Conference
EGNOS	European Geostationary Navigation Overlay Service
ESA	European Space Agency
FD	Fault Detection
FDE	Fault Detection and Exclusion
GBAS	Ground-Based Augmentation System
GEAS	GNSS Evolutionary Architecture Study
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRAD	GLA Research and Development
GSA	European GNSS Agency
HAL	Horizontal alarm Limit
HDOP	Horizontal Dilution of Precision
HMI	Hazardous Misleading Information
HPE	Horizontal Position Error
HPL	Horizontal Protection Level
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICAO	International Civil Aviation Organisation
IEC	International Electrotechnical Commission
INSPIRe	Integrated Navigation System-of-Systems PNT Integrity for Resilience
IMO	International Maritime Organisation
IR	Integrity Risk
ISM	Integrity Support Message
LPV	Localizer Performance with Vertical guidance
MHSS	Multiple Hypothesis Solution Separation
MOPS	Minimum Operational Performance Standards
MGRAIM	Maritime General RAIM
MRAIM	Maritime RAIM
MSC	Maritime Safety Committee
MSI	Maritime Safety Information
MSR	Multi-system shipborne receiver
N/A	Not Applicable
NLOS	Non-Line of sight
NPA	Non-Precision Approach
PFA	Probability of False Alarm
PL	Protection Level

PHMI	Probability of Hazardously Misleading Information
PMD	Probability of Miss detection
PNT	Positioning Navigation and Timing
PVT	Position, Velocity and Time
RAIM	Receiver Autonomous Integrity Monitoring
RTCA	Radio Technical Commission for Aeronautics
RTK	Real-time kinematic positioning
SARPS	Standards and Recommended Practices
SBAS	Satellite Based Augmentation System
SIS	Signal in Space
SOLAS	Safety at Life at Sea
TBC	To Be Confirmed
TTA	Time to Arrival
VAL	Vertical alarm Limit
VHF	Very High Frequency

2 REFERENCES

2.1 Applicable Documents

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.x]:

Table 2-1 Applicable Documents

Ref.	Title	Code	Version	Date
[AD.1]	INSPIRe Technical Proposal, Taylor Airey	T-062-001-02 Part 1	-	June 2022
[AD.2]	INSPIRe Management Proposal, Taylor Airey	T-062-001-02 Part 2	-	June 2022
[AD.3]	INSPIRe Proposal GMV	GMV 10842/21	V2/21	

2.2 Reference Documents

Although not part of this document, the following documents amplify or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.x]:

Table 2-2 Reference Documents

Ref.	Title	Code	Version	Date
[RD.1]	INSPIRe Algorithm documentation (GPS M(G)RAIM)	INSPIRe-GMVNSL-Alg2.1	1.1	02/2023
[RD.2]	INSPIRe Algorithm documentation (DFMC M(G)RAIM)	INSPIRe-GMVNSL-Alg3.1	1.0	03/2023
[RD.3]	AUGUR Web Page Link: https://augur.eurocontrol.int	-	V2.11	02/2023
[RD.4]	EGNOS forecast availability tool Link: https://egnos-user-support.essp-sas.eu/services/safety-of-life-service/forecast-performance/apv1-availability-performance	-	-	02/2023
[RD.5]	Trimble GNSS Planning Online Link: https://www.gnssplanning.com/	-	-	02/2023
[RD.6]	INSPIRe Consolidated Requirements V0.1 Internal	X-062-001-002	0.1	03/08/22

3 REQUIREMENTS CONSOLIDATION

This section provides a review and consolidation of the current RAIM Prototype performance prediction tool being developed.

First, a review of already existing tools is performed to define this tool's requirements. This identifies which aspects of the high-level design, configuration parameters and outputs provided could also be also useful for the M(G)RAIM prediction tool for the maritime domain.

Then, a list of requirements will be provided including an indication of which are applicable for the prototype development in the INSPIRe project.

3.1 Available Forecast tools

This chapter details the available information about the current existing GNSS performance forecast tools.

3.1.1 EUROCONTROL RAIM Prediction Tool (AUGUR)

AUGUR is the web-based service provided by EUROCONTROL for RAIM availability prediction. The AUGUR service is one means by which airspace users can comply with the EASA requirements to verify RAIM availability during pre-flight planning.

AUGUR tool is composed of two different panels, providing different information. The first panel presents the main parameters related to the GPS constellation status for RAIM prediction such as:

- The time period covered (72h since the present day at 00:00 UTC)
- The almanac used in the RAIM prediction
- The NANUs (Notice Advisory to Navstar Users) issued by the US Coast Guard at the USCG NAVCEN website (https://www.navcen.uscg.gov/)

This panel details the main tool's source of information, the GPS almanac that is broadcast by the constellation, and the NANU (Notice Advisory to Navstar Users) messages that warn aviation users of service outages. It also limits the time window for the prediction tool to 72h from the 00:00 UTC of the present day.

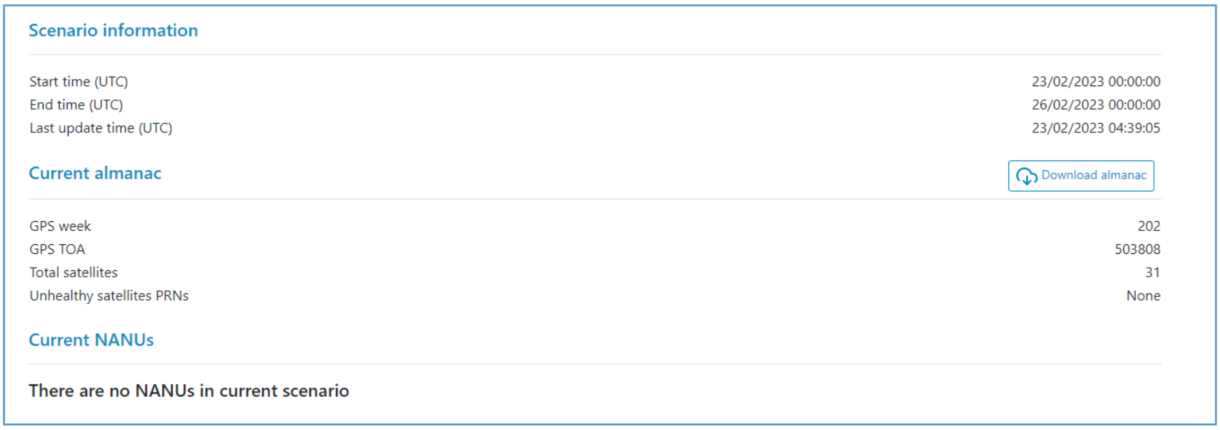


Figure 3-1. AUGUR GPS status panel example [RD.3]

The second panel provides the RAIM prediction outages for one or several airports within the time period defined. The panel requires the following inputs:

- **Scenario Start Time:** start time of the RAIM prediction. By default, the start time is the current day at 00:00 UTC, as defined in the 'Service Status' panel. On the other hand, the user can select a previous date (since 1st September 2020) to obtain the RAIM outages predicted in that time (aka ‘prediction in the past’).

- **Airports:** list of airports where the RAIM availability is predicted. The airports are defined by the ICAO code. Up to 30 airports can be inserted (e.g., LEHZ; LEJR; LERT;) Only for airports in ECAC and MEDA countries and their overseas territories.
- **RAIM Algorithm:** FD (Fault Detection) or FDE (Fault Detection and Exclusion).
- **Selective Availability (SA):** on (unaware) or off (aware). Since May 2000 Selective Availability is not used, and constellation GPS III does not include this feature. However, older receivers, typically certified against TSO-C129, might assume SA is on.
- **Barometric Aiding:** ‘baro aiding’ means the navigation equipment on board incorporates barometric altitude aiding.
- **Mask Angle:** Satellites at a lower elevation than the mask angle are not used in the RAIM prediction. Therefore, selecting higher elevation mask angles (e.g., 7.5, 10 or 12.5º) simulates the effect of satellites blocked by mountains surrounding an aerodrome. Augur does not use a digital terrain model (DTM) to determine the visibility of the satellites.
- **Type of procedure:** APPROACH (RNP 0.3) or TERMINAL (RNP 1.0)

Then, clicking on **"Check outages"** invokes the RAIM prediction calculation and once the calculation is finished the results are presented to the user both in graphical and textual formats. The following output is provided when an outage is detected (BIAR airport) and when is not detected (EGNX):

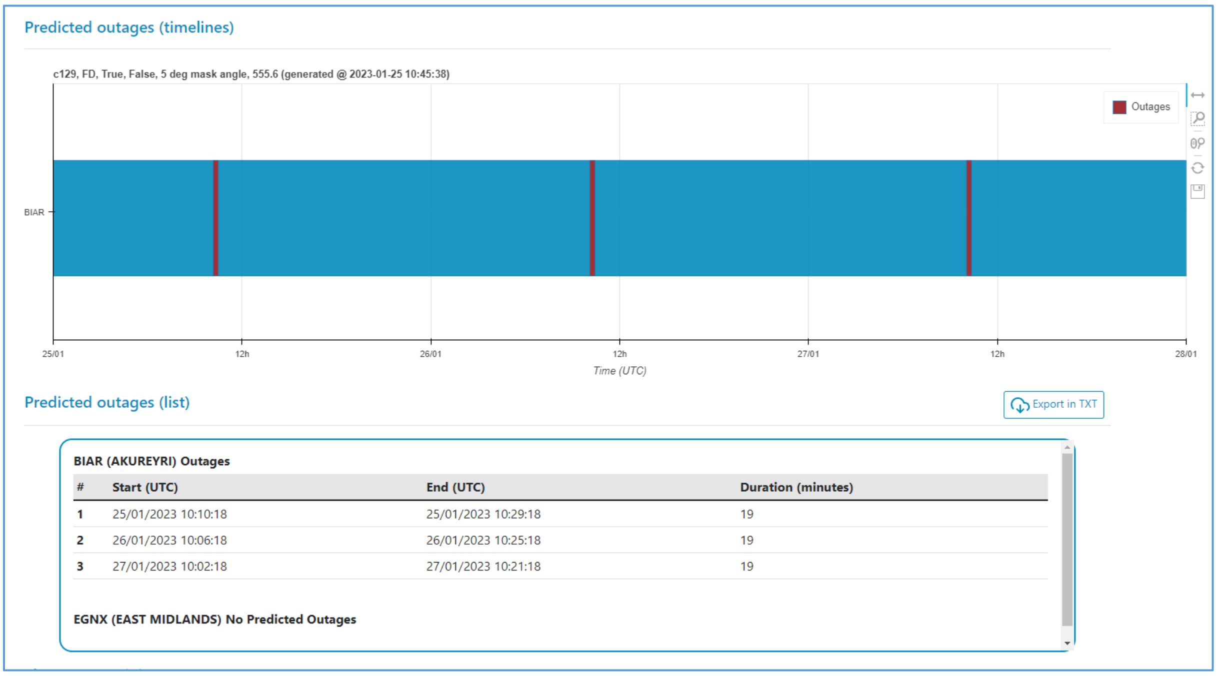


Figure 3-2. AUGUR Terminal/Approach output example [RD.3]

Finally, EUROCONTROL provides GPS RAIM NOTAM proposals thanks to this tool for Airports when this is requested by ANSPs.

3.1.2 EGNOS Availability Forecast Performance

EGNOS Availability Forecast Performance tool is a web application that provides maps for EGNOS service area that depicts expected EGNOS Performance. In a similar way as AUGUR, this tool requires the following information:

- The day covered (within 96h of the present day at 00:00 UTC)

- The GPS constellation almanac
- The NANUs (Notice Advisory to Navstar Users) issued by the US Coast Guard at the USCG NAVCEN web site (https://www.navcen.uscg.gov/)
- RIMS health status
- Historic data about GPS sigmas broadcasted by EGNOS that are extrapolated to the forecasted days

The main difference between this tool and AUGUR is the need for error models and the impact of RIMS health status on the service performances. These models may be estimated from historical data and the expected availability of the system, for example estimating the accuracy of the orbital error depending on the number of RIMS available. Estimation requires a deep knowledge of the system and its design.

Then, with these inputs, performances for a user grid over the EGNOS service area are computed and the following figures are depicted:

- EGNOS APV-I Availability: defined as the percentage of epochs for which the Protection Level is below the Alert Limit for the APV-I services (HPL<40m and VPL<50m) over the total period.
- Corresponding HPL and VPL for the Combined GEO satellite footprints.
- APV-I Availability delta map showing the predicted underperformance for the selected day with respect to the nominal system status.

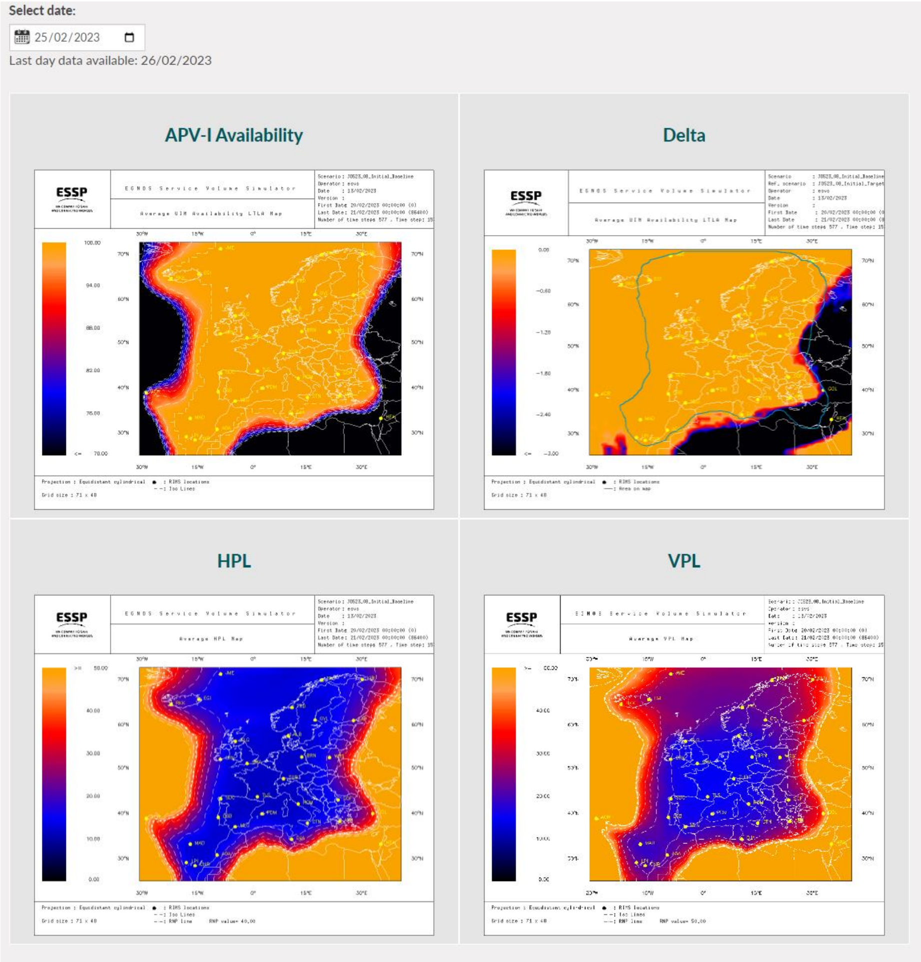


Figure 3-3. EGNOS Availability Forecast output example [RD.4]

The main difference with respect to AUGUR is the capability to compute the performance over an area instead of for a given airport. This allows the tool to create these performance maps. In addition, it does not provide any warning message or NOTAM when performance is insufficient.

3.1.3 Commercial tools

Finally, there are commercial tools that can provide some performance forecasts for GNSS. As an example, Trimble GNSS Planning Online [RD.5] is a web tool that provides satellite visibility and DoP values. Like the previous tools, this tool requires the following information to do so:

- The day covered (up to 24h of the time period)
- The GNSS constellation almanac
- The GNSS constellation status, the user can configure which satellites to be used, even if they are not healthy.
- User location and elevation mask

The main difference with respect to the other tools is that other GNSS core constellations are considered: GLONASS, Galileo, BeiDou and QZSS. The following outputs are provided by the tool:

- Satellite relative positioning: Satellite location with respect to the user location provided as an elevation chart, a sky plot and a World view
- Number of Satellites.
- DoP values: In order to not make any assumptions about typical error models, this tool is only providing the DoP since it depends only on satellite geometry.
- Satellite Visibility.

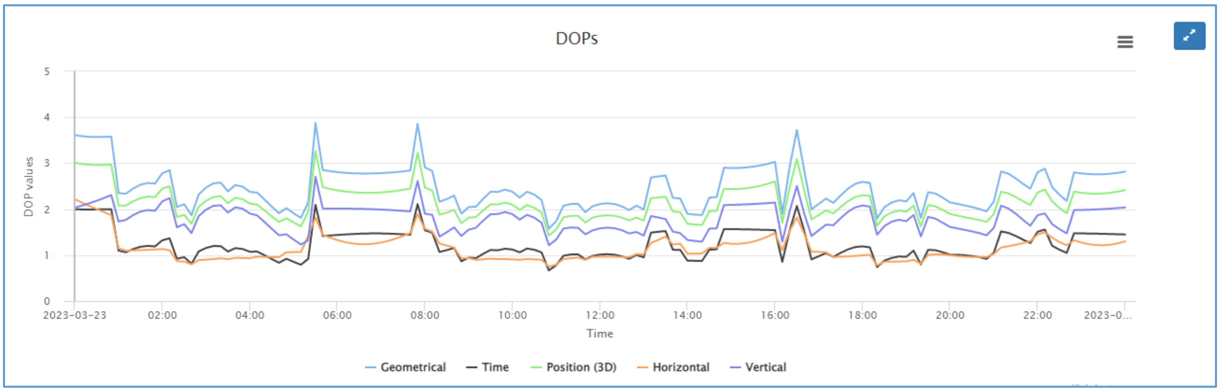


Figure 3-4. Trimble GNSS planning output example [RD.5]

3.2 M(G)RAIM Performance Prediction Tool Requirements

Taking into account the M(G)RAIM algorithm design [RD.1][RD.2] and the aforementioned available tools, the following assumptions and requirements are identified for the Performance Prediction Tool.

For each requirement the following characteristics are specified:

- ID A unique identifier: it is composed of a string and a numeric part.
- Description The content of the requirement.
- Trace-back Points to source material from which the requirement has been derived.

Note: All specified requirements are to be considered mandatory unless otherwise stated.

The unique requirement ID complies with the following format:

[Category].[Group].[###]

Where:

- [Category] can be
  - FUN - functional requirements.
  - INT - interface requirements
- [Group] can be
  - MPT - requirements related to the M(G)RAIM Prediction Tool
  - MSW - requirements related to the M(G)RAIM Prediction Tool Software
- [###] is a numeric increment

3.2.1 Assumptions

Prototype tool will be developed according to the following assumptions:

- Prototype tool will not take pseudo real time information (broadcast Navigation, NANUs/NAGUs, SBAS messages, etc.) and will use pre-configured GNSS constellation geometry and configured error models.
- Prototype tool assume that all satellites in view are being monitored, even in the SBAS case when user have access to SBAS messages.
- Prototype tool assumes no failure of any satellite except configured other way.
- Prototype developed in WP6 could be upgraded if required for the development of other WP.

3.2.2 Functional Requirements

FUN.MPT.001.

The tool shall be able to provide forecast performance in terms of service availability and Protection Level (PL) size, if the PL is computed.

FUN.MPT.002.

The tool shall be able to provide forecast performance for at least 72h ahead.

FUN.MPT.003.

The tool shall be able to provide forecast performance for any user location on the Earth's surface.

FUN.MPT.004.

The tool shall be able to provide performance reports for dates in the past, taking into account past GNSS health system information.

FUN.MPT.005.

The tool shall be able to allow the following configuration parameters:

- User location / User grid definition
- Date and expected time window
- Constellation to be used (GPS/Galileo only available at the moment)

- Satellites to be used
- Frequencies to be used
- Error models
- Elevation mask
- M(G)RAIM and MRAIM configuration parameters
- Navigation phase requirements

3.2.3 Interface Requirements

INT.MPT.001.

The tool shall take as input the last available GNSS constellation ephemeris or the closest one for forecasts in the past.

INT.MPT.002.

The tool shall take as input the NANUs, NAGUs or equivalent messages that provide information about the GNSS constellation and satellite health status.

INT.MPT.003.

The tool shall take into account as inputs augmentation system information, if used, about GNSS health information and signal error estimations.

INT.MPT.004.

The tool shall take into account the aforementioned configuration parameters.

INT.MPT.005.

The tool shall be able to provide, in a single-user mode, the following information along the time window:

- Satellite visibility information
- Expected service outages (due to poor performances or signal unavailability)
- PL size (if computed)
- Expected Accuracy (95%)
- Worst-subset HDOP and GDOP (if needed)
- Foreseen alarms

INT.MPT.006.

The tool shall be able to provide, in a user grid mode, the following information along the time window:

- Availability maps
- PL size maps
- Accuracy (95%) maps
- Foreseen alarms for a given area

INT.MPT.007.

The tool shall be able to raise warnings to those users when the expected performances are not suitable for the configured navigation phase.

INT.MPT.008.

The tool shall be able also to provide the output information in plain text mode.

4 M(G)RAIM PERFORMANCE PREDICTION PROTOTYPE TOOL DESIGN AND TEST SPECIFICATION PLAN

This section provides a high-level design for M(G)RAIM Performance Prediction Prototype Tool. The tool's main processing modules, its inputs and its expected outputs will be detailed in this section. Finally, this section presents an overview of the experimentation plan for the evaluation of the prediction tool prototype and a summary of the results of functional testing.

4.1 M(G)RAIM Performance Prediction Prototype Tool Design

This section provides a general overview of M(G)RAIM Performance Prediction Prototype Tool design. The prototype tool is based on the following main modules:

- **User Location & Satellite visibility**: These two modules take as input the desired user location (single point or a grid of users) and the GNSS constellation almanac to compute the relative constellation geometry.
- **Error model computation**: This module considers the background GNSS error models to compute the weight matrix. In addition, the GNSS health status is considered in order to exclude flagged satellites. This GNSS health status considers the NANUs/NAGUs messages and could include messages from augmentation systems.
- **M(G)RAIM module**: This module computes the M(G)RAIM performances, Accuracy, PL and alarms, for the configured scenario.
- **Performance Statistics**: To provide to the user with the required statistics, this module takes the M(G)RAIM performances and process them as required.
- **Monitoring System (Optional)**: Finally, this additional module could monitor the real performances and compare it against the forecasted ones, to fine tuning and refine the used error models.

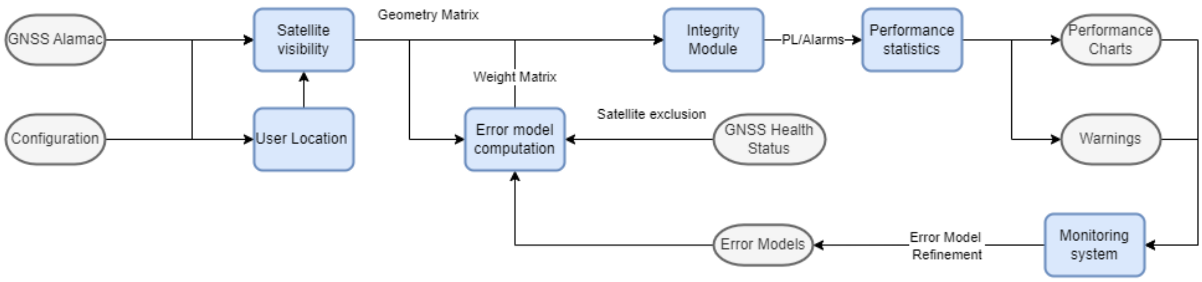


Figure 4-1. M(G)RAIM Performance Prediction prototype tool

4.1.1 Inputs

M(G)RAIM Performance Prediction Prototype Tool requires the following inputs:

- **Configuration**: The tool considers the following configuration parameters:
  - User location / User grid definition
  - Date and expected time window
  - Constellation(s) to be used
  - Satellites to be used
  - M(G)RAIM configuration parameters
  - Navigation phase requirements

- **GNSS almanac**: Tool requires the closest available GNSS constellation ephemeris to the user configured date. These ephemeris in an operational tool should be obtained from a network of receivers decoding real data[1]. However, in this prototype the almanac will be obtained from a navigation RINEX file or a plain text file with the satellite orbital information.
- **GNSS Health Status**: The operational tool should take as input the NANUs, NAGUs or equivalent messages that provide information about the GNSS constellation and satellite health status. In addition, it should take into account as inputs augmentation system information, if used, about GNSS health information.
- **Error models**: Finally, a signal error model for each constellation and frequency is provided to the M(G)RAIM Performance Prediction Prototype Tool. These models in the operational tool could be provided by a user configuration or taken from augmentation system signal error estimations. In addition, the M(G)RAIM monitoring system could compare the forecast against the real performances and refine the models. In the prototype tool this function will be performed manually tunning the error models introduced by configuration.

4.1.2 Processing

From a functional perspective, the M(G)RAIM Performance Prediction Tool should perform the following high-level processing. Please note that processing described applies equally to an operational tool and also to the prototype.

4.1.2.1 User Location & Satellite visibility

These two modules together take as input the desired user location (single point or a grid of users) and the GNSS constellation almanac to compute the relative constellation geometry.

- **Inputs**:
  - User location / User grid definition: From configuration it is required to input the user location, or the parameters that defines the user grid unambiguously. This location is usually given by coordinates of a user or the parameters that define the grid coordinates.
  - Date and expected time window: From configuration it is required to input the desired date and for how many hours the forecast is needed. Please, note that the combination of the date and the time window cannot exceed 72h from 00:00 UTC of the current date.
  - Constellation to be used: From configuration it shall be selected which constellation to be used.
  - Satellites to be used: From configuration, it shall be selected if any satellite is excluded by any reason prior to the health checks.
  - GNSS almanac: Orbital parameters of configured constellation are required to estimate satellite location for the desired time interval.
- **Processing**; the input information should be handled according to the following steps:
  - Satellite orbital information is decoded and satellite position, of every satellite configured, is propagated to every epoch configured. Satellite position shall be computed in an Earth Centred Earth Fixed (ECEF) reference frame.
  - The following steps shall be performed per user configured or per epoch if a dynamic single user is configured:
    - User location is converted from coordinates (lat, lon, h) into an ECEF xyz vector.

[1] I.e. from ftps gdc.cddis.eosdis.nasa.gov or igs.org

        - Rotation matrix ECEF<->ENU/NED reference is computed for the user location.
    - The following steps shall be performed per user and per epoch configured:
        - The relative satellite position from the user's point of view is computed in the ECEF reference frame and then converted into ENU/NED.
        - Satellite azimuth and elevation are then computed, and elevation mask exclusion is applied to identify visible satellites.
- **Outputs**:
    - One elevation and azimuth angle per line of sight, user and epoch configured.

4.1.2.2 Error model computation

This module considers the background GNSS error models and GNSS health status in order to compute the weight matrix.

- **Inputs**:
    - Satellite relative positioning: For the configuration, it is required to input the user location, or the parameters that define the user grid unambiguously. This location is usually given by the coordinates of a user or the parameters that define the grid coordinates.
    - Configured Error models: Preliminary background models should be configured in order to provide the required information to the M(G)RAIM algorithm even if no external information is provided. These models need to be conservative to over-bound the error since they are used for integrity purposes, for a wide variety of environments.
    - Refined Error Models: Feedback information about current real performances could be considered if augmentation systems or any other kind of monitoring system is deployed. These refined models will be prioritised on top of the configured ones since they are expected to better fit the real performances.
    - GNSS Health Status: GNSS status information such as NANUs, NAGUs or equivalent messages shall be considered as inputs, together with information broadcast by the GNSS core constellation and also the augmentation system, if used. This integrity information will be used to exclude faulty satellites from the forecast computation.
- **Processing**: the input information should be handled according to the following steps:
    - The following steps shall be performed per user and per epoch configured:
        - Configured Error models are applied to each visible satellite measurement, depending usually on satellite elevation. Then one model is obtained per line of sight. These models will be different for each GNSS constellation or combination of measurements.
        - Feedback information, if available, will be decoded and a satellite measurement model will be obtained, depending on the GNSS constellation or combination of measurements. The refined error model obtained for each satellite will then overwrite the one obtained from the configured model.
        - GNSS Health status information shall be decoded and healthy flags should be obtained for the visible satellites. If the satellite is flagged as unhealthy for any reason, the weight of that satellite should be set equal to 0.
- **Outputs**:
    - One variance per line of sight, per user and epoch configured.

4.1.2.3 Integrity Module

This module computes the M(G)RAIM performances, PL, and alarms, for the configured scenario.

- **Inputs**:
  - Satellite location: From the previous module, one elevation and azimuth angle per line of sight, per user and epoch is required.
  - Variance: From the previous module, one variance per line of sight, per user and epoch is required.
  - Configuration parameters:
    - M(G)RAIM configuration parameters should be provided, including first of all the algorithm selection (MRAIM or MGRAIM) and all specific parameters required for the algorithm computation [RD.1][RD.2].
    - Navigation phase requirements: Navigation requirements are required to set some key parameters required for the algorithm computation [RD.1][RD.2].
- **Processing**: the input information should be handled according to the following steps:
  - MRAIM or MGRAIM processing is performed according to the detailed information contained in D2.1 and D3.1 [RD.1][RD.2].
- **Outputs**:
  - Warnings/Alarms: The tool provides warnings to those users when the expected performances are not suitable for the configured navigation phase.
  - Protection Level: Protection Level size performance is provided for the selected configuration.
  - Accuracy Level: An estimate of the 95% fault-free Accuracy performance is also provided.

4.1.2.4 Performance Statistic

In order to provide the required statistics, this module takes the M(G)RAIM performances and processes them as required.

- **Inputs**:
  - Warnings/Alarms: Alarms per user and epoch are taken to be processed.
  - Protection Level: Protection Level size per user and epoch are taken to be processed.
  - Accuracy and DOP values: per user per epoch
  - Configuration parameters:
    - Navigation phase requirements: Navigation requirements are required to provide performance statistics again the given threshold.
    - User location / User grid definition: User location is required to plot the statistics in a chart or a map.
    - Date and expected time window: A date and time window is required to plot results for the configured time.
- **Processing**: the input information should be handled according to the following steps:
  - MRAIM or MGRAIM outcomes should be plotted in a figure along time for a given user.
  - MRAIM or MGRAIM outcomes statistics (percentiles, availability, etc.) should be computed according to the configuration.

- **Outputs**:
  - Warnings/Alarms: Devoted messages in text format and figures when the expected performances are not suitable for the configured navigation phase.
  - Protection Level: Protection Level size charts and/or maps for the selected configuration.

4.1.2.5 Monitoring System

This additional module could monitor the real performances and compare it against the forecasted ones, in order to fine tune and refine the used error models.

- **Inputs**:
  - Warnings/Alarms: Alarms per user and epoch are taken to be analysed.
  - Protection Level: Protection Level size per user and epoch are taken to be analysed.
  - Real performances: Monitoring system collects information from real data in order to be processed according to the algorithm selected [RD.1][RD.2].
- **Processing**: the input information should be handled according to the following steps:
  - MRAIM or MGRAIM Performance Prediction forecast are compared against the real performances for a given user on a given time window. If performances are too optimistic or pessimistic, actions should be performed in order to tune error models.
- **Outputs**:
  - Refined error models: Updated error models obtained after correction actions.

4.1.3 Outputs

Finally, the M(G)RAIM Performance Prediction Prototype Tool provides the following outputs:

- **Performance charts**:
  - The tool, in a single user mode, provides the following information along the time window:
    - Satellite visibility information
    - Expected service outages (due to poor performances or signal unavailability)
    - PL size (if appropriate)
    - Expected 95% Accuracy performance
  - The tool, in a user grid mode, provides the following information along the time window:
    - Availability maps
    - PL size maps
    - Accuracy maps

    Please note that an operational tool may provide this information via a web interface or a devoted report in, for example, pdf format. However, these charts are provided by the prototype tool in as independent images.
- **Warnings/Alarms**: The tool raises warnings to those users when the expected performances are not suitable for the configured navigation phase. These alarms in the operational tool may be provided via web interface or a devoted text message. In the operational tool it will be provided as images for the user or selected area.
- **Other outputs**: Finally, the tool also provides the output information in plain text mode.

4.2 M(G)RAIM Performance Prediction Prototype Tool Test Specification

This section contains the test cases that have been created to test the functionality of INSPIRe Performance Prediction Prototype Tool described in the current document. The following test specification describes which tests are to be executed and provide a high-level description of the purpose of the test along with required data and test tools.

Table 4-1 below identifies a set of test cases proposed. To demonstrate that the Performance Prediction Prototype Tool is compliant with its functional and interface requirements, it is necessary to provide a trace of the system requirements in the test activities. Each requirement will be traced to the test that verifies it.

Each test case will be defined based on the following format:

- **TC** - Prefix to indicate this is a Test Case Identifier.
- **[Function]** - is the name of the software component under testing.
- **[ID#] -** sequential numbering for each case.

The test cases identified are executed for both MGRAIM and MRAIM

Table 4-1. MGRAIM Functional Test Specification

Test Case ID	Objective/Test sets	Description	Success Criteria	Traceability Requirements
TC.MPT.001	To check that files are read, and a solution is generated as expected	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: ▪ MGRAIM algorithm selection ▪ Single user selection ▪ Forecast for the following day (24h) ▪ GPS + Galileo ▪ Nominal error models configured for Dual Frequency mode. ▪ Coastal navigation	The tool shall be able to provide for the 24h selected: ▪ Satellite visibility information ▪ Expected service outages. ▪ PL size ▪ Foreseen alarms ▪ Warnings to those users when the expected performances are not suitable. ▪ Output information in plain text mode	FUN.MPT.001 FUN.MPT.005 INT.MPT.001 INT.MPT.004 INT.MPT.005 INT.MPT.007 INT.MPT.008
TC.MPT.002	To check that tool can provide a forecast for at least 72h	Same configuration as TC.MPT.001 but forecast is selected for the following 72h	The tool shall be able to provide for the 72h selected the same output as TC.MPT.001	FUN.MPT.001 FUN.MPT.002 FUN.MPT.005 INT.MPT.004

TC.MPT.003	To check that tool is able to provide a forecast for the past days	Same configuration as TC.MPT.001 but forecast is selected for longer than 1 week before the test.	The tool shall be able to provide for the 24h selected the same output as TC.MPT.001	FUN.MPT.001 FUN.MPT.004 FUN.MPT.005 INT.MPT.001 INT.MPT.004 INT.MPT.005 INT.MPT.007 INT.MPT.008
TC.MPT.004	To check that tool is able to provide a forecast of every surface on Earth in a grid mode	Same configuration as TC.MPT.001 but a grid of users is selected to cover the whole Earth's surface	The tool shall be able to provide for the 24h selected: ▪ Availability maps ▪ PL size maps ▪ Foreseen alarms for a given area ▪ Warnings to those users when the expected performances are not suitable ▪ Output information in plain text mode	FUN.MPT.001 FUN.MPT.003 FUN.MPT.005 INT.MPT.004 INT.MPT.006 INT.MPT.007 INT.MPT.008
TC.MPT.005	To check that tool is able to provide a forecast excluding satellites from NANUs, NAGUs or equivalent	Same configuration as TC.MPT.001 and provide a synthetic NANUs and NAGUs message excluding one satellite in each constellation	The tool shall be able to provide for the 24h selected the same output as TC.MPT.001 excluding the two satellites considered	FUN.MPT.001 INT.MPT.001 INT.MPT.002
TC.MPT.006	To check that tool is able to provide a forecast considering augmentation system information	Same configuration as TC.MPT.001 including SBAS messages	The tool shall be able to provide for the 24h selected the same output as TC.MPT.001 taking into account Satellite integrity and error characterisation information	FUN.MPT.001 INT.MPT.001 INT.MPT.003
TC.MPT.007	To check that tool is able to provide a forecast for different navigation phase	Same configuration as TC.MPT.001 for Coastal navigation phase	The tool shall be able to provide for the 24h selected the same output as TC.MPT.001 with much more alarms, due to the more demanding navigation phase	FUN.MPT.001 FUN.MPT.005 INT.MPT.001 INT.MPT.004 INT.MPT.005 INT.MPT.007 INT.MPT.008

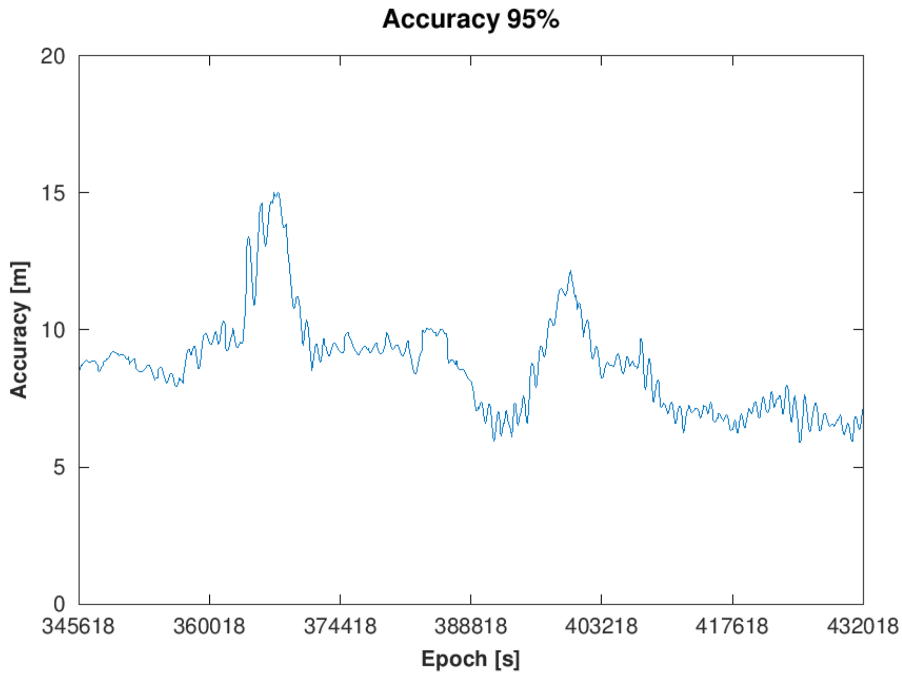
TC.MPT.008	To check that tool is able to provide a forecast considering different frequencies of usage	Same configuration as TC.MPT.001 but: ▪ Single-frequency error models ▪ GPS only constellation	The tool shall be able to provide for the 24h selected the same output as TC.MPT.001 taking into account error models for Single frequency cases and only GPS constellation	FUN.MPT.001 FUN.MPT.005 INT.MPT.001 INT.MPT.004 INT.MPT.005 INT.MPT.007 INT.MPT.008

5 VALIDATION RESULTS

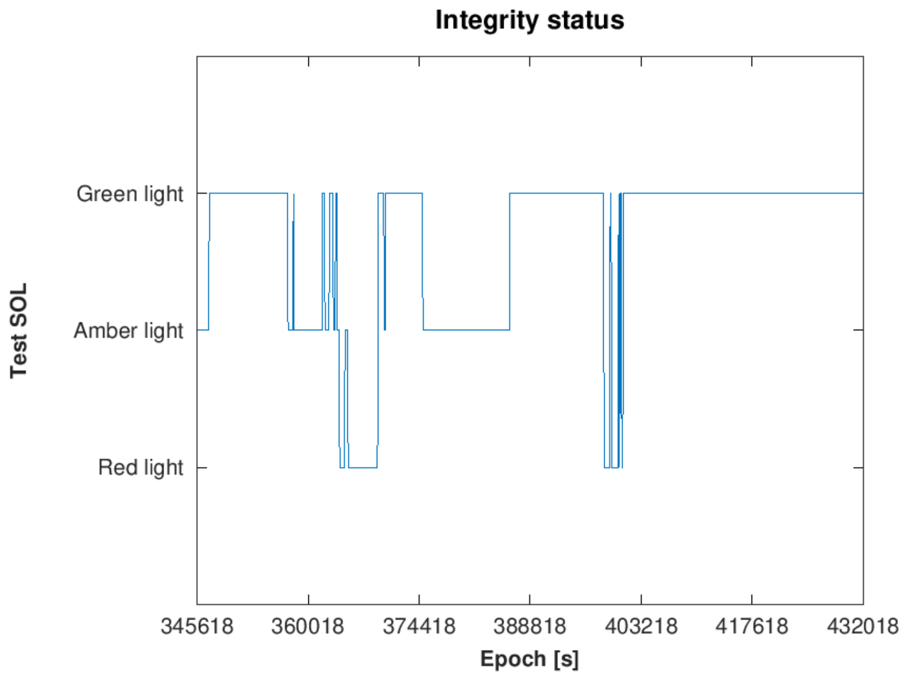
This section will contain the validation results from the verification and validation plan detailed in the previous section.

5.1 TC.MPT.001

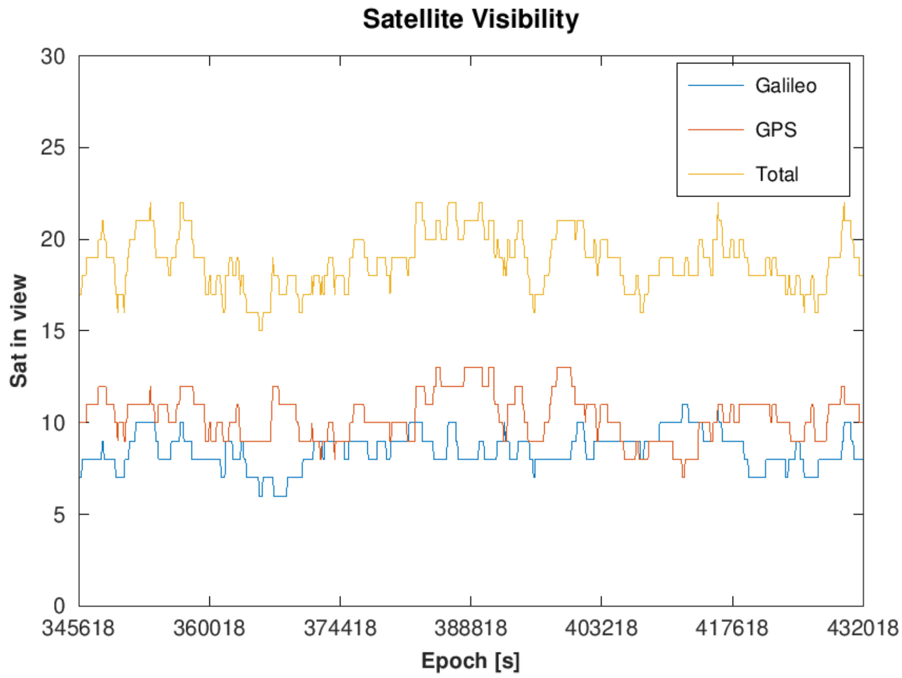
Test Code	TC.MPT.001 MGRAIM		
Test Objective	To check that files are read, and a solution using MGRAIM is generated as expected for a single location for a 24 h period.		
Test Experiment Location	GMV Laboratory	**Test Experiment Equipment**	PC or laptop running Windows OS
Dependence SW	Octave 6.1.0		
Constellation	GPS, Galileo		
Duration Time	The execution: 100 s time step Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59		
Input Data	Galileo ephemerides GPS ephemerides		
Processing	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: ▪ MGRAIM algorithm selection ▪ Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351] ▪ Forecast for 13/04/2023 from 00:00:00 - 23:59:59 ▪ GPS + Galileo ▪ Nominal error models configurable. The error models used can be found in the document [RD.2] ▪ Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m		
Outcome criteria	▪ The tool shall decode, process the information and provide accuracy results in the range of [5-20]m for the configuration selected ▪ The tool shall decode, process the information and provide traffic light status along the scenario ▪ The tool shall decode, process the information and provide satellite visibility along the scenario ▪ The tool shall provide the outputs in plain text mode		
Outcome (Pass/Fail)	**PASS**		
Results	The tool decodes and processes the information, giving values between the range previously mentioned.		

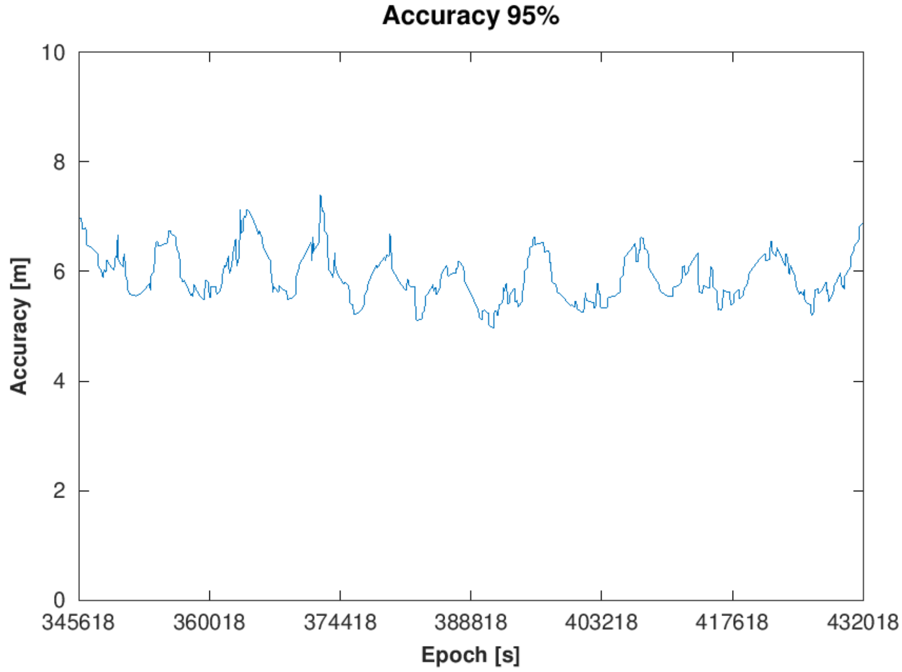


The tool provides an output of light traffic for the whole scenario. Considering that the Accuracy threshold is 10 meters in coastal navigation, the following results are obtained.

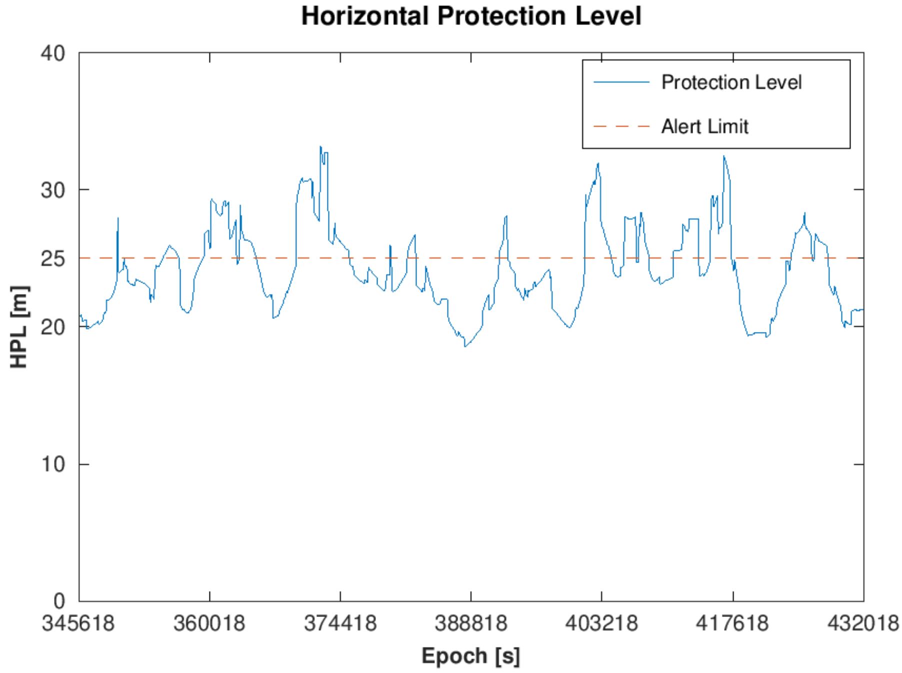


The tool decodes, processes the information, and provides satellite visibility across the scenario.
.

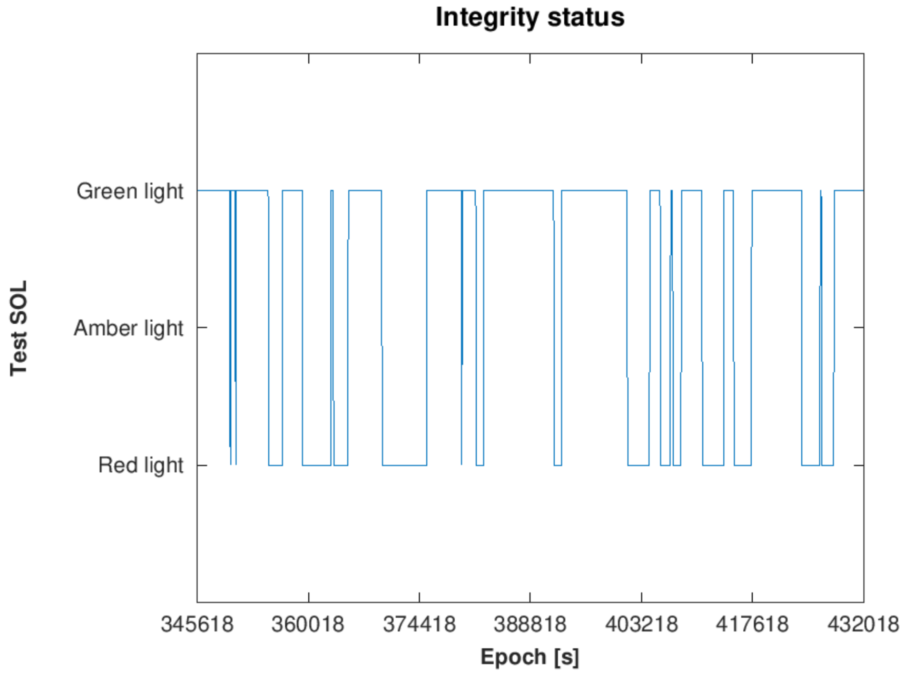
	 The tool provides the outputs in plain text mode:  simulation_data.txt

Test Code	TC.MPT.001 MRAIM		
Test Objective	To check that files are read, and a solution using MRAIM is generated as expected for a single location for a 24 h period.		
Test Experiment Location	GMV Laboratory	**Test Experiment Equipment**	PC or laptop running Windows OS
Dependence SW	Octave 6.1.0		
Constellation	GPS, Galileo		
Duration Time	The execution: 100 s timestep Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59		
Input Data	Galileo ephemerides GPS ephemerides		
Processing	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: ▪ MRAIM algorithm selection ▪ Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351] ▪ Forecast for 13/04/2023 from 00:00:00 - 23:59:59 ▪ GPS + Galileo ▪ Nominal error models configurable. The error models used can be found in the document [RD.2] ▪ Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m		
Outcome criteria	▪ The tool shall decode, process the information and provide Accuracy results in the range of [5-10]m for the configuration selected ▪ The tool shall decode, process the information and provide HPL results in the range of [5-35]m for the configuration selected ▪ The tool shall decode, process the information and provide traffic light status along the scenario ▪ The tool shall decode, process the information and provide satellite visibility along the scenario ▪ The tool shall provide the outputs in plain text mode		
Outcome (Pass/Fail) **Results**	**PASS** The tool decodes and processes the information, giving values of Accuracy between the range previously mentioned.  		

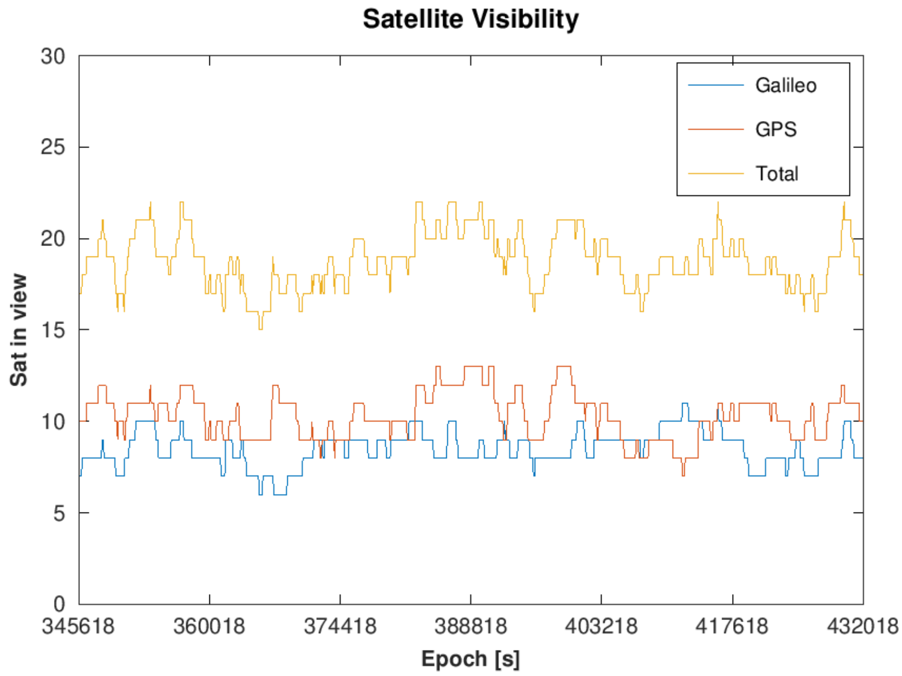
The tool decodes, processes the information and provides the Horizontal Protection Level illustrating the Alert Limit of 25m. The tool decodes and processes the information, giving values of Horizontal protection levels between the range previously mentioned.



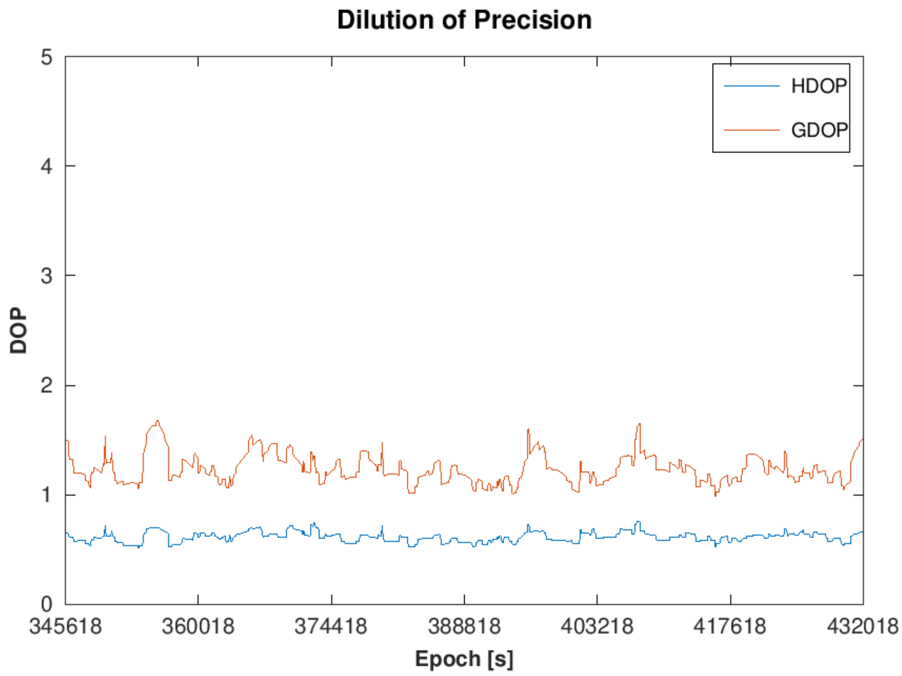
The tool provides an output of light traffic for the whole scenario. Taking into account that the Alert Limit is 25 meters in coastal navigation, the following results are obtained.



The tool decodes, processes the information and provides satellite visibility across the scenario.



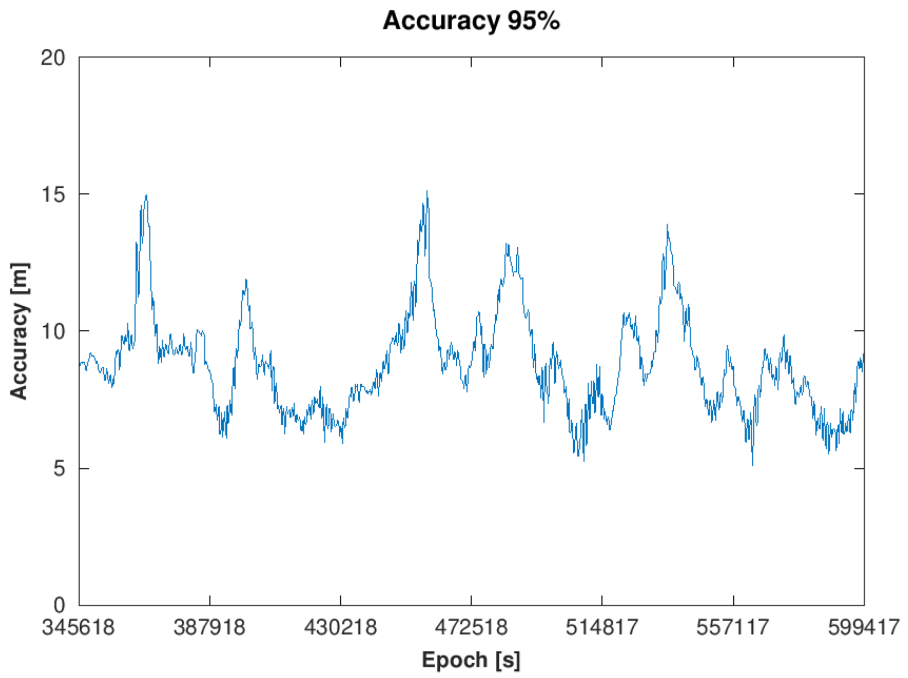
The tool decodes, processes the information HDOP and GDOP.

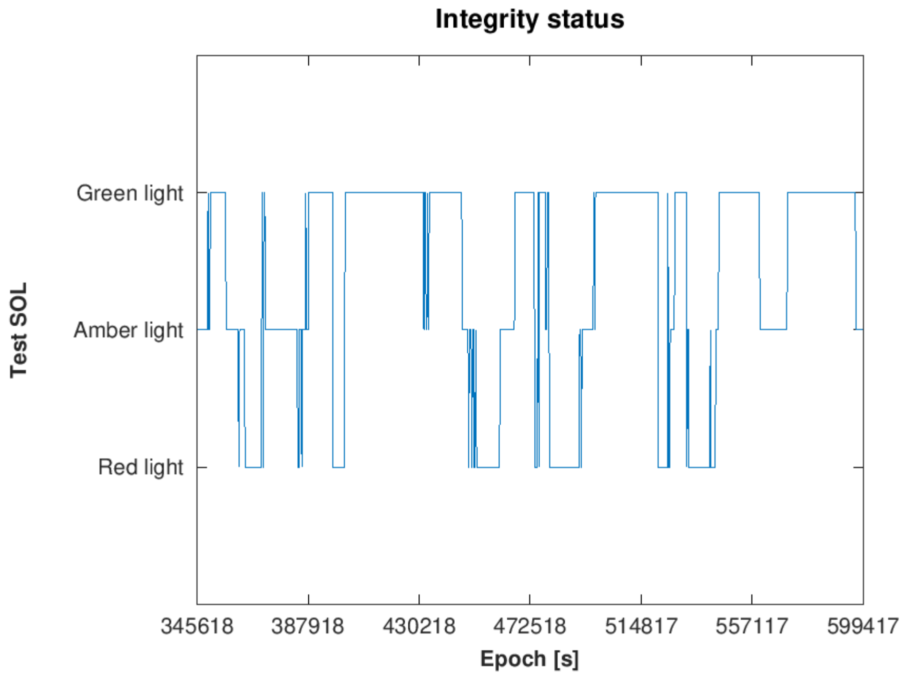
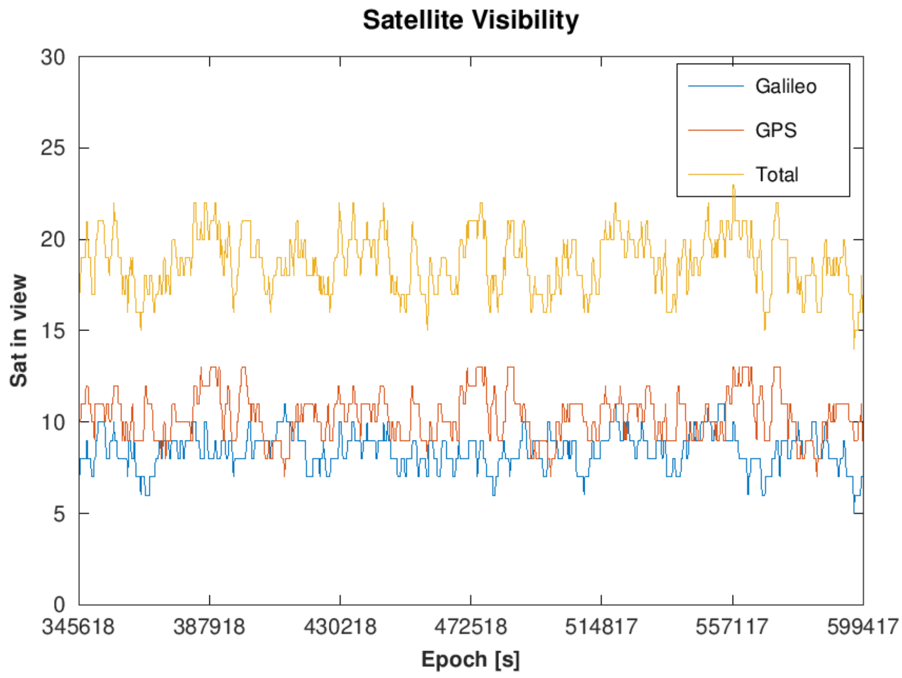


The tool provides the outputs in plain text mode:

simulation_data.txt

5.2 TC.MPT.002

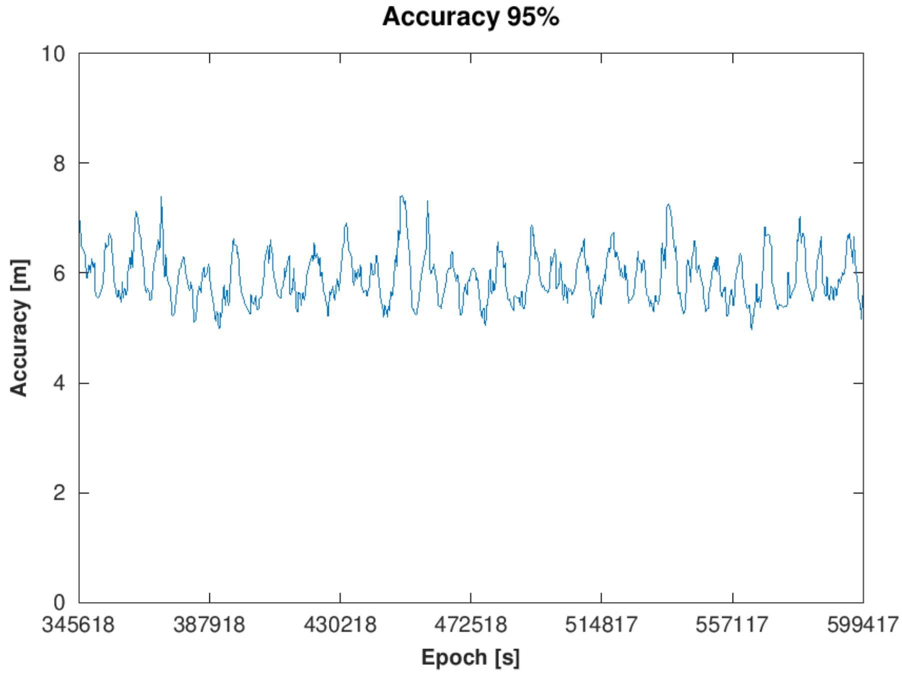
Test Code	TC.MPT.002 MGRAIM		
Test Objective	To check that files are read, and a solution using MGRAIM is generated as expected for a single location for a 72h period.		
Test Experiment Location	GMV Laboratory	**Test Experiment Equipment**	PC or laptop running Windows OS
Dependence SW	Octave 6.1.0		
Constellation used	GPS, Galileo		
Duration Time[s]	The execution: 300 s timestep Period studied 72 h, forecast for 13/04/2023 from 00:00:00 to 15/04/2023 23:59:59		
Input Data	Galileo ephemerides GPS ephemerides		
Processing	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: ■ MGRAIM algorithm selection ■ Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351] ■ Forecast for 13/04/2023 from 00:00:00 to 15/04/2023 23:59:59 ■ GPS + Galileo ■ Nominal error models configurable. The error models used can be found in the document [RD.2] ■ Coastal navigation. Accuracy threshold = 10 m; Integrity Alert Limit = 25 m		
Outcome criteria	■ The tool shall decode, process the information and provide accuracy results in the range of [5-20]m for the configuration selected, in particular for 72h ahead ■ The tool shall decode, process the information and provide traffic light status along the scenario, in particular for 72h ahead ■ The tool shall decode, process the information and provide satellite visibility along the scenario , in particular for 72h ahead		
Outcome (Pass/Fail) **Results**	**PASS** The tool decodes and processes the information, giving Accuracy values in the range previously mentioned.  The tool provides an output of light traffic for the whole scenario. Taking into account that the Accuracy threshold is 10 meters in coastal navigation, the following results are obtained.		

	 The tool decodes, processes the information and provides satellite visibility across the scenario. 

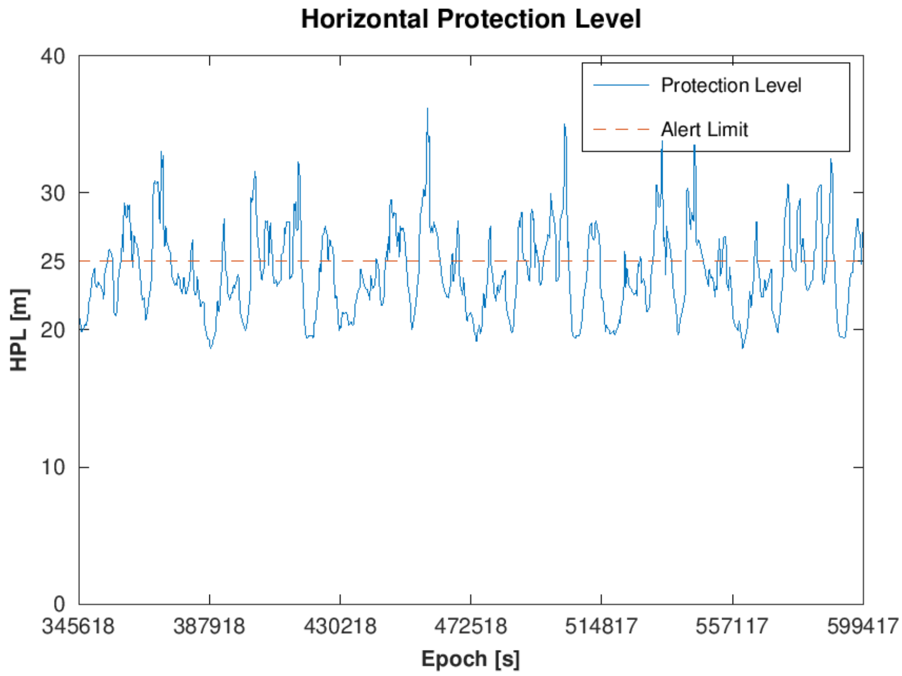
<table>
<tr><th>Test Code</th><th colspan="3">TC.MPT.002 MRAIM</th></tr>
<tr><td>Test Objective</td><td colspan="3">To check that files are read, and a solution using MRAIM is generated as expected for a single location for a 72 h period.</td></tr>
<tr><td>Test Experiment Location</td><td>GMV Laboratory</td><td>Test Experiment Equipment</td><td>PC or laptop running Windows OS</td></tr>
<tr><td>Dependence SW</td><td colspan="3">Octave 6.1.0</td></tr>
<tr><td>Constellation used</td><td colspan="3">GPS, Galileo</td></tr>
<tr><td>Duration Time[s]</td><td colspan="3">The execution: 300 s time step

Period studied 72h, forecast for 13/04/2023 from 00:00:00 to 15/04/2023 23:59:59</td></tr>
<tr><td>Input Data</td><td colspan="3">Galileo ephemerides
GPS ephemerides</td></tr>
<tr><td>Processing</td><td colspan="3">Execution of the Performance Prediction Prototype tool using a nominal configuration which includes:
- MRAIM algorithm selection
- Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351]
- Forecast for 13/04/2023 from 00:00:00 - 23:59:59
- GPS + Galileo
- Nominal error models configurable. The error models used can be found in the document [RD.2]
- Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m</td></tr>
<tr><td>Outcome criteria</td><td colspan="3">- The tool shall decode, process the information and provide Accuracy results in the range of [5-8]m for the configuration selected, in particular for 72h ahead
- The tool shall decode, process the information and provide HPL results in the range of [20-40]m for the configuration selected, in particular for 72h ahead
- The tool shall decode, process the information and provide traffic light status along the scenario, in particular for 72h ahead
- The tool shall decode, process the information and provide satellite visibility along the scenario , in particular for 72h ahead</td></tr>
<tr><td rowspan="2">Outcome (Pass/Fail)

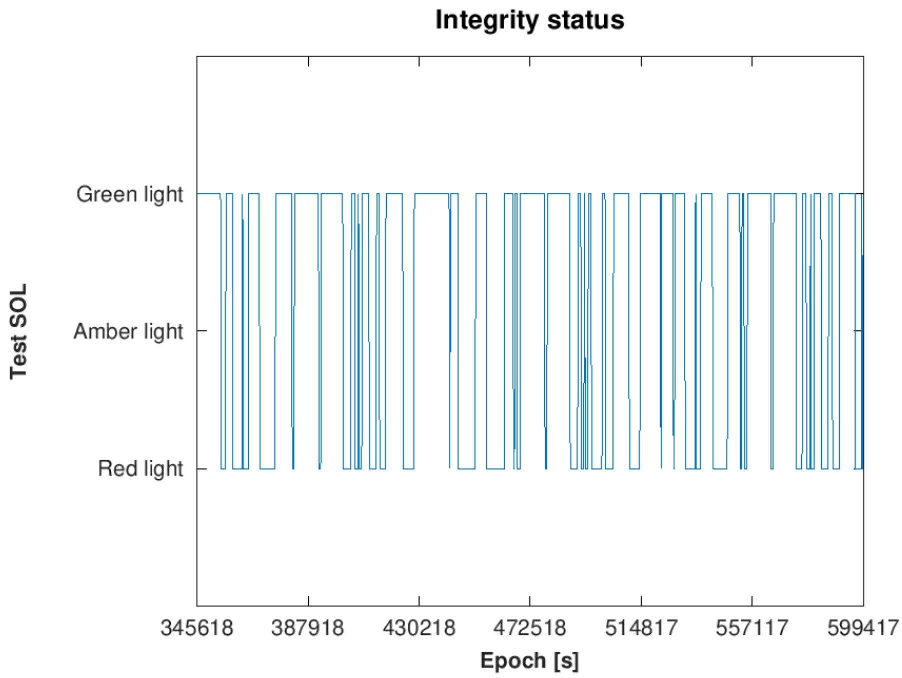
Results</td><td colspan="3">PASS</td></tr>
<tr><td colspan="3">The tool decodes and processes the information, giving Protection Level values in the range previously mentioned.



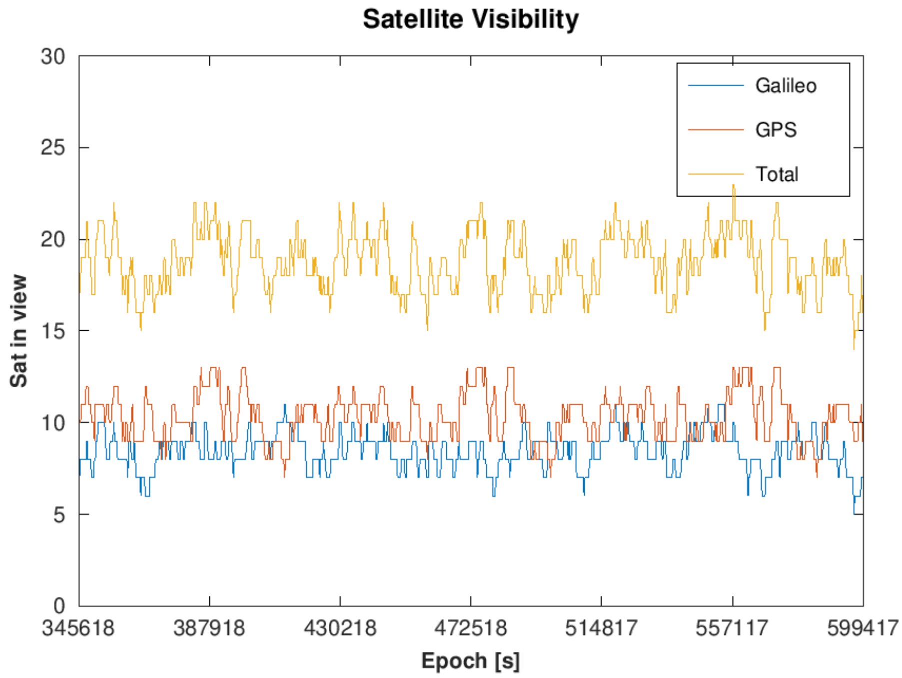
The tool decodes and processes the information, giving Protection Level values in the range previously mentioned. The tool decodes, processes the information and provides the Horizontal Protection Level illustrating the Alert Limit of 25m.</td></tr>
</table>



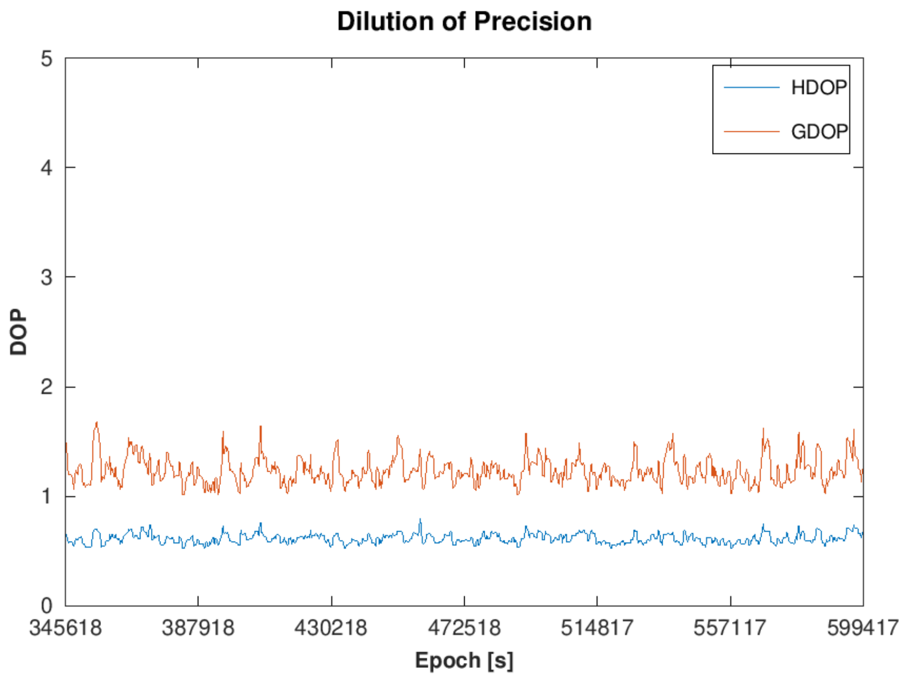
The tool provides an output of light traffic for the whole scenario. Taking into account that the Alert Limit is 25 meters in coastal navigation, the following results are obtained.



The tool decodes, processes the information and provides satellite visibility across the scenario.

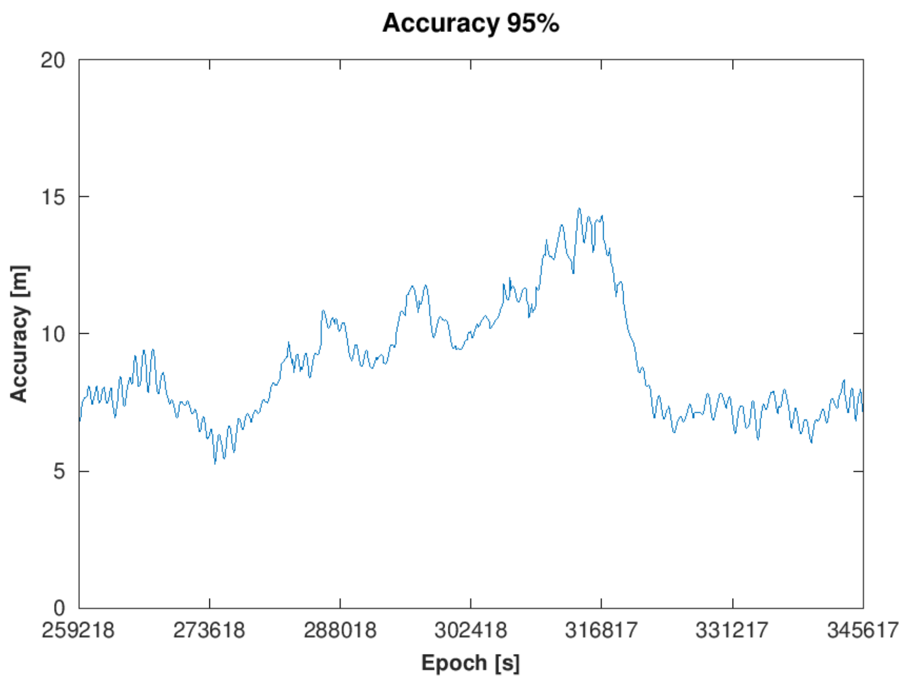


The tool decodes, processes the information HDOP and GDOP across the scenario.

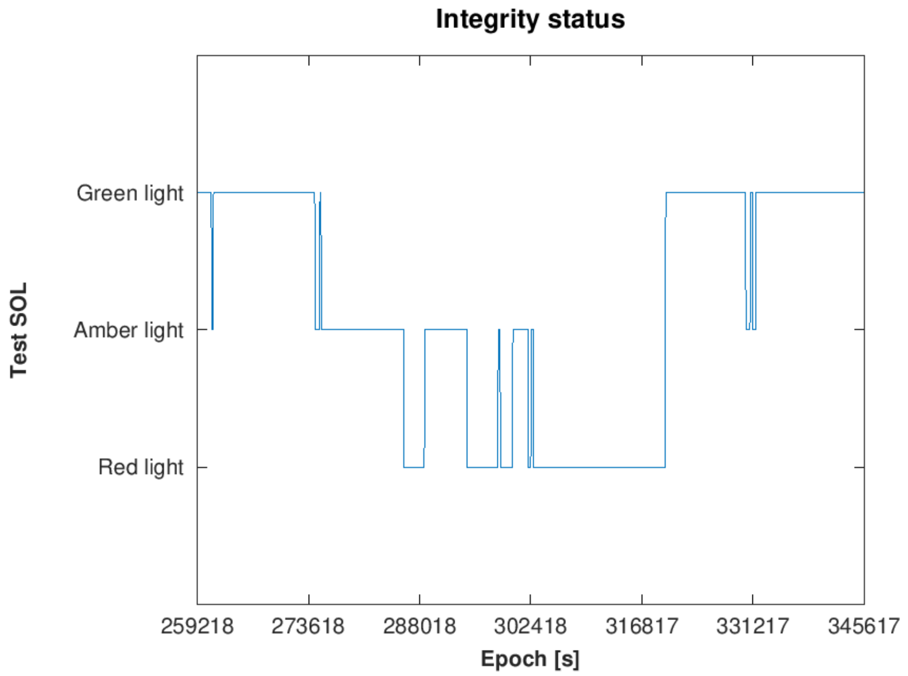
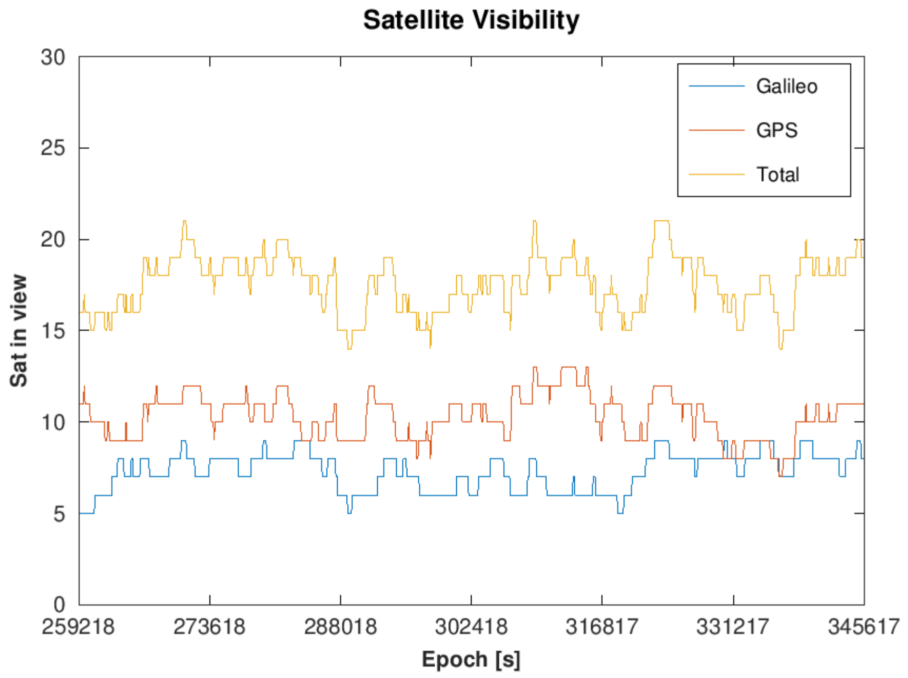


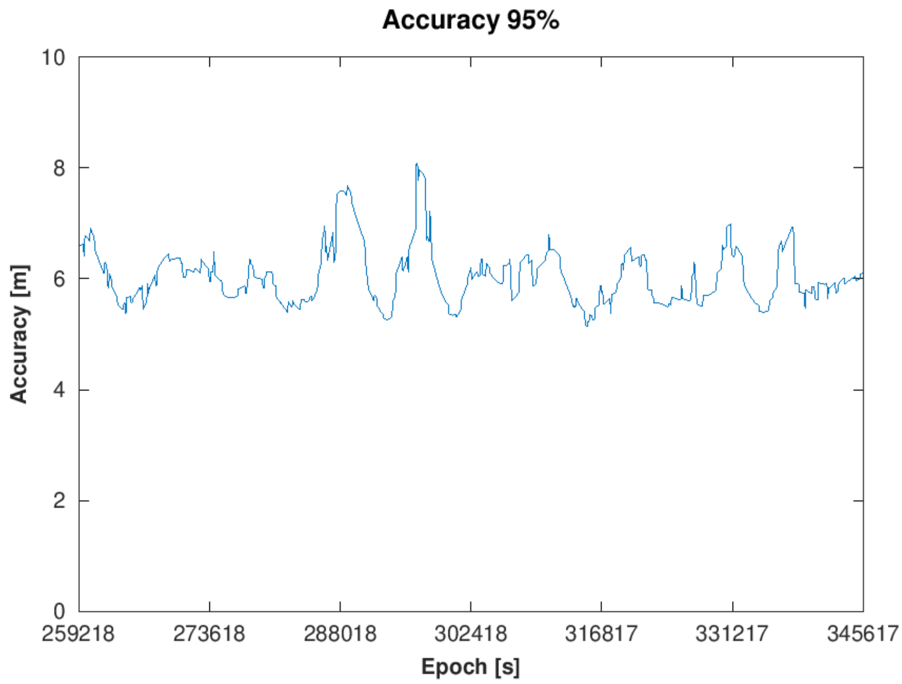
5.3 TC.MPT.003

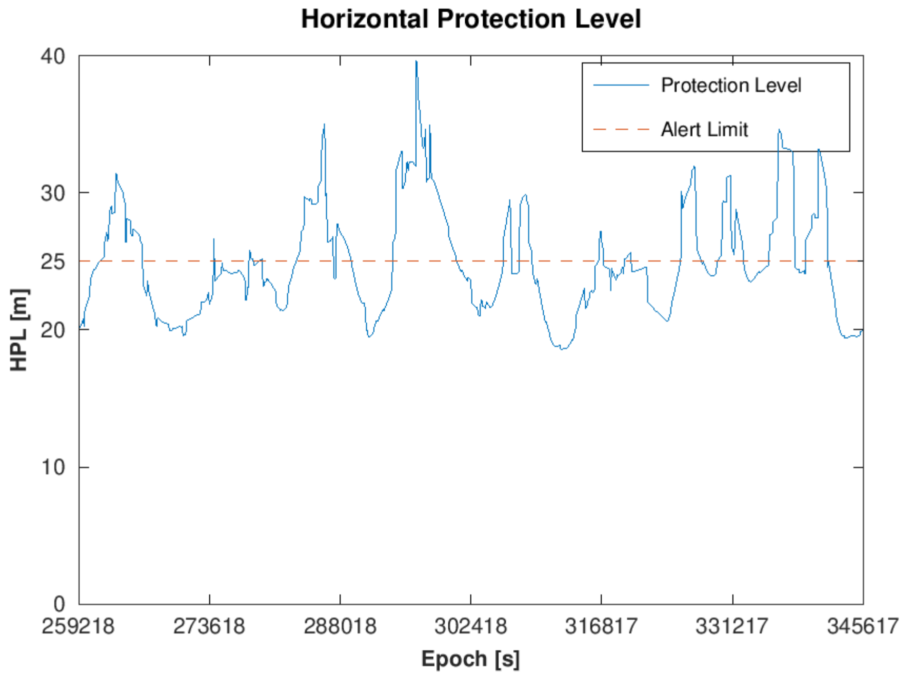
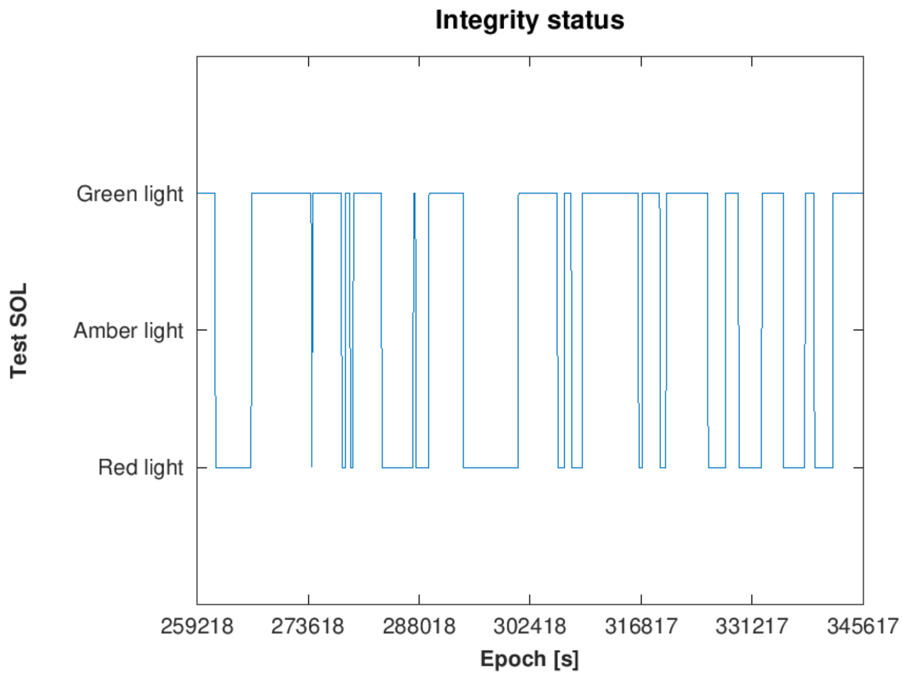
<table>
<tr><th>Test Code</th><th colspan="3">TC.MPT.003 MGRAIM</th></tr>
<tr><td>Test Objective</td><td colspan="3">To check that files are read, and a solution using MGRAIM is generated as expected for a single location for a 24 h period previous the period in TC.MPT.001.</td></tr>
<tr><td>Test Experiment Location</td><td>GMV Laboratory</td><td>Test Experiment Equipment</td><td>PC or laptop running Windows OS</td></tr>
<tr><td>Dependence SW</td><td colspan="3">Octave 6.1.0</td></tr>
<tr><td>Constellation used</td><td colspan="3">GPS, Galileo</td></tr>
<tr><td>Duration Time</td><td colspan="3">The execution: 100 s time step
Period studied 24h, forecast for 03/04/2023 from 00:00:00 - 23:59:59</td></tr>
<tr><td>Input Data</td><td colspan="3">Galileo ephemerides
GPS ephemerides</td></tr>
<tr><td>Processing</td><td colspan="3">Execution of the Performance Prediction Prototype tool using a nominal configuration which includes:
▪ MGRAIM algorithm selection
▪ Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351]
▪ Forecast for 03/04/2023 from 00:00:00 - 23:59:59
▪ GPS + Galileo
▪ Nominal error models configurable. The error models used can be found in the document [RD.2]
▪ Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m</td></tr>
<tr><td>Outcome criteria</td><td colspan="3">▪ The tool shall decode, process the information and provide accuracy results in the range of [5-20]m for the configuration selected
▪ The tool shall decode, process the information and provide traffic light status along the scenario
▪ The tool shall decode, process the information and provide satellite visibility along the scenario , in particular for past days</td></tr>
<tr><td rowspan="2">Outcome (Pass/Fail)

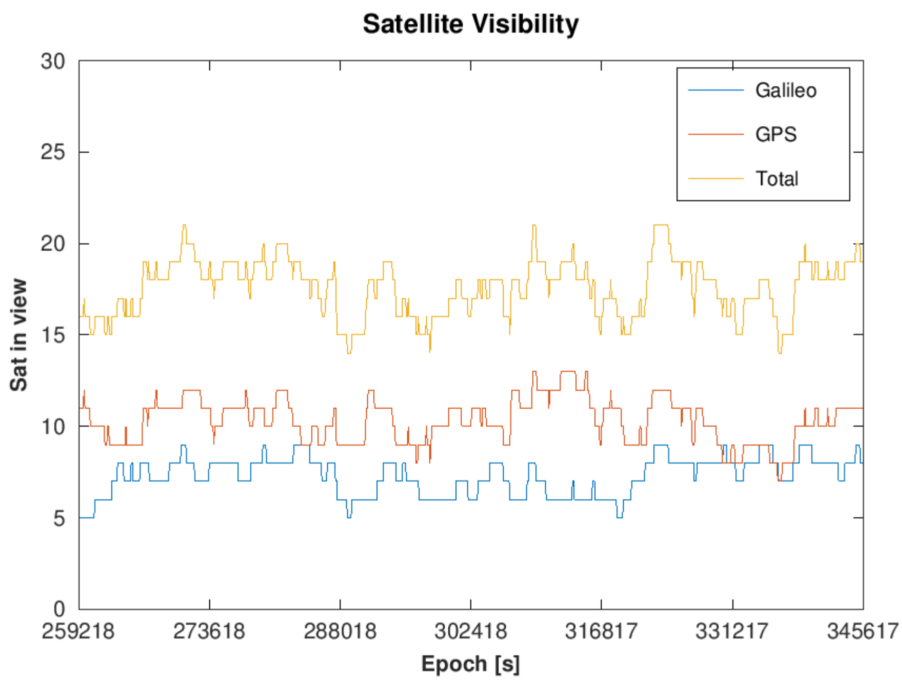
Results</td><td colspan="3">PASS</td></tr>
<tr><td colspan="3">The tool decodes and processes the information, giving Accuracy in the range previously mentioned.


The tool provides an output of light traffic for the whole scenario. Taking into account that the Accuracy threshold is 10 meters in coastal navigation, the following results are obtained.</td></tr>
</table>

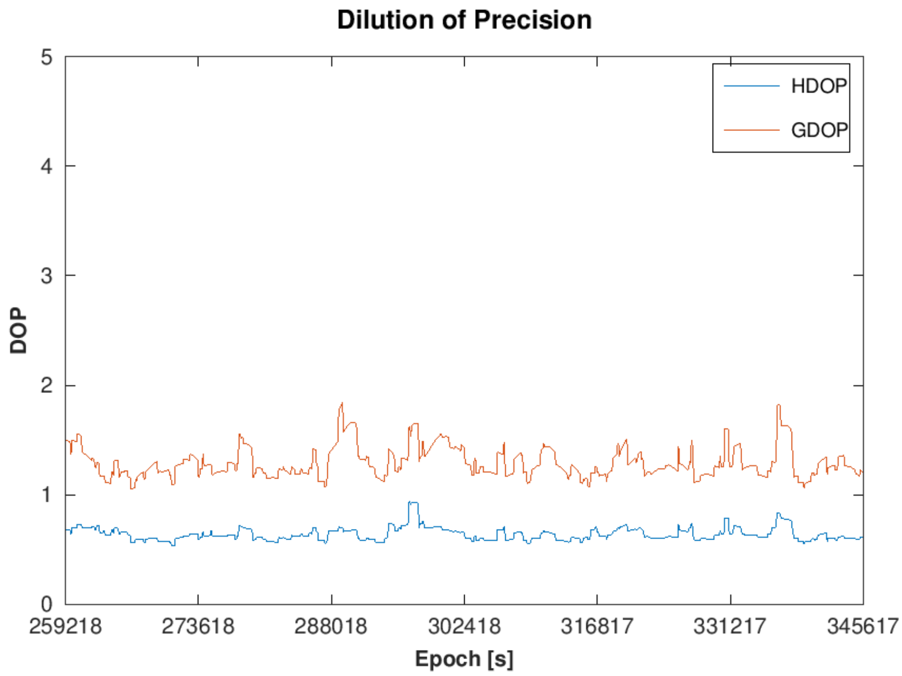
	 The tool decodes, processes the information and provides satellite visibility across the scenario. 

Test Code	**TC.MPT.003 MRAIM**		
Test Objective	To check that files are read, and a solution using MRAIM is generated as expected for a single location for a 24 h period previous the period in TC.MPT.001.		
Test Experiment Location	GMV Laboratory	**Test Experiment Equipment**	PC or laptop running Windows OS
Dependence SW	Octave 6.1.0		
Constellation used	GPS, Galileo		
Duration Time[s]	The execution: 100 s time step Period studied 24h, forecast for 03/04/2023 from 00:00:00 - 23:59:59		
Input Data	Galileo ephemerides GPS ephemerides		
Processing	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: - MRAIM algorithm selection - Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351] - Forecast for 03/04/2023 from 00:00:00 - 23:59:59 - GPS + Galileo - Nominal error models configurable. The error models used can be found in the document [RD.2] - Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m		
Outcome criteria	- The tool shall decode, process the information and provide HPL results in the range of [5-10]m for the configuration selected - The tool shall decode, process the information and provide HPL results in the range of [20-50]m for the configuration selected - The tool shall decode, process the information and provide traffic light status along the scenario, in particular for past days - The tool shall decode, process the information and provide satellite visibility along the scenario , in particular for past days		
Outcome (Pass/Fail) **Results**	**PASS** The tool decodes and processes the information, giving Accuracy values previously mentioned.  The tool decodes and processes the information, giving Protection Level values previously mentioned. The tool decodes, processes the information and provides the Horizontal Protection Level illustrating the Alert Limit of 25m.		

	 The tool provides an output of light traffic for the whole scenario. Considering that the Accuracy threshold is 10 meters in coastal navigation, the following results are obtained.  The tool decodes, processes the information and provides satellite visibility across the scenario.



The tool decodes, processes the information and provides for the HDOP and GDOP across the scenario.

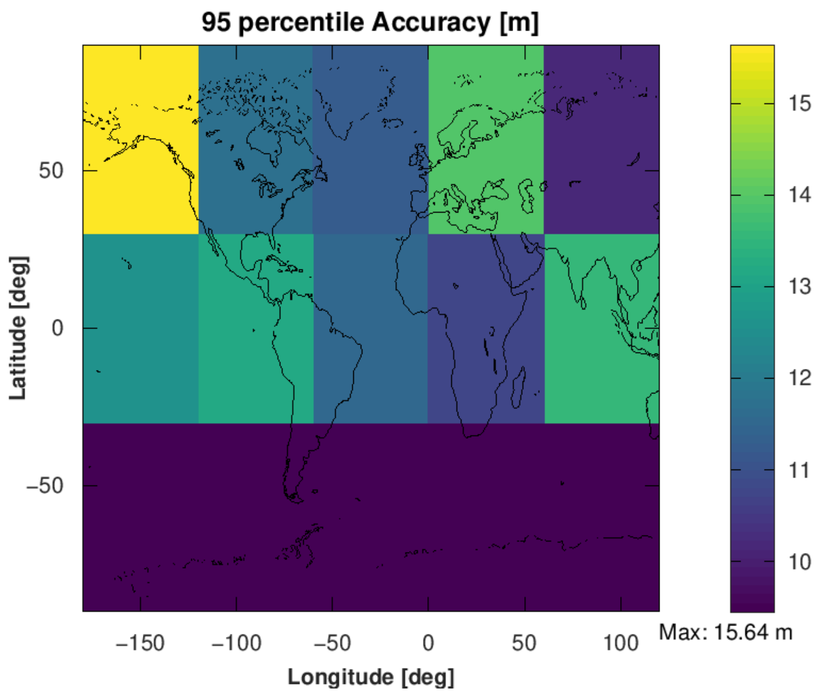


5.4 TC.MPT.004

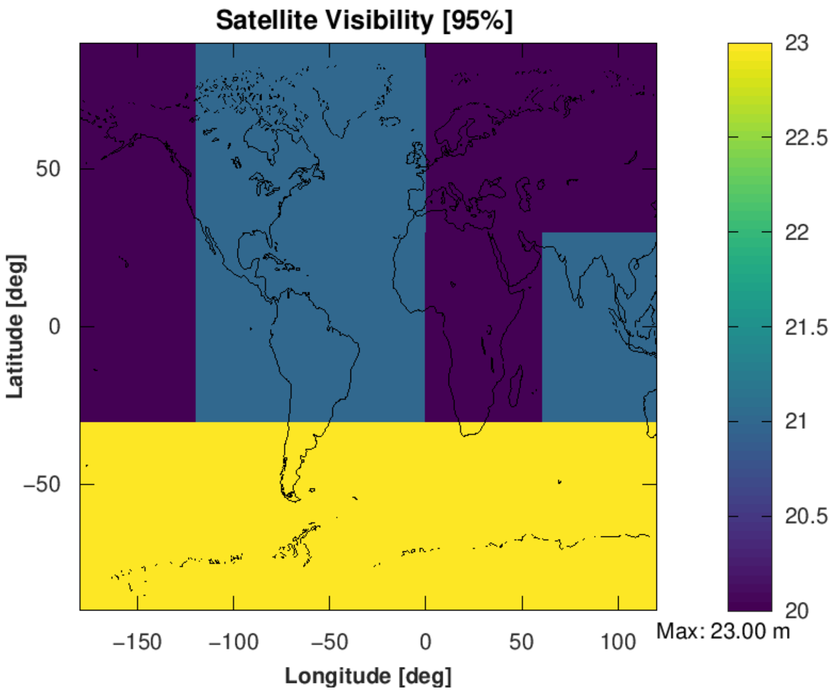
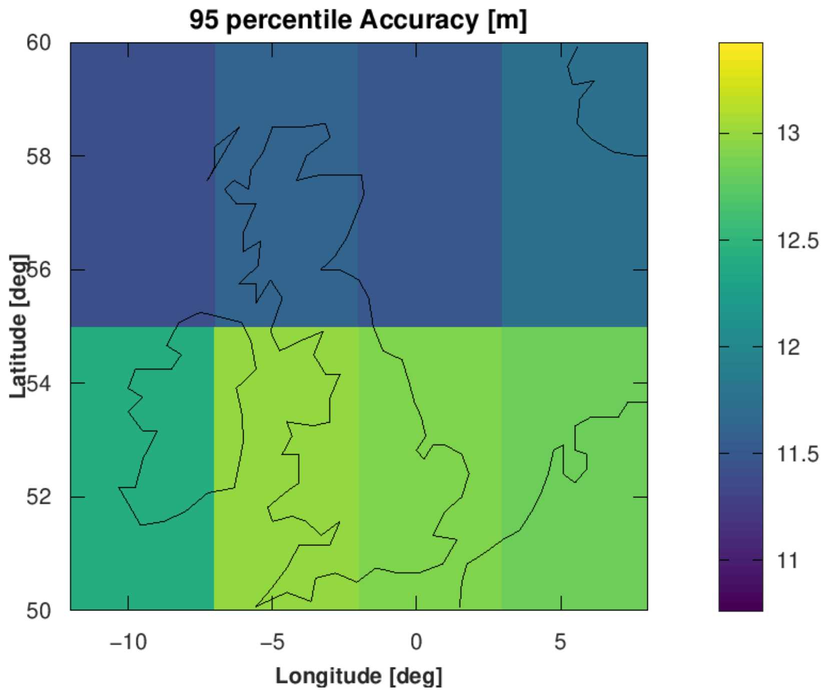
<table>
<tr><th>Test Code</th><th colspan="3">TC.MPT.004 MGRAIM</th></tr>
<tr><td>Test Objective</td><td colspan="3">To check that files are read, and a solution using MGRAIM is generated as expected for a single location for a 24 h period for every surface on Earth in a grid mode.</td></tr>
<tr><td>Test Experiment Location</td><td>GMV Laboratory</td><td>Test Experiment Equipment</td><td>PC or laptop running Windows OS</td></tr>
<tr><td>Dependence SW</td><td colspan="3">Octave 6.1.0</td></tr>
<tr><td>Constellation used</td><td colspan="3">GPS, Galileo</td></tr>
<tr><td>Duration Time</td><td colspan="3">The execution: 100 s time step
Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59</td></tr>
<tr><td>Input Data</td><td colspan="3">Galileo ephemerides
GPS ephemerides</td></tr>
<tr><td>Processing</td><td colspan="3">Execution of the Performance Prediction Prototype tool using a nominal configuration which includes:
- MGRAIM algorithm selection
- Grid mode selection
- Forecast for 13/04/2023 from 00:00:00 - 23:59:59
- GPS + Galileo
- Nominal error models configurable. The error models used can be found in the document [RD.2]
- Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m</td></tr>
<tr><td>Outcome criteria</td><td colspan="3">- The tool shall decode, process the information and provide accuracy results for a grid of users the surface of the Earth. The percentile 95% will be depicted in maps and will provide values in the range of [10-14]m over UK area. An additional map for the world will be added.
- The tool shall decode, process the information and provide satellite visibility for a grid of users the surface of the Earth . This information will be depicted in maps with percentiles of the number of satellites</td></tr>
<tr><td rowspan="2">Outcome (Pass/Fail)

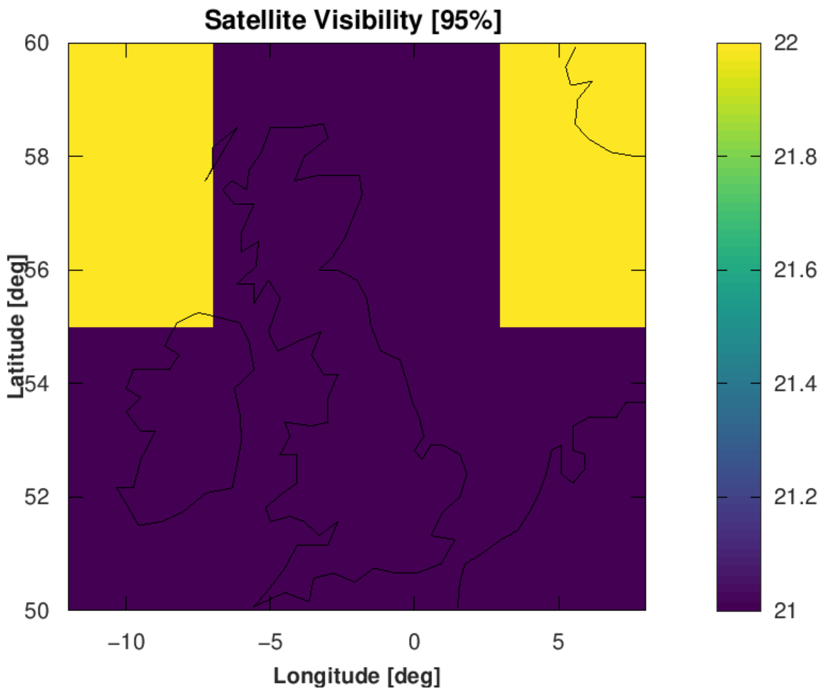
Results</td><td colspan="3">PASS</td></tr>
<tr><td colspan="3">Results for the World:

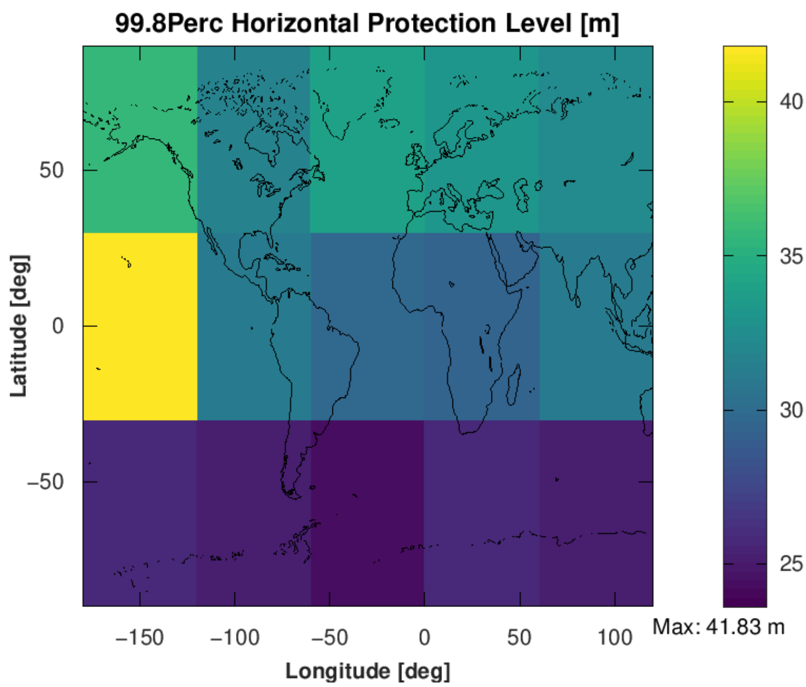
The tool decodes and processes the information, giving the percentile 95% in the range previously mentioned.

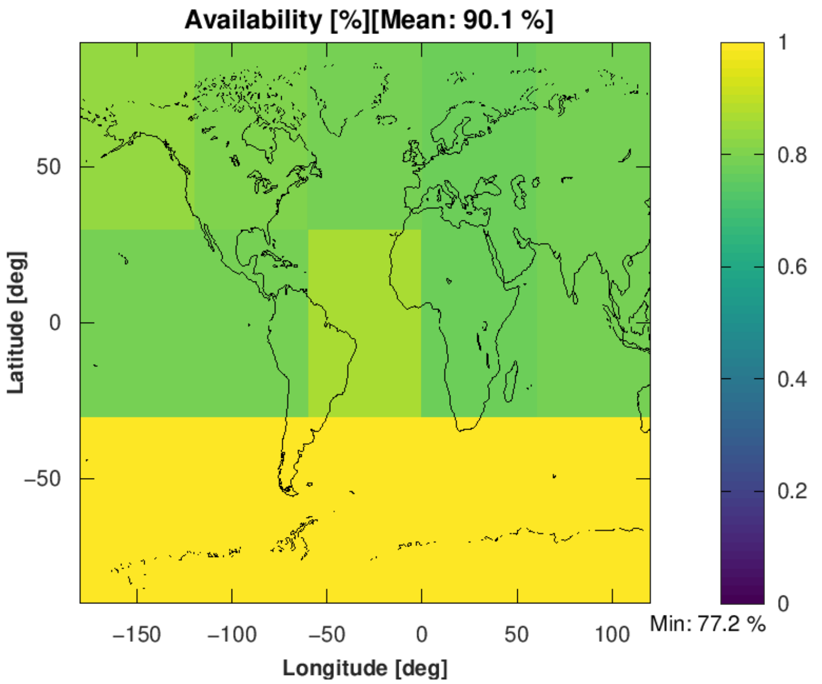


The tool decodes, processes the information, and provides satellite visibility across the scenario.</td></tr>
</table>

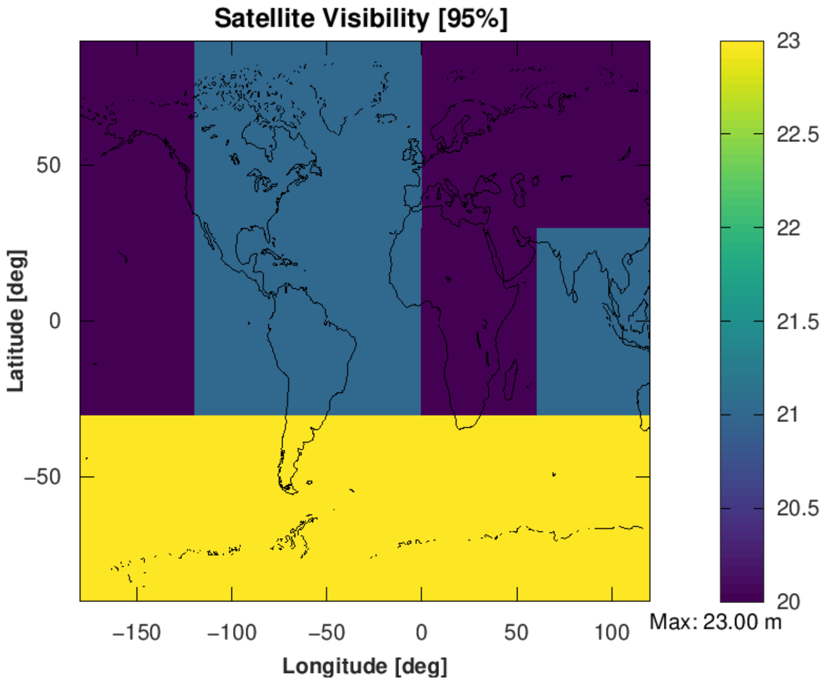
	 **Results for the UK area:** The tool decodes and processes the information, giving the percentile 95% in the range previously mentioned.  The tool decodes, processes the information, and provides satellite visibility across the scenario.


Satellite Visibility [95%]
Latitude [deg]
Longitude [deg]
60
58
56
54
52
50
−10
−5
0
5
22
21.8
21.6
21.4
21.2
21

Test Code	TC.MPT.004 MRAIM		
Test Objective	To check that files are read, and a solution using MRAIM is generated as expected for a single location for a 24 h period for every surface on Earth in a grid mode.		
Test Experiment Location	GMV Laboratory	**Test Experiment Equipment**	PC or laptop running Windows OS
Dependence SW	Octave 6.1.0		
Constellation used	GPS, Galileo		
Duration Time	The execution: 100 s time step Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59		
Input Data	Galileo ephemerides GPS ephemerides		
Processing	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: ▪ MRAIM algorithm selection ▪ Grid mode selection ▪ Forecast for 13/04/2023 from 00:00:00 - 23:59:59 ▪ GPS + Galileo ▪ Nominal error models configurable. The error models used can be found in the document [RD.2] ▪ Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m		
Outcome criteria	▪ The tool shall decode, process the information and provide HPL results for a grid of users the surface of the Earth. The percentile 99.8% will be depicted in maps and will provide values in the range of [20-45]m over UK area ▪ The tool shall decode, process the information and provide satellite visibility for a grid of users the surface of the Earth . This information will be depicted in satellite visibility percentile maps		
Outcome (Pass/Fail) **Results**	**PASS** **Results for the World** The tool decodes and processes the information, giving Protection Level values for users around the world.  The tool decodes, processes the information and provides traffic light status for a grid of users around the world.		

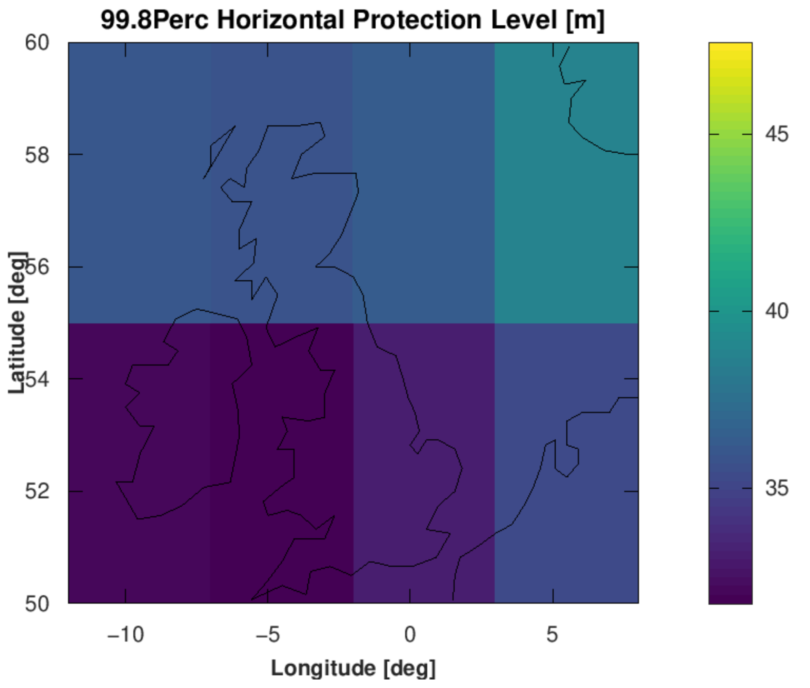


The tool decodes, processes the information, and provides satellite visibility across the scenario for users around the world.

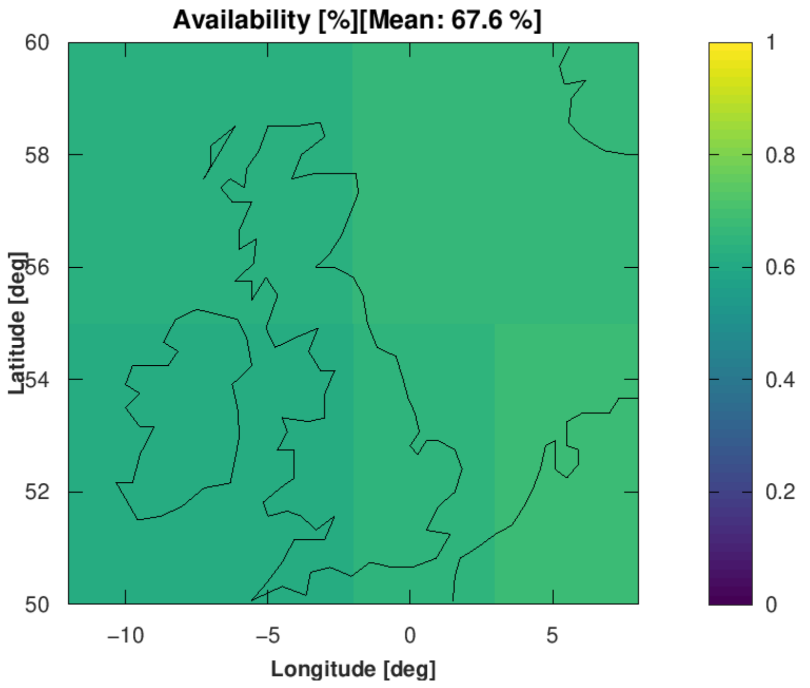


Results for the UK area

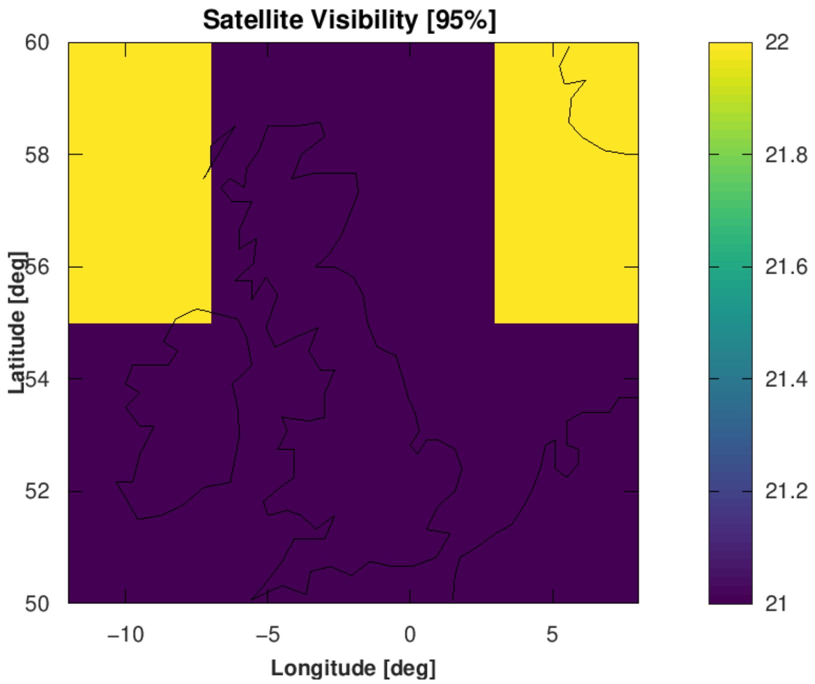
The tool decodes and processes the information, giving Protection Level values in the range previously mentioned.



The tool decodes, processes the information and provides traffic light status for a grid of users in the studied area.



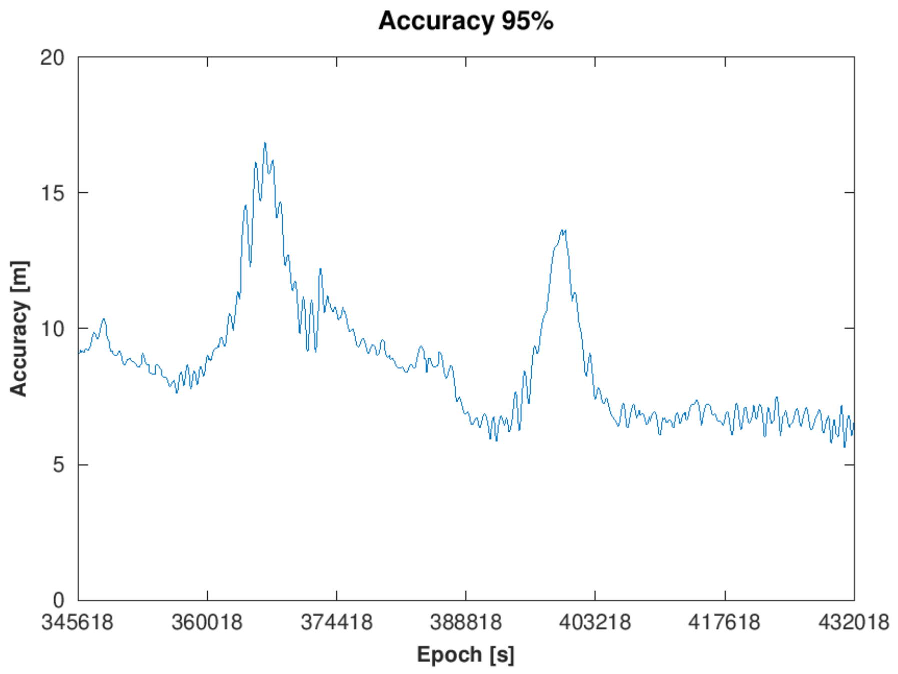
The tool decodes, processes the information, and provides satellite visibility across the scenario for a grid of users in the studied area.

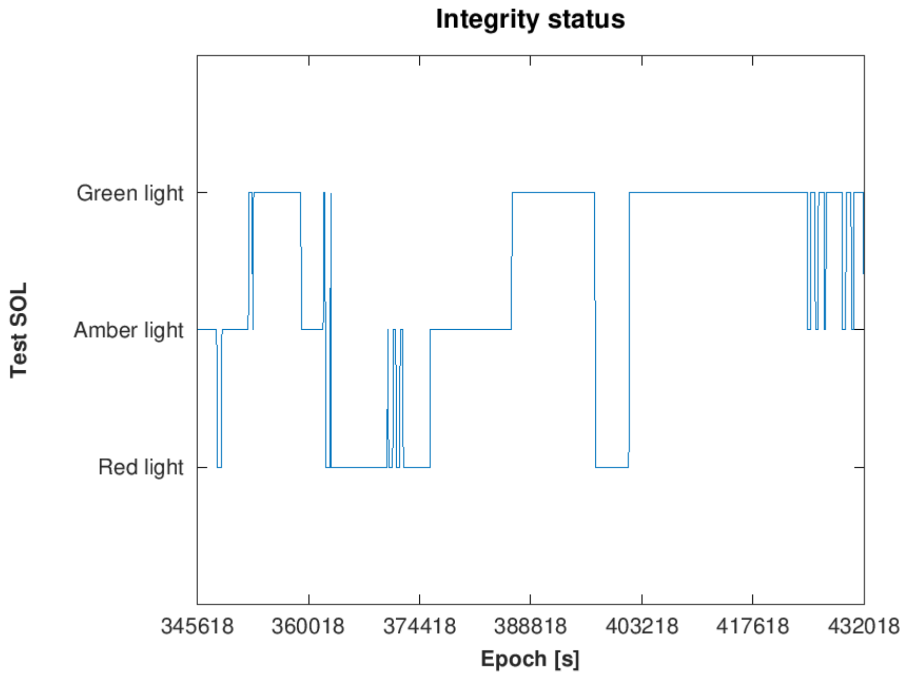
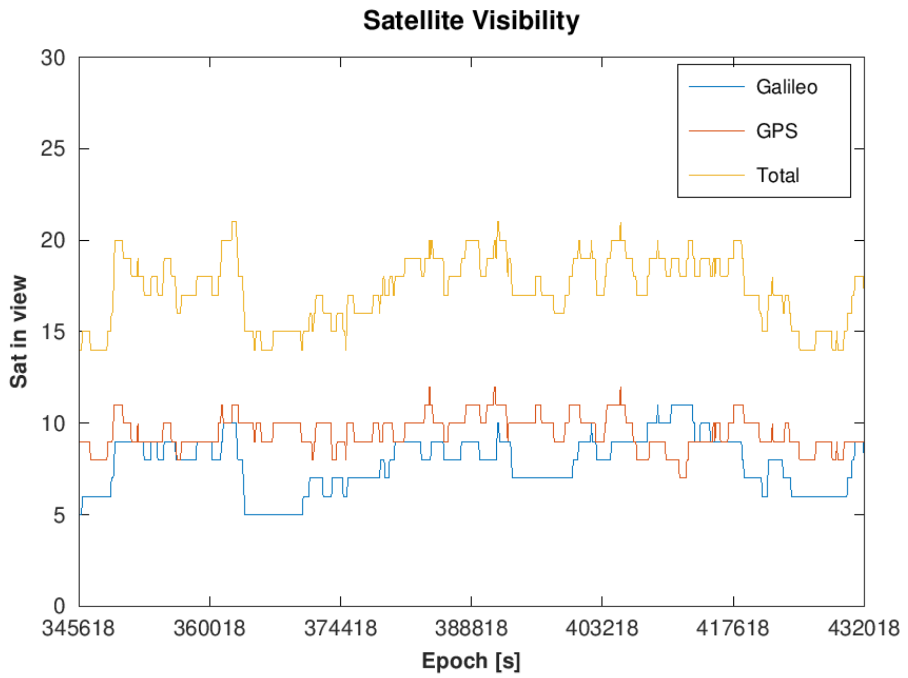
Satellite Visibility [95%]
Latitude [deg]
Longitude [deg]
60
58
56
54
52
50
−10
−5
0
5
22
21.8
21.6
21.4
21.2
21

5.5 TC.MPT.005

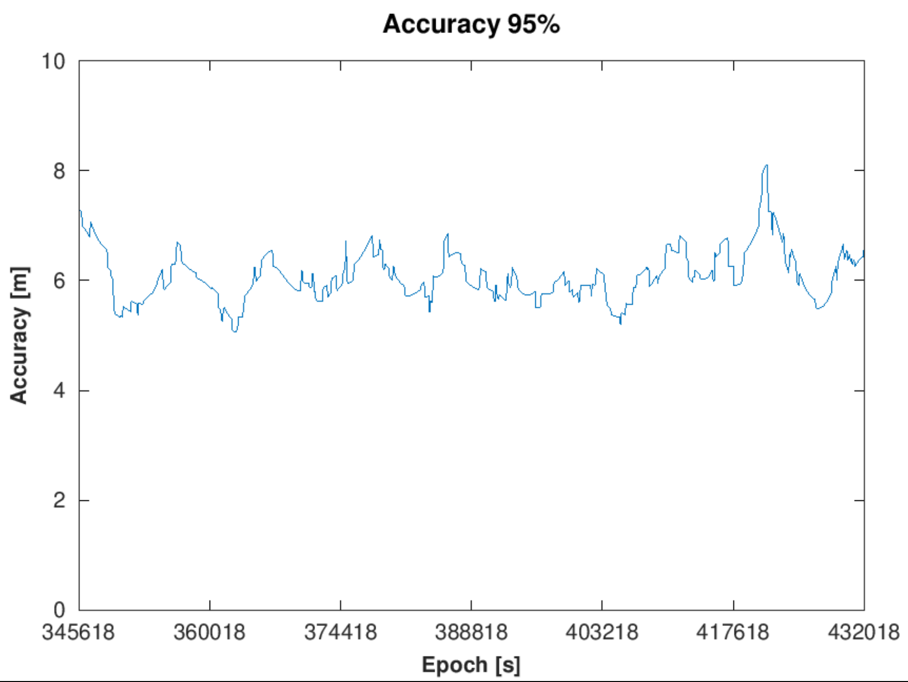
Test Code	TC.MPT.005 MGRAIM		
Test Objective	To check that files are read, and a solution using MGRAIM is generated as expected for a single location for a 24 h period excluding satellites from NANUs, NAGUs or equivalent.		
Test Experiment Location	GMV Laboratory	**Test Experiment Equipment**	PC or laptop running Windows OS
Constellation used	GPS, Galileo		
Duration Time	The execution: 100 s time step Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59		
Input Data	Galileo ephemerides GPS ephemerides		
Processing	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: ▪ MGRAIM algorithm selection ▪ Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351] ▪ Forecast for 13/04/2023 from 00:00:00 - 23:59:59 ▪ GPS + Galileo ▪ Nominal error models configurable. The error models used can be found in the document [RD.2] Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m A synthetic NANUs and NAGUs message excluding one satellite in each constellation, in this case G21 E13		
Outcome criteria	▪ The tool shall decode, process the information and provide accuracy results in the range of [5-20]m for the selected configuration, and they will be higher compared to the TC.MPT.001 ▪ The tool shall decode, process the information and provide traffic light status along the scenario ▪ The tool shall decode, process the information and provide satellite visibility along the scenario . This information shall clearly indicate that satellites are not visible when applying the integrity information if compared against TC.MPT.001 results		
Outcome (Pass/Fail)	**PASS**		
Results	The tool decodes and processes the information, giving Accuracy values in the range previous mentioned.		



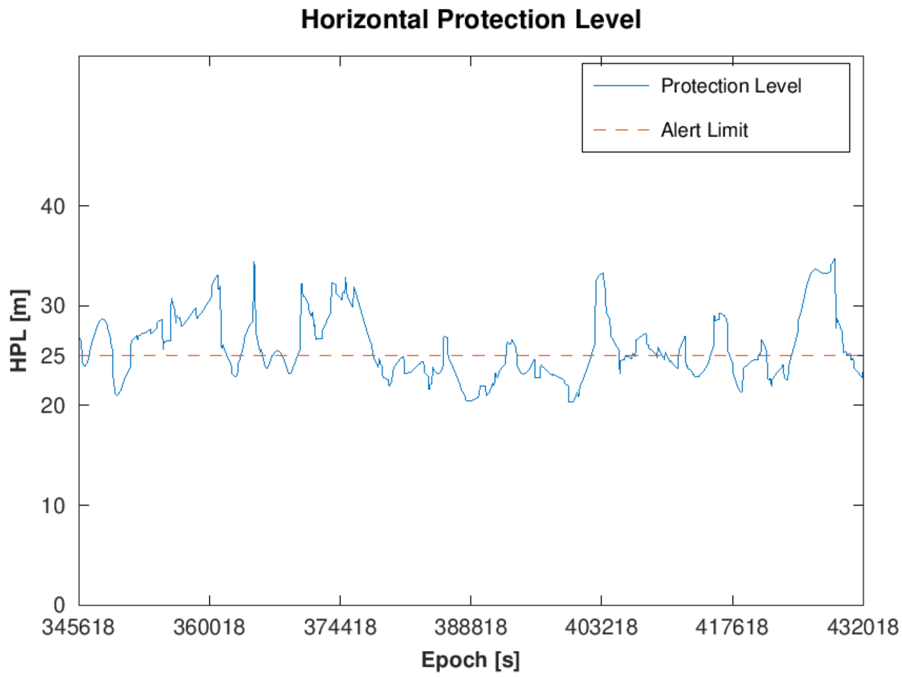
The tool provides an output of light traffic for the whole scenario. Considering that the Accuracy threshold is 10 meters in coastal navigation, the following results are obtained.

	 The tool decodes, processes the information, and provides satellite visibility across the scenario. 

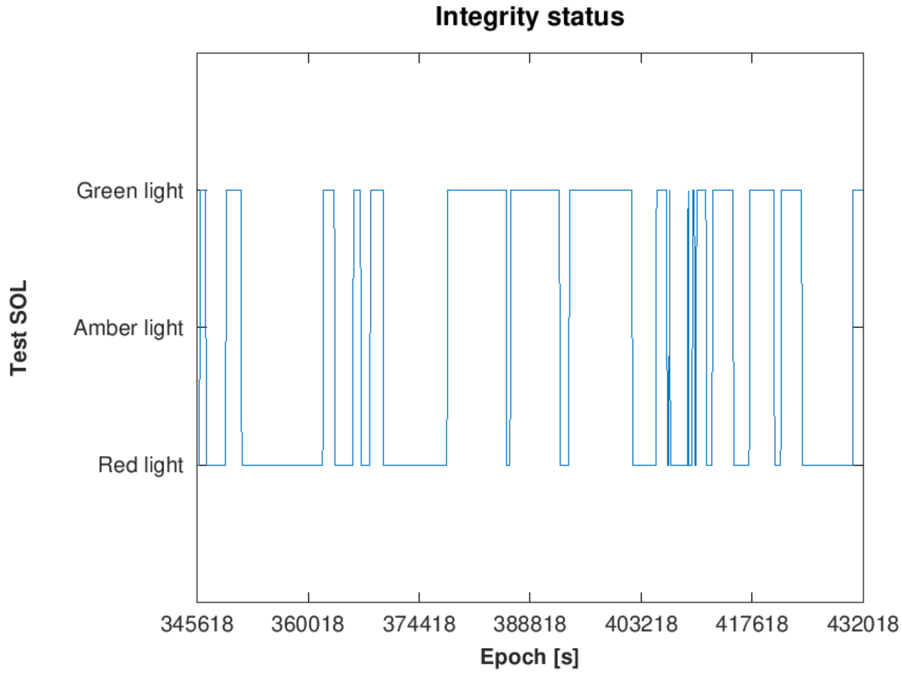
<table>
<tr><th>Test Code</th><th colspan="3">TC.MPT.005 MRAIM</th></tr>
<tr><td>Test Objective</td><td colspan="3">To check that files are read, and a solution using MRAIM is generated as expected for a single location for a 24 h period excluding satellites from NANUs, NAGUs or equivalent.</td></tr>
<tr><td>Test Experiment Location</td><td>GMV Laboratory</td><td>Test Experiment Equipment</td><td>PC or laptop running Windows OS</td></tr>
<tr><td>Dependence SW</td><td colspan="3">Octave 6.1.0</td></tr>
<tr><td>Constellation used</td><td colspan="3">GPS, Galileo</td></tr>
<tr><td>Duration Time</td><td colspan="3">The execution: 100 s time step
Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59</td></tr>
<tr><td>Input Data</td><td colspan="3">Galileo ephemerides
GPS ephemerides</td></tr>
<tr><td>Processing</td><td colspan="3">Execution of the Performance Prediction Prototype tool using a nominal configuration which includes:
- MRAIM algorithm selection
- Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351]
- Forecast for 13/04/2023 from 00:00:00 - 23:59:59
- GPS + Galileo
- Nominal error models configurable. The error models used can be found in the document [RD.2]
- Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m
A synthetic NANUs and NAGUs message excluding one satellite in each constellation, in this case G21 E13</td></tr>
<tr><td>Outcome criteria</td><td colspan="3">- The tool shall decode, process the information and provide Accuracy results in the range of [5-10]m for the selected configuration, and they will be higher compared to the TC.MPT.001
- The tool shall decode, process the information and provide HPL results in the range of [20-40]m for the selected configuration, and they will be higher compared to the TC.MPT.001
- The tool shall decode, process the information and provide traffic light status along the scenario
- The tool shall decode, process the information and provide satellite visibility along the scenario . This information shall clearly indicate that satellites are not visible when applying the integrity information if compared against TC.MPT.001 results</td></tr>
<tr><td rowspan="2">Outcome (Pass/Fail)

Results</td><td colspan="3">PASS</td></tr>
<tr><td colspan="3">The tool decodes and processes the information, giving Accuracy values in the range previous mentioned.

</td></tr>
</table>

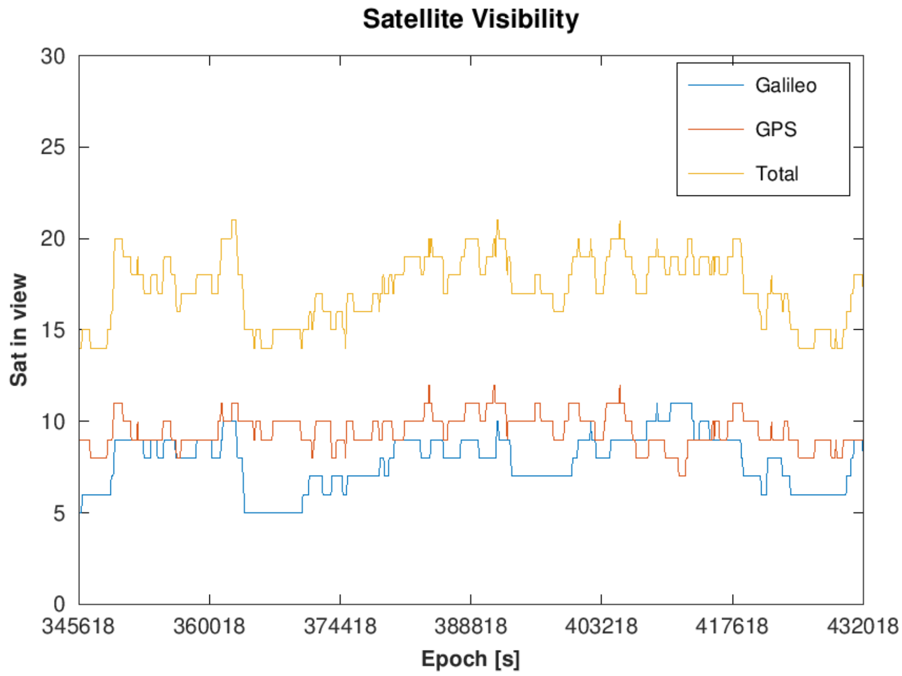
The tool decodes and processes the information, giving Protection Level values in the range previous mentioned. The tool decodes, processes the information and provides the Horizontal Protection Level illustrating the Alert Limit of 25m.



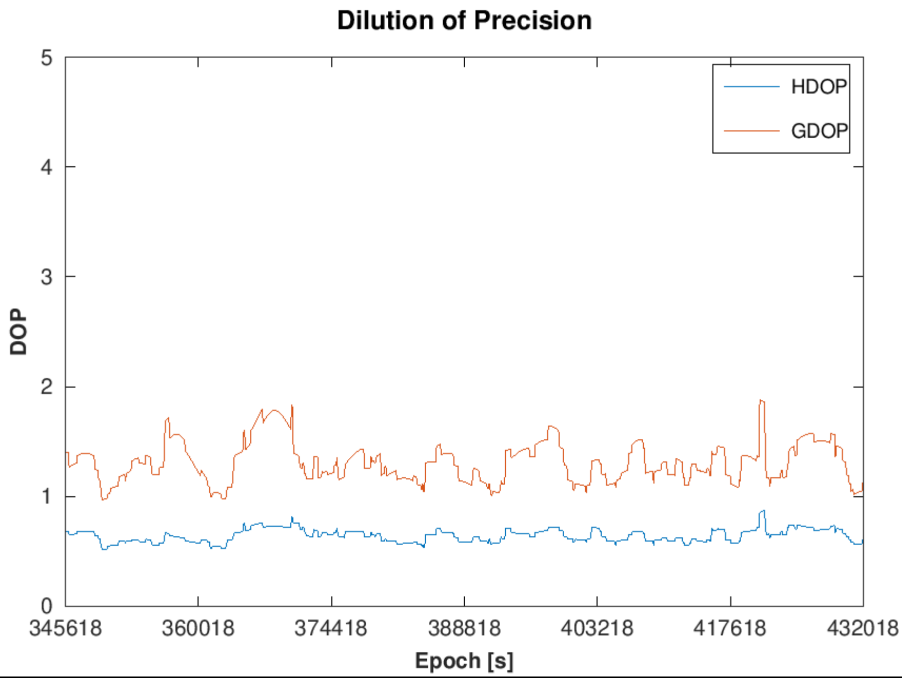
The tool provides an output of light traffic for the whole scenario. Considering that the Integrity Alert Limit is 25 meters in coastal navigation, the following results are obtained.



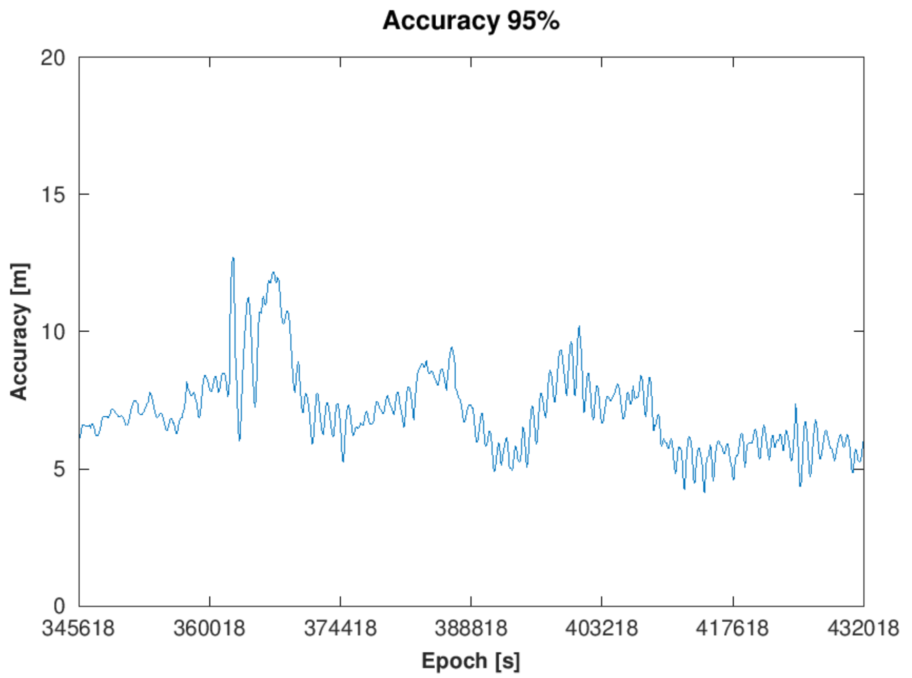
The tool decodes, processes the information and provides satellite visibility across the scenario.

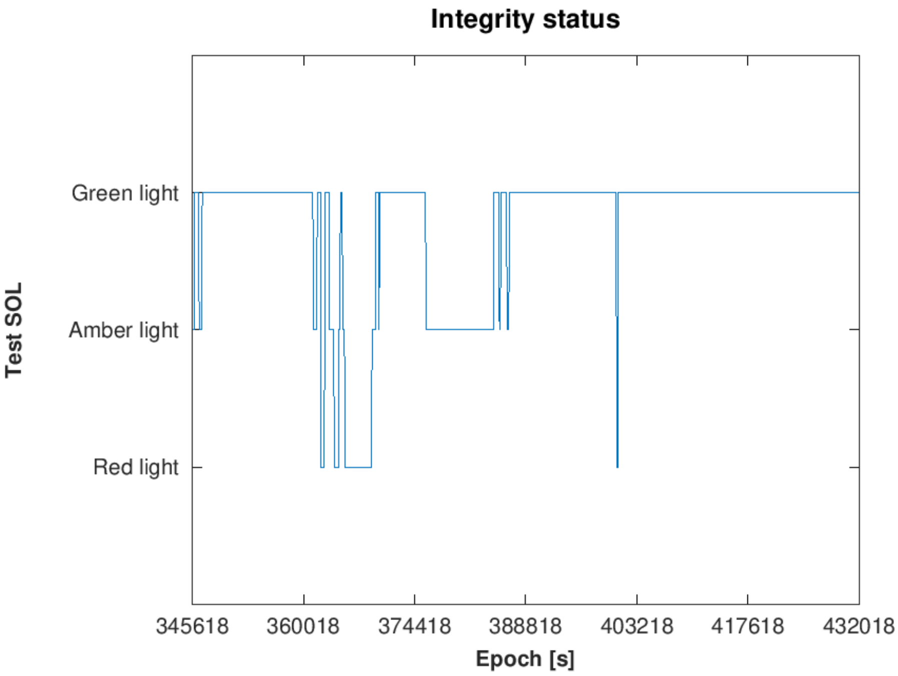


The tool decodes, processes the information HDOP and GDOP across the scenario.

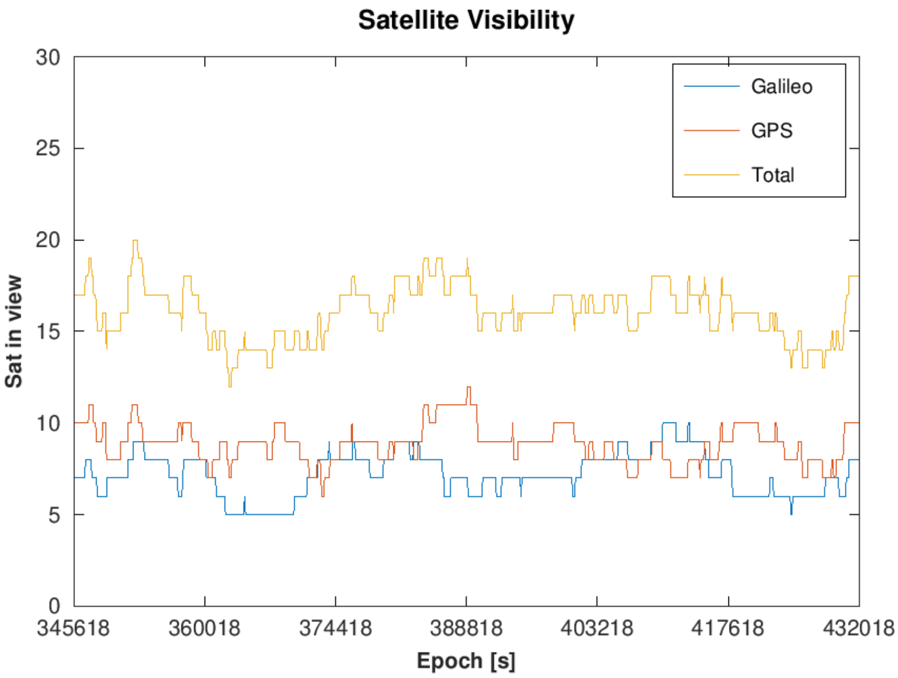


5.6 TC.MPT.006

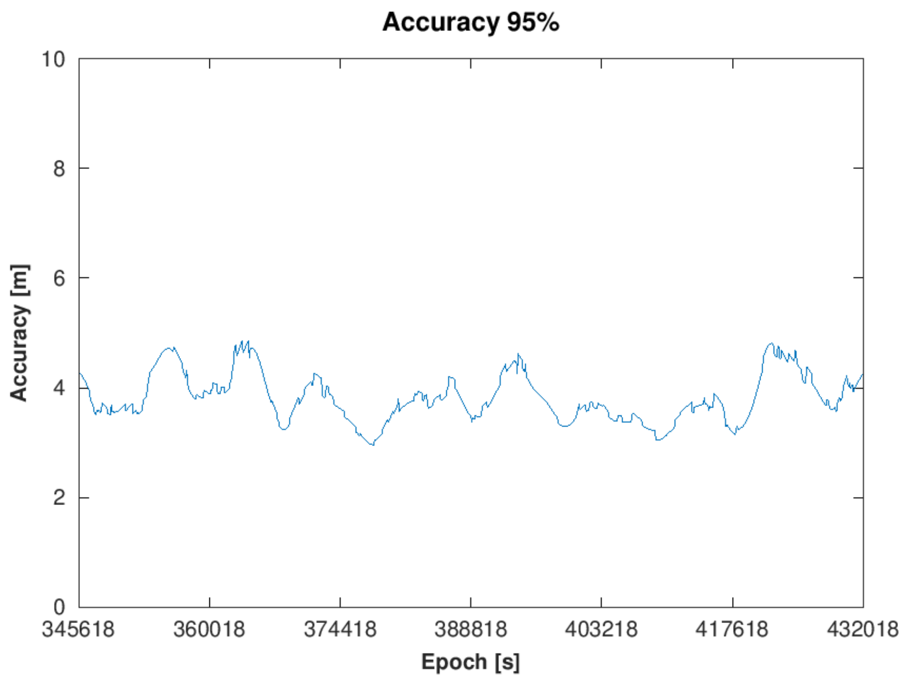
Test Code	TC.MPT.006 MGRAIM		
Test Objective	To check that files are read, and a solution using MGRAIM is generated as expected for a single location for a 24 h period.		
Test Experiment Location	GMV Laboratory	**Test Experiment Equipment**	PC or laptop running Windows OS
Dependence SW	Octave 6.1.0		
Constellation used	GPS, Galileo		
Duration Time	The execution: 100 s time step Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59		
Input Data	Galileo ephemerides GPS ephemerides		
Processing	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: ▪ MGRAIM algorithm selection ▪ Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351] ▪ Forecast for 13/04/2023 from 00:00:00 - 23:59:59 ▪ GPS + Galileo + SBAS ▪ Nominal error models configurable. The error models used can be found in the document [RD.2] ▪ Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m		
Outcome criteria	▪ The tool shall decode, process the information and provide accuracy results in the range of [3-15]m for the configuration selected. Accuracy improvement shall be clearly visible if compared against TC.MPT.001 results ▪ The tool shall decode, process the information and provide traffic light status along the scenario ▪ The tool shall decode, process the information and provide satellite visibility along the scenario .		
Outcome (Pass/Fail) **Results**	**PASS** The tool decodes and processes the information, giving Accuracy values in the range previous mentioned.  The tool provides an output of light traffic for the whole scenario. Considering that the Accuracy threshold is 10 meters in coastal navigation, the following results are obtained		



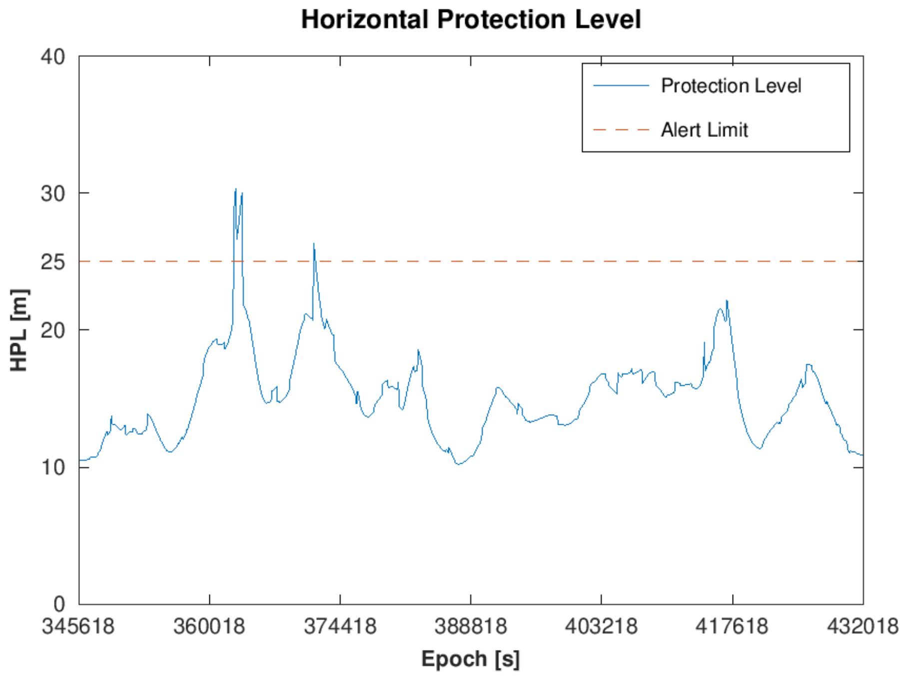
The tool decodes, processes the information and provides satellite visibility across the scenario.



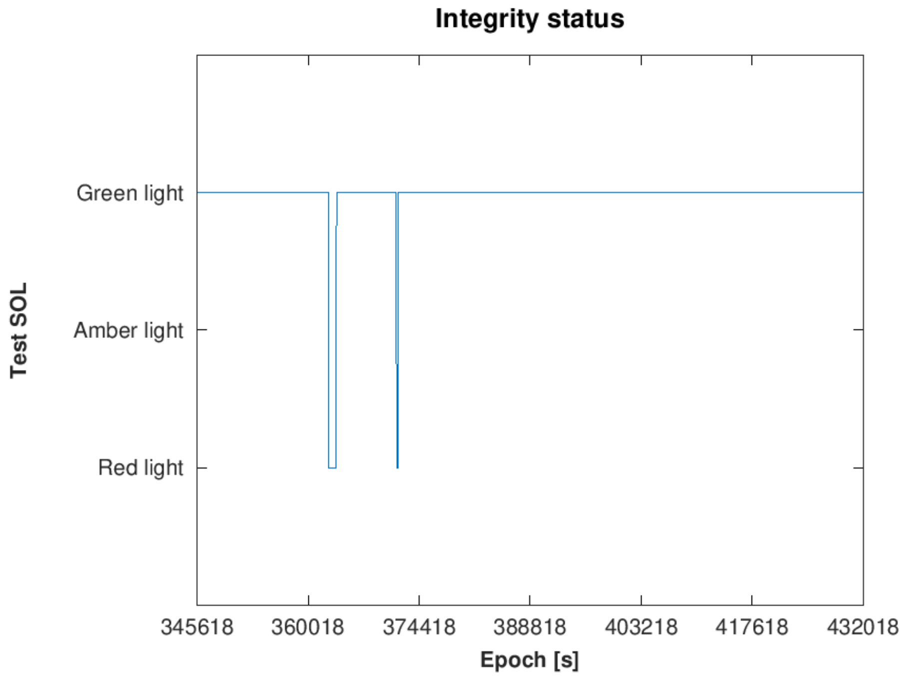
<table>
<tr><th>Test Code</th><th colspan="3">TC.MPT.006 MRAIM</th></tr>
<tr><td>Test Objective</td><td colspan="3">To check that files are read, and a solution using MRAIM is generated as expected for a single location for a 24 h period.</td></tr>
<tr><td>Test Experiment Location</td><td>GMV Laboratory</td><td>Test Experiment Equipment</td><td>PC or laptop running Windows OS</td></tr>
<tr><td>Dependence SW</td><td colspan="3">Octave 6.1.0</td></tr>
<tr><td>Constellation used</td><td colspan="3">GPS, Galileo</td></tr>
<tr><td>Duration Time</td><td colspan="3">The execution: 100 s time step
Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59</td></tr>
<tr><td>Input Data</td><td colspan="3">Galileo ephemerides
GPS ephemerides</td></tr>
<tr><td>Processing</td><td colspan="3">Execution of the Performance Prediction Prototype tool using a nominal configuration which includes:
■ MRAIM algorithm selection
■ Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351]
■ Forecast for 13/04/2023 from 00:00:00 - 23:59:59
■ GPS + Galileo + SBAS
■ Nominal error models configurable. The error models used can be found in the document [RD.2]
■ Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m</td></tr>
<tr><td>Outcome criteria</td><td colspan="3">■ The tool shall decode, process the information and provide HPL results in the range of [2-6]m for the configuration selected. Accuracy improvement shall be clearly visible if compared against TC.MPT.001 results
■ The tool shall decode, process the information and provide HPL results in the range of [10-30]m for the configuration selected. Accuracy improvement shall be clearly visible if compared against TC.MPT.001 results
■ The tool shall decode, process the information and provide traffic light status along the scenario
■ The tool shall decode, process the information and provide satellite visibility along the scenario</td></tr>
<tr><td rowspan="2">Outcome (Pass/Fail)

Results</td><td colspan="3">PASS</td></tr>
<tr><td colspan="3">The tool decodes and processes the information, giving Accuracy values in the range previous mentioned.

</td></tr>
</table>

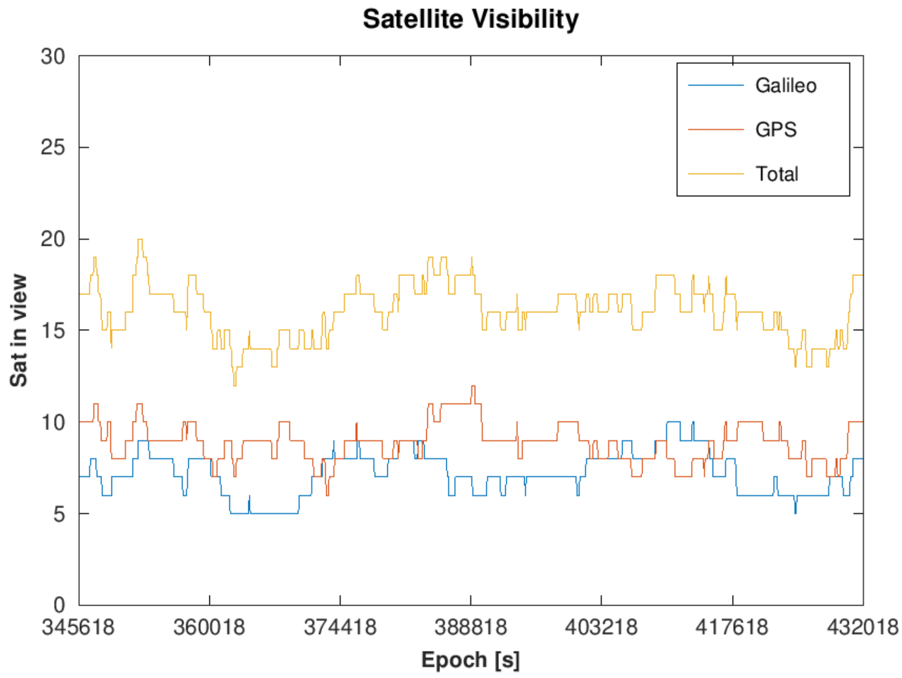
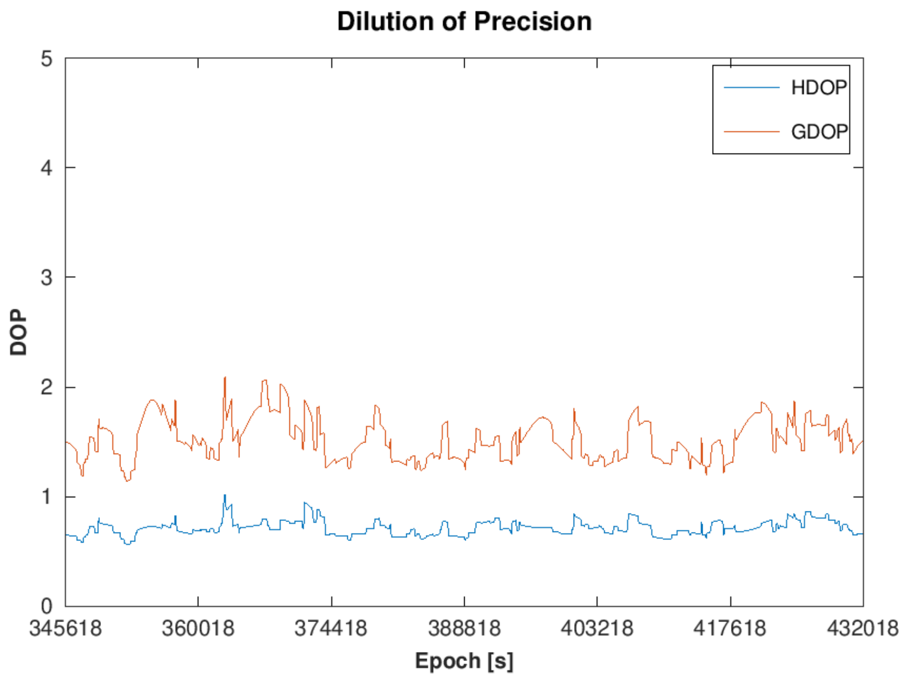
The tool decodes and processes the information, giving Protection Level values in the range previous mentioned. The tool decodes, processes the information and provides the Horizontal Protection Level illustrating the Alert Limit of 25m.



The tool provides an output of light traffic for the whole scenario. Considering that the Integrity Alert Limit is 25 meters in coastal navigation, the following results are obtained.



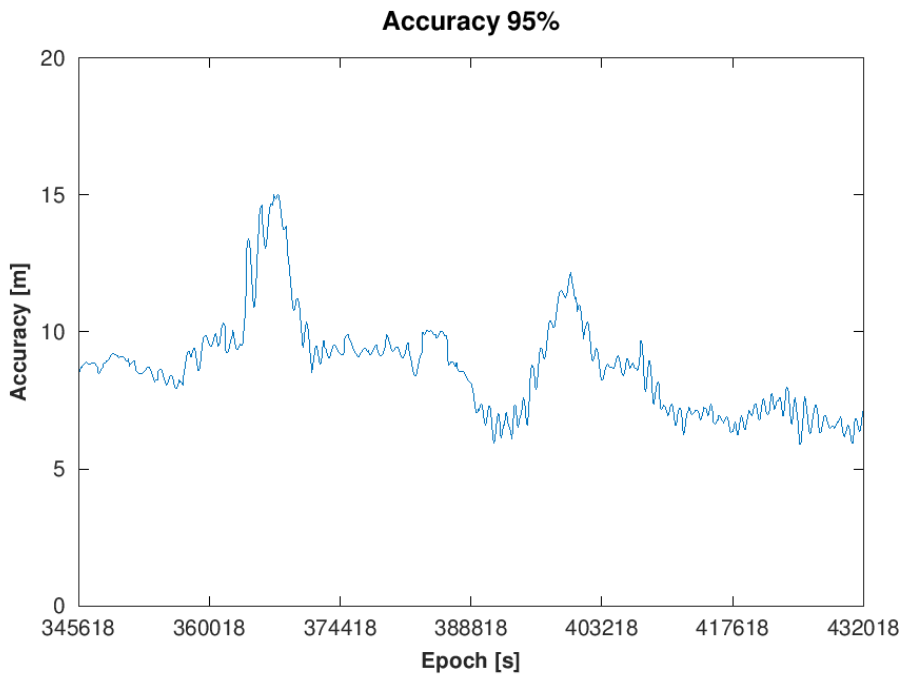
The tool decodes, processes the information and provides satellite visibility across the scenario.

	 The tool decodes, processes the information and provides for the HDOP and GDOP across the scenario. 

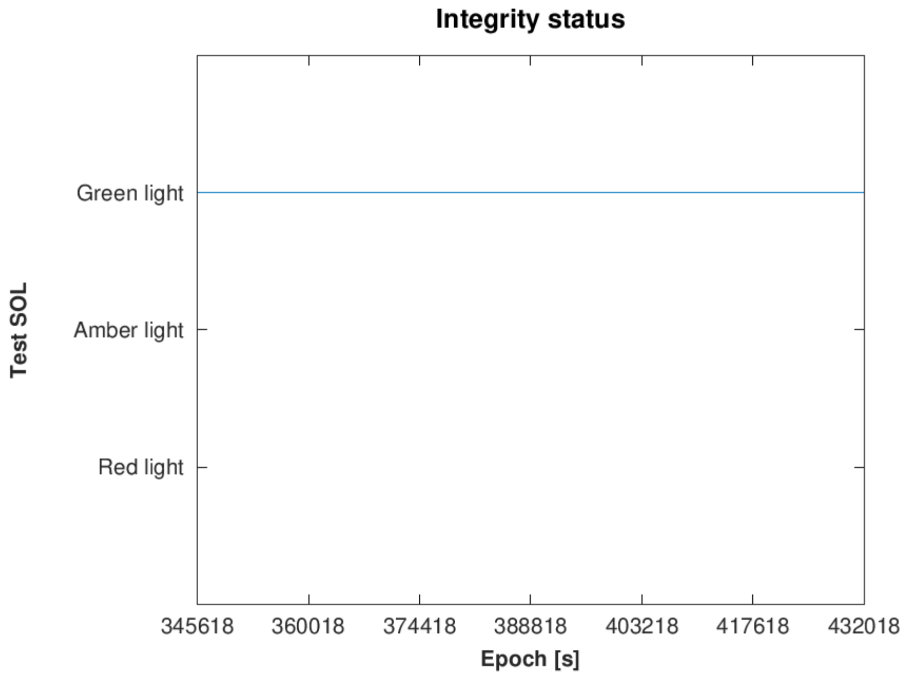
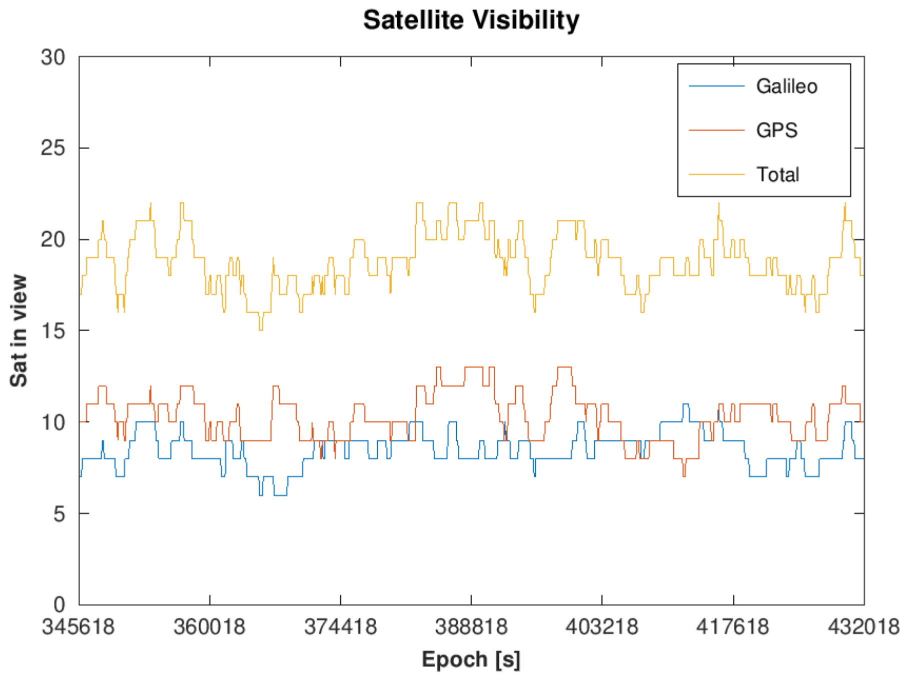
5.7 TC.MPT.007

<table>
<tr><th>Test Code</th><th colspan="3">TC.MPT.007 MGRAIM</th></tr>
<tr><td>Test Objective</td><td colspan="3">To check that files are read, and a solution using MGRAIM is generated as expected for a single location for a 24 h period.</td></tr>
<tr><td>Test Experiment Location</td><td>GMV Laboratory</td><td>Test Experiment Equipment</td><td>PC or laptop running Windows OS</td></tr>
<tr><td>Dependence SW</td><td colspan="3">Octave 6.1.0</td></tr>
<tr><td>Constellation used</td><td colspan="3">GPS, Galileo</td></tr>
<tr><td>Duration Time</td><td colspan="3">The execution: 100 s time step

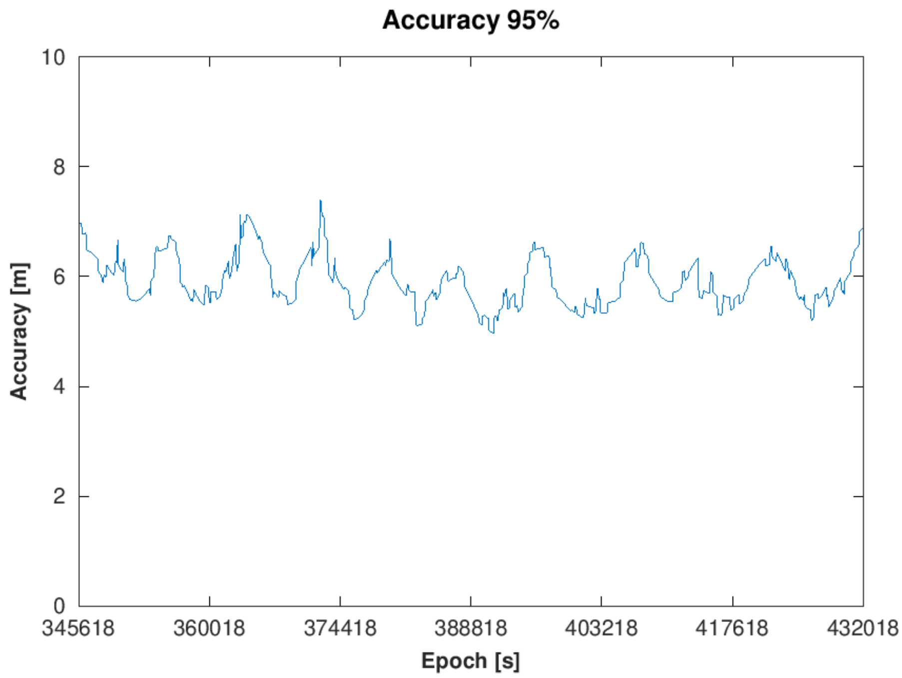
Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59</td></tr>
<tr><td>Input Data</td><td colspan="3">Galileo ephemerides
GPS ephemerides</td></tr>
<tr><td>Processing</td><td colspan="3">Execution of the Performance Prediction Prototype tool using a nominal configuration which includes:
■ MGRAIM algorithm selection
■ Grid mode selection
■ Forecast for 13/04/2023 from 00:00:00 - 23:59:59
■ GPS + Galileo
■ Nominal error models configurable. The error models used can be found in the document [RD.2]
■ Ocean navigation: Accuracy threshold = 100 m; No Integrity Alert Limit</td></tr>
<tr><td>Outcome criteria</td><td colspan="3">■ The tool shall decode, process the information and provide accuracy results in the range of [5-15]m for the configuration selected. These results shall be exactly the same as TC.MPT.001 results
■ The tool shall decode, process the information and provide traffic light status along the scenario. This availability shall be significantly increased with respect to TC.MPT.001 results
■ The tool shall decode, process the information and provide satellite visibility along the scenario . These results shall be exactly the same as TC.MPT.001 results</td></tr>
<tr><td rowspan="2">Outcome (Pass/Fail)

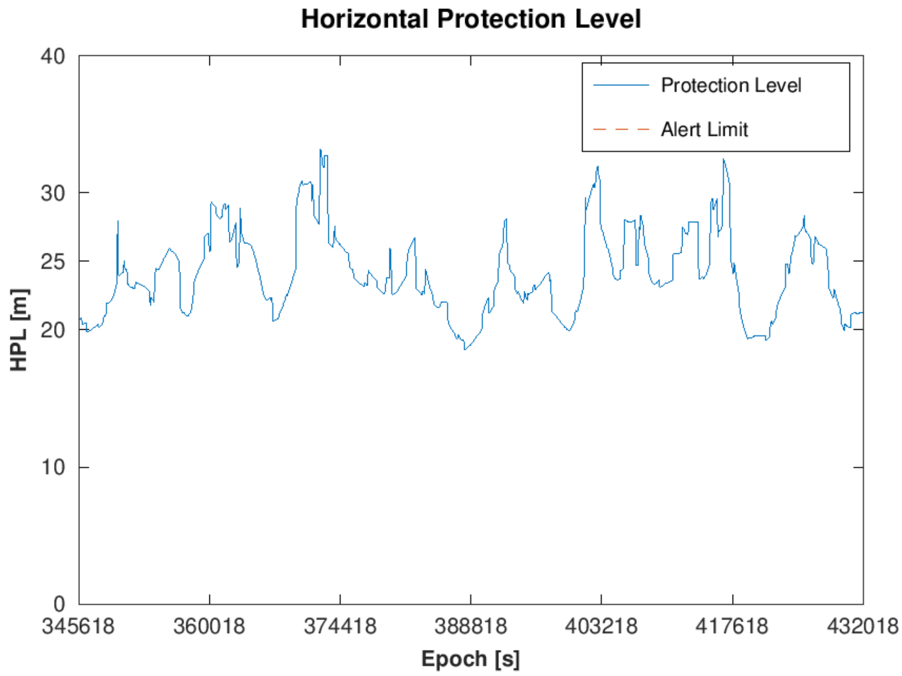
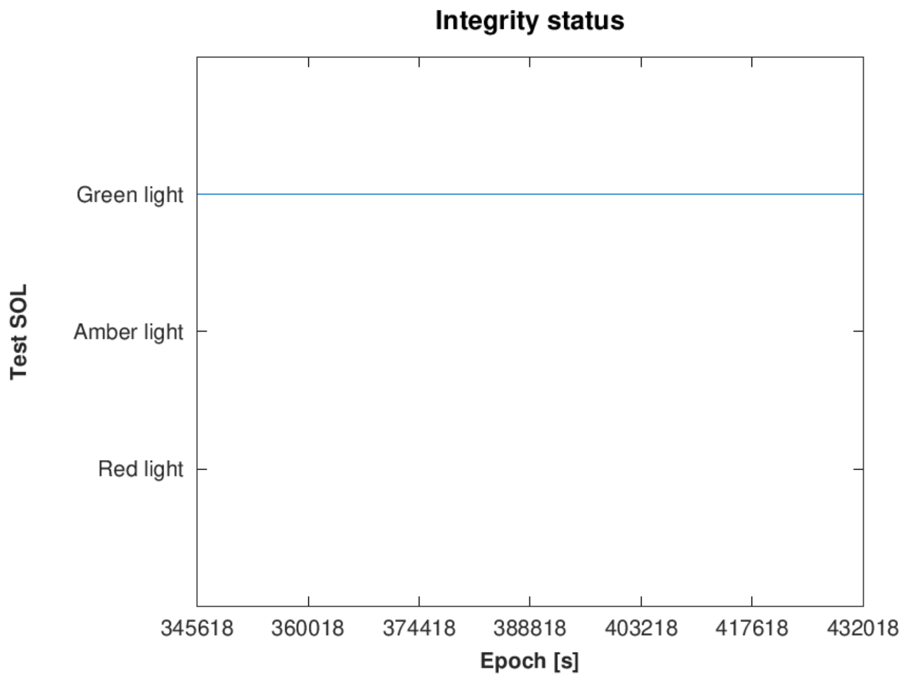
Results</td><td colspan="3">PASS</td></tr>
<tr><td colspan="3">The tool decodes and processes the information, giving Accuracy values in the range previous mentioned. The results are the same as TC.MPT.001 results.


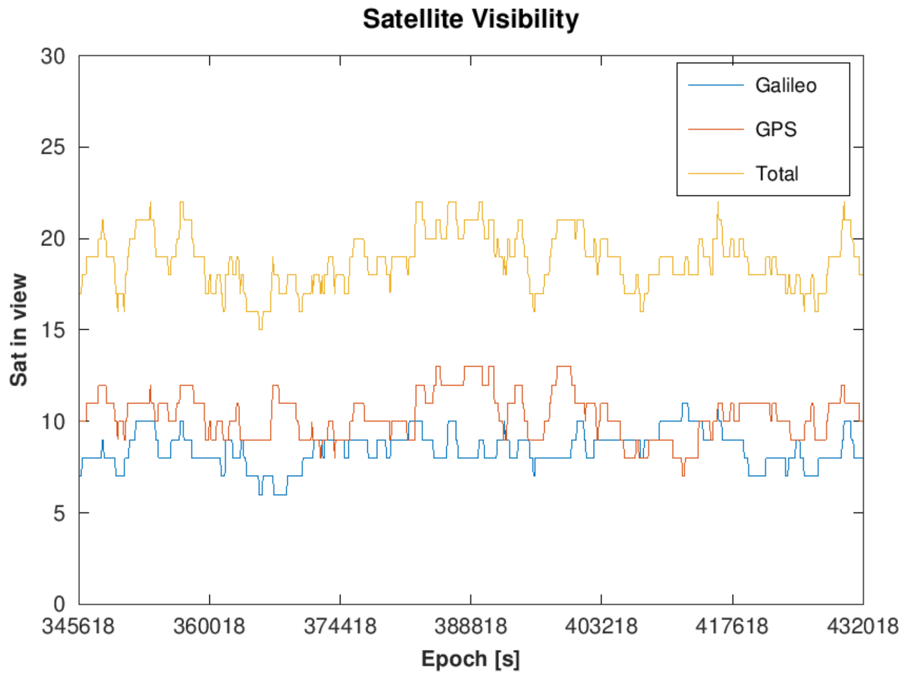
The tool provides an output of light traffic for the whole scenario. No alarms due to the navigation phase can be seen compared to TC.MPT.001.</td></tr>
</table>

	 The tool decodes, processes the information and provides satellite visibility across the scenario taking into account integrity alarms. 

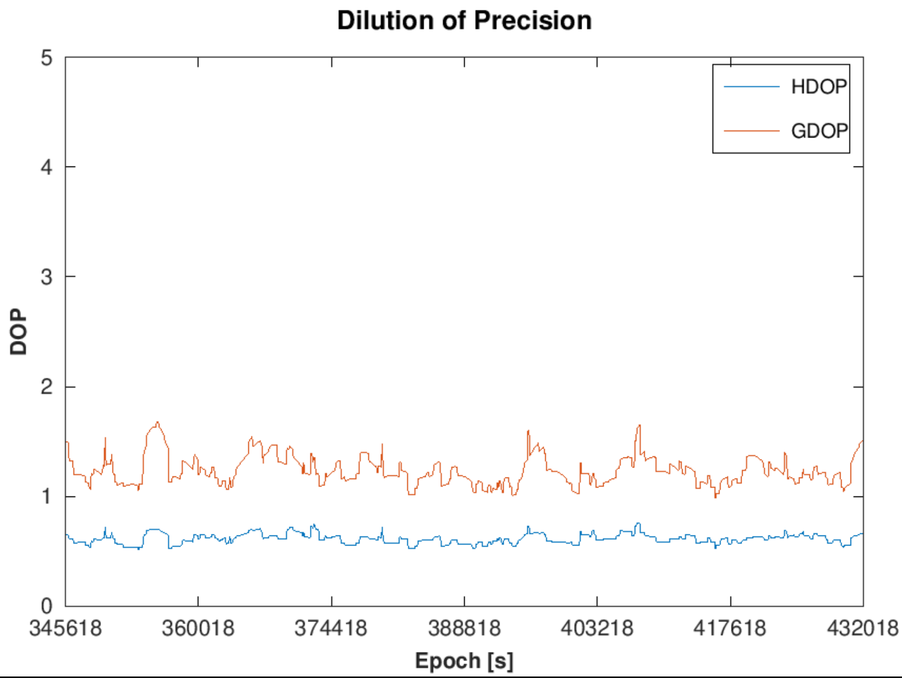
<table>
<tr><th>Test Code</th><th colspan="3">TC.MPT.007 MRAIM</th></tr>
<tr><td>Test Objective</td><td colspan="3">To check that files are read, and a solution using MRAIM is generated as expected for a single location for a 24 h period.</td></tr>
<tr><td>Test Experiment Location</td><td>GMV Laboratory</td><td>Test Experiment Equipment</td><td>PC or laptop running Windows OS</td></tr>
<tr><td>Dependence SW</td><td colspan="3">Octave 6.1.0</td></tr>
<tr><td>Constellation used</td><td colspan="3">GPS, Galileo</td></tr>
<tr><td>Duration Time</td><td colspan="3">The execution: 100 s time step
Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59</td></tr>
<tr><td>Input Data</td><td colspan="3">Galileo ephemerides
GPS ephemerides</td></tr>
<tr><td>Processing</td><td colspan="3">Execution of the Performance Prediction Prototype tool using a nominal configuration which includes:
MRAIM algorithm selection
Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351]
Forecast for 13/04/2023 from 00:00:00 - 23:59:59
GPS + Galileo
Nominal error models configurable. The error models used can be found in the document [RD.2]
Ocean navigation: Accuracy threshold = 100 m; No Integrity Alert Limit</td></tr>
<tr><td>Outcome criteria</td><td colspan="3">The tool shall decode, process the information and provide accuracy results in the range of [4-8]m for the configuration selected. These results shall be exactly the same as TC.MPT.001 results
The tool shall decode, process the information and provide HPL results in the range of [20-40]m for the configuration selected. These results shall be exactly the same as TC.MPT.001 results
The tool shall decode, process the information and provide traffic light status along the scenario. This availability shall be significantly increased with respect to TC.MPT.001 results
The tool shall decode, process the information and provide satellite visibility along the scenario . These results shall be exactly the same as TC.MPT.001 results</td></tr>
<tr><td rowspan="2">Outcome (Pass/Fail)

Results</td><td colspan="3">PASS</td></tr>
<tr><td colspan="3">The tool decodes and processes the information, giving Accuracy values in the range previous mentioned. The results are the same as TC.MPT.001 results.

The tool decodes and processes the information, giving Protection Level values in the range previous mentioned. The results are the same as TC.MPT.001 results.</td></tr>
</table>

	 The tool provides an output of light traffic for the whole scenario. No alarms due to the navigation phase can be seen compared to TC.MPT.001.  The tool decodes, processes the information and provides satellite visibility across the scenario.



The tool decodes, processes the information and provides for the HDOP and GDOP across the scenario,

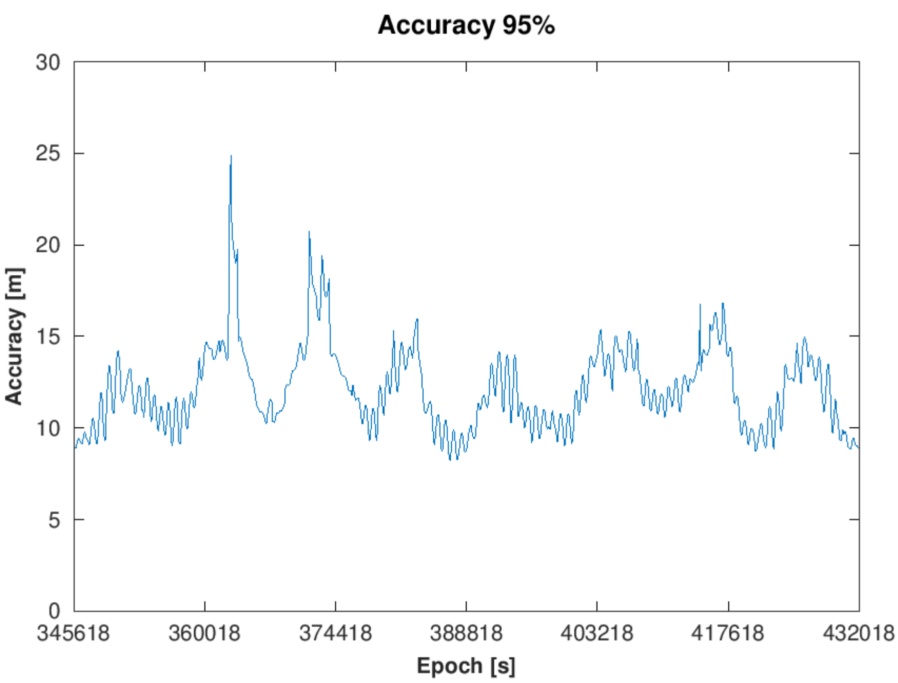


5.8 TC.MPT.008

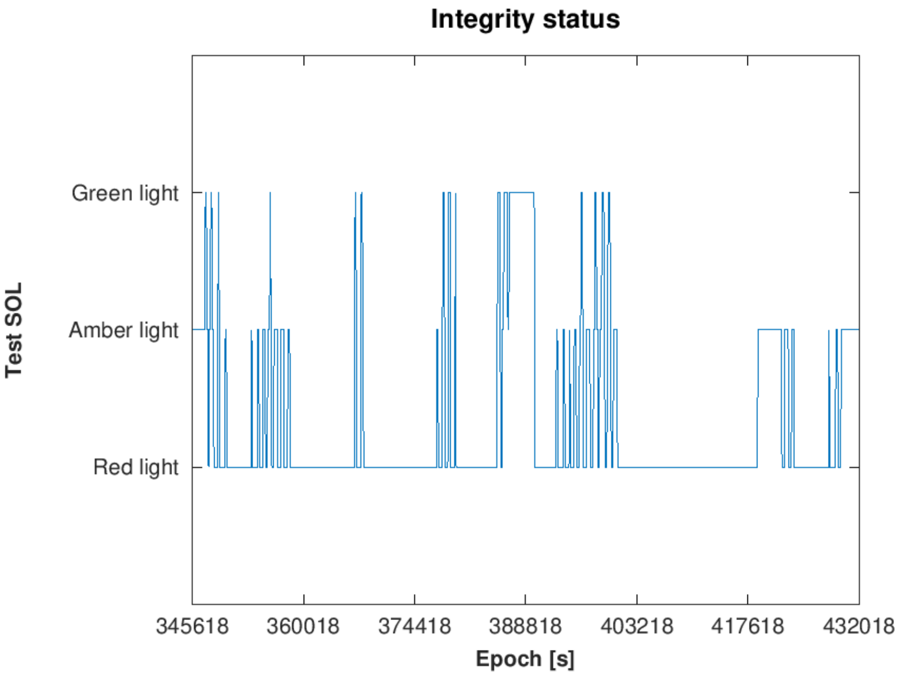
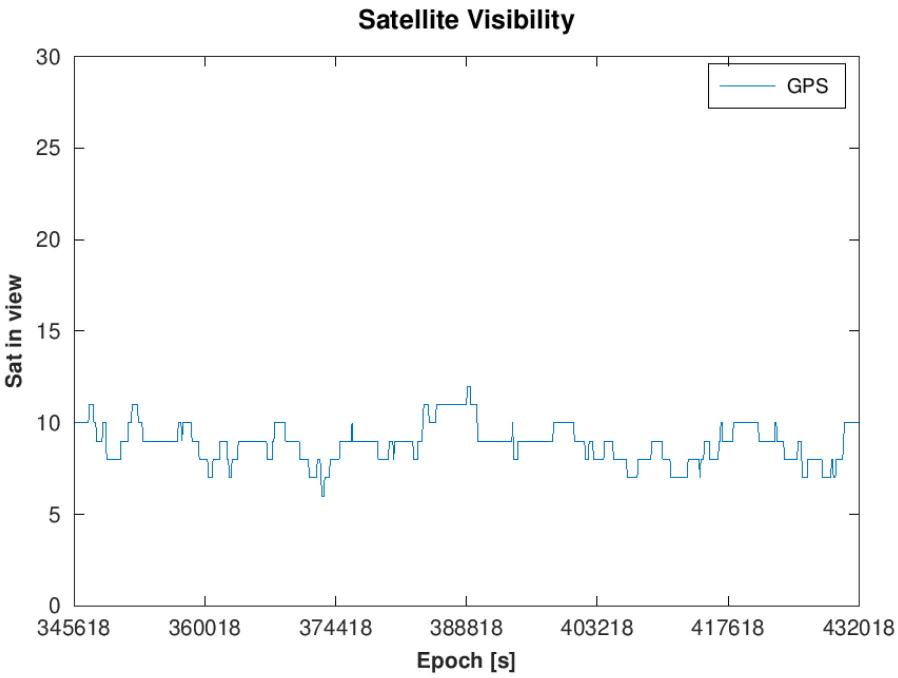
<table>
<tr><th>Test Code</th><th colspan="3">TC.MPT.008 MGRAIM</th></tr>
<tr><td>Test Objective</td><td colspan="3">To check that files are read, and a solution using MGRAIM is generated as expected for a single location for a 24 h period.</td></tr>
<tr><td>Test Experiment Location</td><td>GMV Laboratory</td><td>Test Experiment Equipment</td><td>PC or laptop running Windows OS</td></tr>
<tr><td>Dependence SW</td><td colspan="3">Octave 6.1.0</td></tr>
<tr><td>Constellation used</td><td colspan="3">GPS</td></tr>
<tr><td>Duration Time</td><td colspan="3">The execution: 100 s time step
Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59</td></tr>
<tr><td>Input Data</td><td colspan="3">GPS ephemerides</td></tr>
<tr><td>Processing</td><td colspan="3">Execution of the Performance Prediction Prototype tool using a nominal configuration which includes:

MGRAIM algorithm selection
Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351]
Forecast for 13/04/2023 from 00:00:00 - 23:59:59
GPS
Nominal error models configurable. The error models used can be found in the document [RD.2]
Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m
</td></tr>
<tr><td>Outcome criteria</td><td colspan="3">
The tool shall decode, process the information and provide accuracy results in the range of [5-25]m for the configuration selected. These results shall be higher than TC.MPT.001 results
The tool shall decode, process the information and provide traffic light status along the scenario. This availability shall be significantly reduced with respect to TC.MPT.001 results
The tool shall decode, process the information and provide satellite visibility along the scenario .
</td></tr>
<tr><td rowspan="2">Outcome (Pass/Fail)

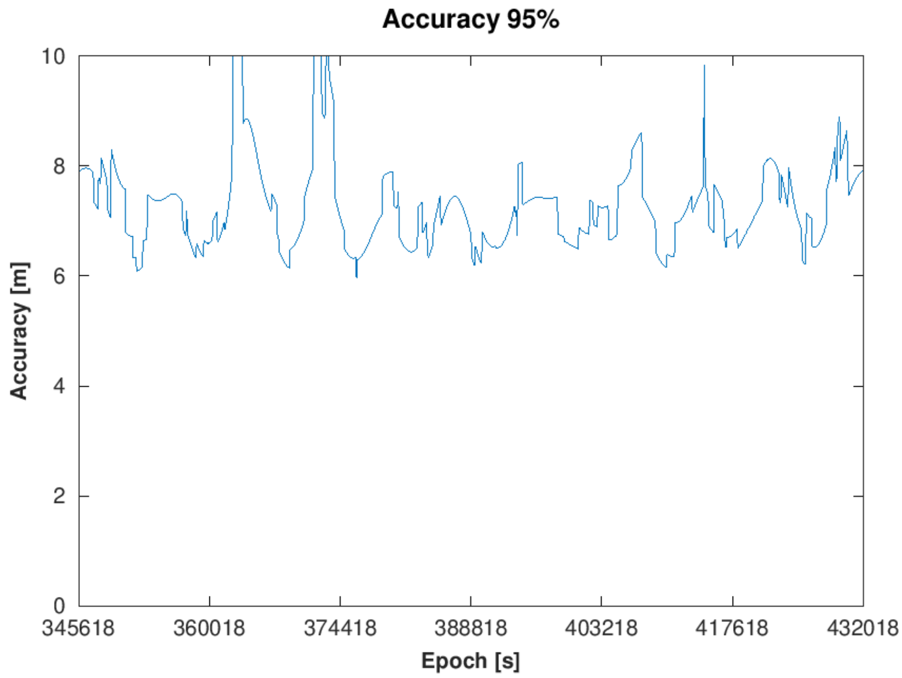
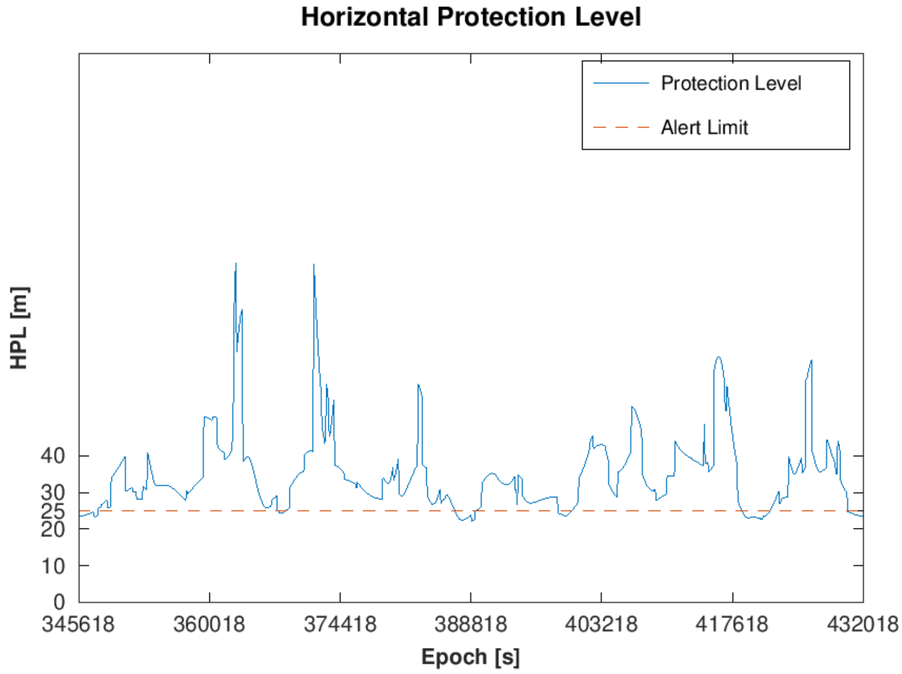
Results</td><td colspan="3">PASS</td></tr>
<tr><td colspan="3">The tool decodes and processes the information, giving Accuracy values in the range previous mentioned. The values higher than in TC.MPT.001.

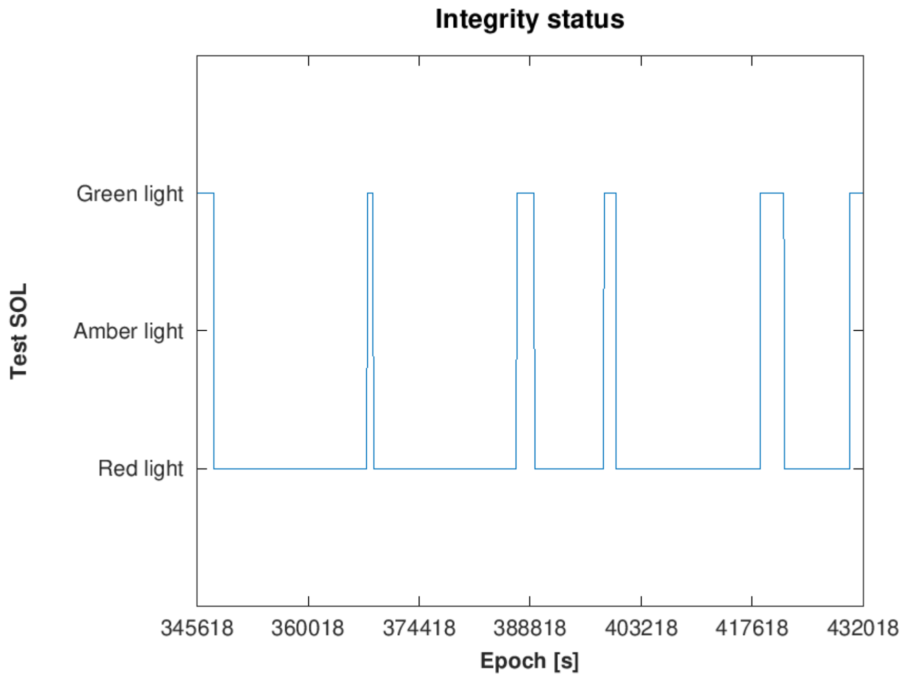


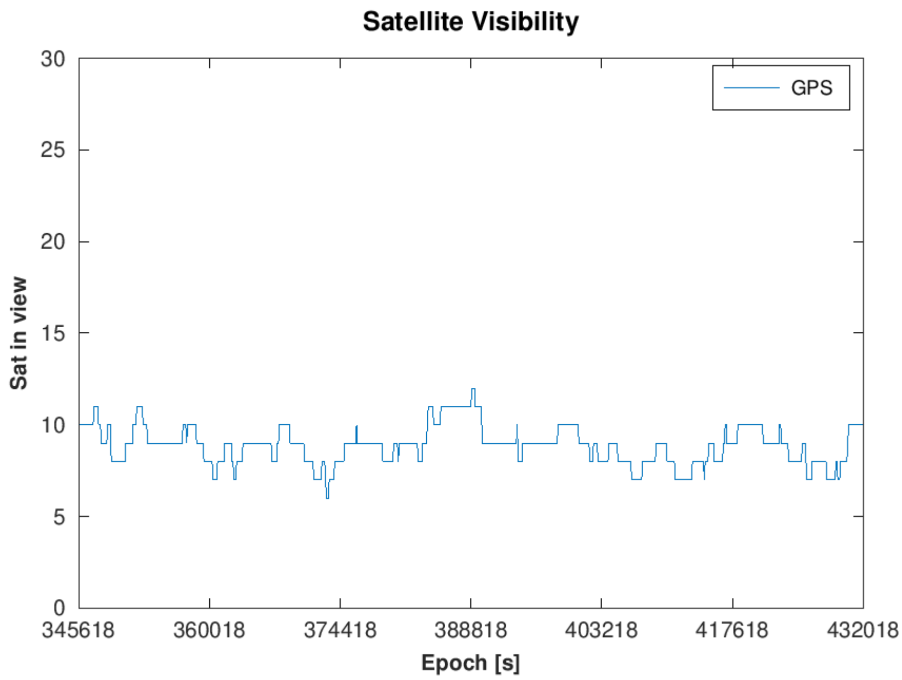
The tool provides an output of light traffic for the whole scenario. More alarms can be seen compared to TC.MPT.001.</td></tr>
</table>

	 The tool decodes, processes the information and provides satellite visibility across the scenario. 

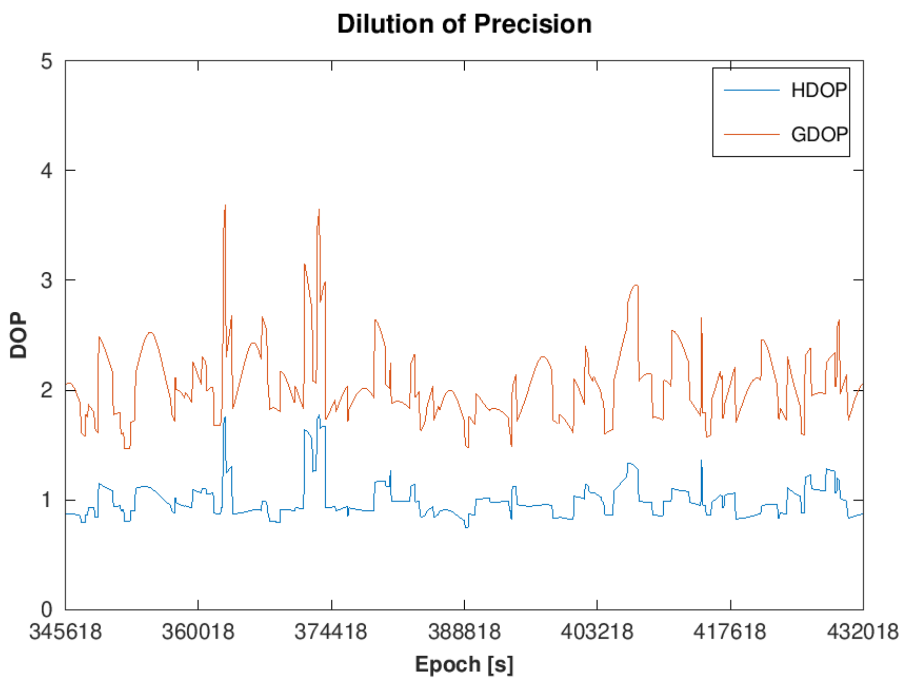
Test Code	TC.MPT.008 MRAIM		
Test Objective	To check that files are read, and a solution using MRAIM is generated as expected for a single location for a 24 h period.		
Test Experiment Location	GMV Laboratory	**Test Experiment Equipment**	PC or laptop running Windows OS
Dependence SW	Octave 6.1.0		
Constellation used	GPS		
Duration Time	The execution: 100 s time step Period studied 24h, forecast for 13/04/2023 from 00:00:00 - 23:59:59The execution for 100 s time step last 16.4 s Period studied 24h, forecast for 13/04/2023		
Input Data	GPS ephemerides		
Processing	Execution of the Performance Prediction Prototype tool using a nominal configuration which includes: - MRAIM algorithm selection - Single user selection [Lat: 52.95115, Lon: -1.18356, h: 90.53351] - Forecast for 13/04/2023 from 00:00:00 - 23:59:59 - GPS - Nominal error models configurable. The error models used can be found in the document [RD.2] - Coastal navigation: Accuracy threshold = 10 m; Integrity Alert Limit = 25 m		
Outcome criteria	- The tool shall decode, process the information and provide Accuracy results in the range of [6+]m for the configuration selected. These results shall be higher than TC.MPT.001 results - The tool shall decode, process the information and provide HPL results in the range of [20+]m for the configuration selected. These results shall be higher than TC.MPT.001 results - The tool shall decode, process the information and provide traffic light status along the scenario. This availability shall be significantly reduced with respect to TC.MPT.001 results - The tool shall decode, process the information and provide satellite visibility along the scenario . This results shall be lower than the TC.MPT.001 results as a single constellation is considered, in this case the minimum elevation angle is 10º		
Outcome (Pass/Fail)	**PASS**		
Results	The tool decodes and processes the information, giving Accuracy values in the range previous mentioned.		

	 The tool decodes and processes the information, giving Protection Level values in the range previous mentioned.. The tool decodes, processes the information and provides the Horizontal Protection Level illustrating the Alert Limit of 25m.  The tool provides an output of light traffic for the whole scenario. More alarms can be seen compared to TC.MPT.001.

<table>
<tr><td></td><td>


The tool decodes, processes the information and provides satellite visibility across the scenario. It can be observed that the number of satellites decreased due to the minimum elevation angle considered to develop this scenario, in comparison with the TC.MPT.001.


The tool decodes, processes the information, and provides for the HDOP and GDOP across the scenario. Here, as in the previous case, the DOP is higher.
</td></tr>
</table>

	 Dilution of Precision HDOP GDOP DOP Epoch [s] 0 1 2 3 4 5 345618 360018 374418 388818 403218 417618 432018

6 USER MANUAL FOR THE PROTOTYPE TOOL

The INSPIRe SVS Prototype is a tool developed to emulate the M(G)RAIM Performance Prediction Service with the same functional capabilities. The following chapter contains a brief description of the main prototype features and detailed information about how to use the tool.

6.1 INSPIRe SVS Prototype General Description

The INSPIRe service volume prototype software developed in Octave 6.2 for Windows. It is composed of several scripts organized in folders and therefore it requires no installation. The INSPIRe service volume prototype software has no further dependencies than the standard installed with Octave.

The tool is developed according to section 3.2 to provide user performances for a single or a grid of users using MGRAIM or MRAIM algorithm according to a given configuration. Detailed tool description is contained in section 4.1

Inside of the inspire-svs folder, the following subfolders/files can be found:

- **data_906**: Contains the ephemeris data of the studied constellations with the following names for Galileo and GPS respectively.
  - eph_GAL_906
  - eph_GPS_1930

  The layout of the file is briefly explained later in Section 6.2.1.1.1
- **Simulations**: This folder contains the scenario folders with the configuration functions needed to generate the configuration files, and the function to generate them.

  Whitin this folder, there are several **'SIM_X' folders**: is the scenario used in the service volume, they can be copied and changed in order to obtain the desired results. Each of them contains:
  - Input: contains
    - The function to set a configuration file is under the name:
      < create_TCINSPIReSVS_"subcase".m>, where subcase has to be set up
    - The function to create a configuration file is under the name:
      < run_create_config.m>

    A new folder called TCINSPIReSVS is generated when the tool is launched. This will contain the different subcases folders wanted with the configuration files.
  - Output: contains the outputs of the tool in an internal folder under the name TCINSPIReSVS in which the desired output plots as well as the files with information in plain text mode can be found.
- **src**: contains the source code of the tool, including the functions used to plot the results.
- **RAIM_SVS_main**: is the main function of the tool.
- **run_TC**: This is the tool executable from which the INSPIRe-svs interface is launched.

The folder structure is depicted in diagram in Figure 6-1.

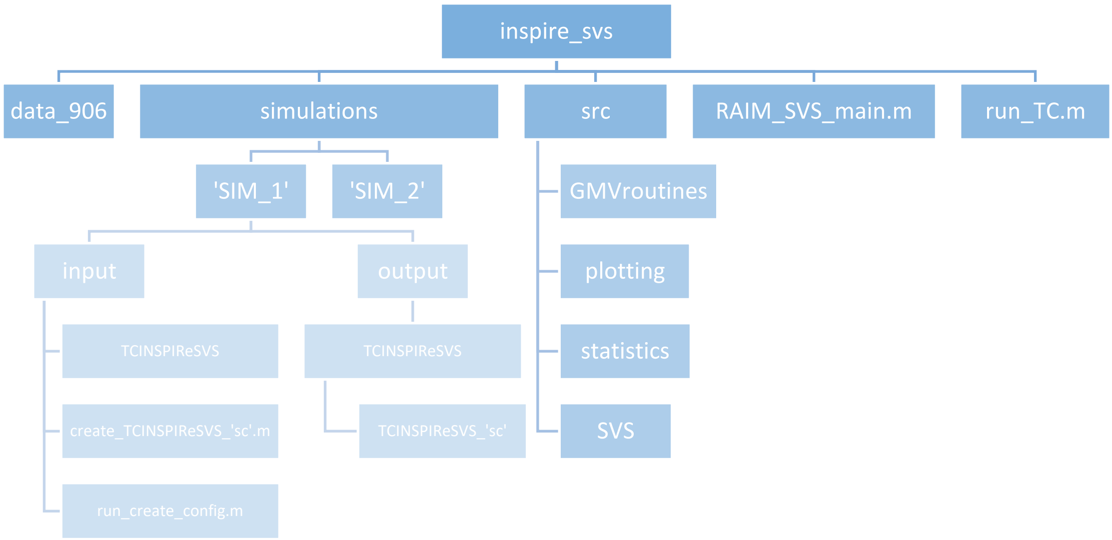


Figure 6-1. M(G)RAIM Performance Prediction prototype. Tool Directory Structure

6.2 INSPIRE SVS Prototype Usage

This section contains the key information for the INSPIRe SVS prototype usage. It contains detailed information about the input and outputs and how to run the tool.

6.2.1 Input and Output Files

6.2.1.1 Input files

The inspire_svs software requires two input files to work properly, which correspond to the constellation ephemeris and the scenario configuration. Description and structure of these files can be found next.

6.2.1.1.1 CONSTELLATION EPHEMERIS

Constellation ephemeris file (Figure 6-2) must be stored in the data_906 folder under the name <ConstellationName>.mat in a MATLAB structure format.

Each constellation ephemeris is input into inspire_svs as a matrix which includes the following columns per satellite introduced:

- Satellite ID (PRN)
- Mean anomaly at reference time of ephemeris (rad)
- Eccentricity (unitless)
- Semi-major axis (m)
- Right ascension of ascending node at TOE (rad)
- Rate of right ascension of ascending node (rad)
- Inclination (rad)
- Argument of perigee (rad)
- Reference time of ephemeris (s).

```
# name: eph
# type: matrix
# rows: 24
# columns: 9
 1 4.1807616901999998 0 26559800.001129892 3.2827025235999998 -8.1206679437000001e-09 0.95993108859999998 0 0
 2 2.3247785636999998 0 26559800.001129892 3.2827025235999998 -8.1206679437000001e-09 0.95993108859999998 0 0
 3 5.9880501306999996 0 26559800.001129892 3.2827025235999998 -8.1206679437000001e-09 0.95993108859999998 0 0
 4 0.23073252711 0 26559800.001129892 3.2827025235999998 -8.1206679437000001e-09 0.95993108859999998 0 0
 5 0.91402892927000001 0 26559800.001129892 4.3299000748000003 -8.1206679437000001e-09 0.95993108859999998 0 0
 6 2.526364092300001 0 26559800.001129892 4.3299000748000003 -8.1206679437000001e-09 0.95993108859999998 0 0
 7 4.9111819821999996 0 26559800.001129892 4.3299000748000003 -8.1206679437000001e-09 0.95993108859999998 0 0
 8 3.0681142921000002 0 26559800.001129892 4.3299000748000003 -8.1206679437000001e-09 0.95993108859999998 0 0
 9 1.4536847340000001 0 26559800.001129892 5.3770976260000003 -8.1206679437000001e-09 0.95993108859999998 0 0
 10 5.9901445257999999 0 26559800.001129892 5.3770976260000003 -8.1206679437000001e-09 0.95993108859999998 0 0
 11 5.4293702370999997 0 26559800.001129892 5.3770976260000003 -8.1206679437000001e-09 0.95993108859999998 0 0
 12 3.7170277079999998 0 26559800.001129892 5.3770976260000003 -8.1206679437000001e-09 0.95993108859999998 0 0
 13 1.8612191143000001 0 26559800.001129892 0.14110987002 -8.1206679437000001e-09 0.95993108859999998 0 0
 14 4.1339868662999999 0 26559800.001129892 0.14110987002 -8.1206679437000001e-09 0.95993108859999998 0 0
 15 0.11466813185999999 0 26559800.001129892 0.14110987002 -8.1206679437000001e-09 0.95993108859999998 0 0
 16 2.4219934030000001 0 26559800.001129892 0.14110987002 -8.1206679437000001e-09 0.95993108859999998 0 0
 17 2.9401816579000002 0 26559800.001129892 1.1883074212 -8.1206679437000001e-09 0.95993108859999998 0 0
 18 4.7823766833999999 0 26559800.001129892 1.1883074212 -8.1206679437000001e-09 0.95993108859999998 0 0
 19 0.65414940364999996 0 26559800.001129892 1.1883074212 -8.1206679437000001e-09 0.95993108859999998 0 0
 20 5.3249995478000001 0 26559800.001129892 1.1883074212 -8.1206679437000001e-09 0.95993108859999998 0 0
 21 3.6704274169 0 26559800.001129892 2.2355049723999998 -8.1206679437000001e-09 0.95993108859999998 0 0
 22 5.5264105434999999 0 26559800.001129892 2.2355049723999998 -8.1206679437000001e-09 0.95993108859999998 0 0
 23 1.3372712729 0 26559800.001129892 2.2355049723999998 -8.1206679437000001e-09 0.95993108859999998 0 0
 24 1.8633135094 0 26559800.001129892 2.2355049723999998 -8.1206679437000001e-09 0.95993108859999998 0 0
```

Figure 6-2. Input file. Constellation ephemeris

6.2.1.1.2 SCENARIO CONFIGURATION DEFINITION

This file must be in the scenario input folder under the name < TCINSPIReSVS_'sc' >.m

The scenario configuration definition is input into inspire_svs as '.m' file in a MATLAB structure format. Here all the configuration parameters must be modified depending on the scenario to be simulated, among others:

- Epoch studied: any time range can be simulated, taking into account a time step to suit the desired one, as well as the date of the simulation.
- Mode in which the tool can be launched: MRAIM or MGRAIM.
- User mode: selection of single point study or mapping study at any part of the Earth surface.
- Number of constellations: suitable for Galileo and GPS.
- Satellite elevation angle: minimum elevation angle required to calculate the solution.
- Error modelling: all error models can be modified.
- M(G)RAIM configuration parameters, among others:
  - DOP thresholds (for MGRAIM only)
  - Satellite fault probabilities (for MRAIM only)
  - Constellation fault probabilities (for MRAIM only)
  - Maximum nominal biases (for MRAIM only)
  - Mean fault duration (for MRAIM only)
- Navigation phase requirements
  - Accuracy threshold (for MGRAIM only)
  - False Alarm rate
  - Integrity Risk required (for MRAIM only)
  - Alarm Limit (for MRAIM only)
- Satellite exclusion: in order to emulate real constellation health.

6.2.1.2 Output Files

The inspire_svs output files correspond to the files that are generated after the tool execution; those correspond to the scenario file generated.

Once the scenario file has been processed, the configuration file <sim_config_TCINSPIReSVS_'sc'> will be automatically generated in a folder, inside the input folder, named TCINSPIReSVS_'sc'. A structure of said file can be found in Figure 6-3.

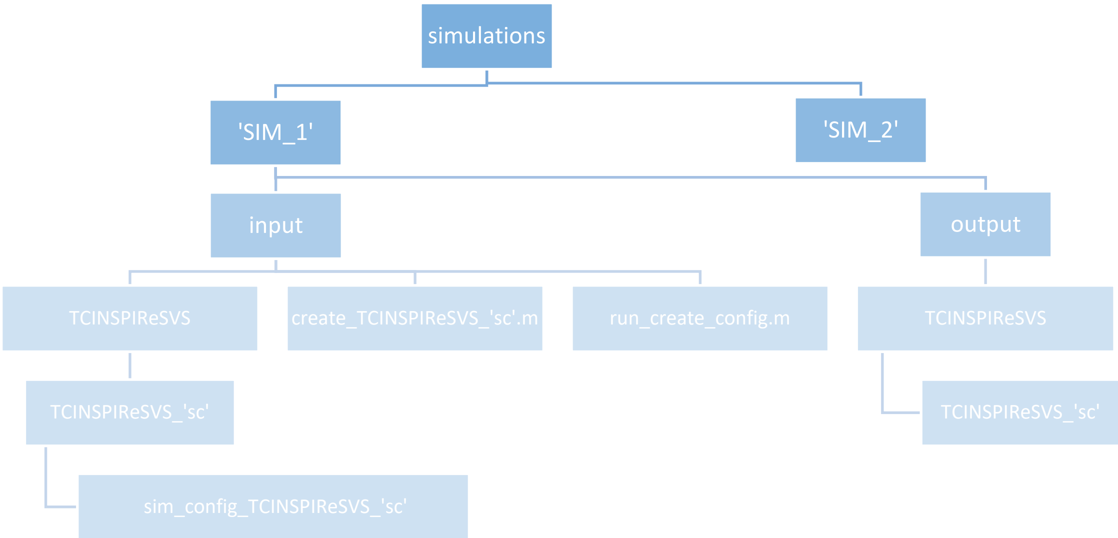


Figure 6-3. M(G)RAIM Performance Prediction prototype. Simulations Directory Structure

Depending on the plot mode selected the tool will generate a folder called ModeRAIM_Points or ModeRAIM_Maps, and the solution will be automatically save a file information in plain text mode under the name <simulation_data_'SIM_X'> as well as the plots generated.

6.2.1.2.1 Plain text file

The INSPIRE SVS prototype tool provides two or three text files, depending on the execution mode

- **simulation_data_XXXX**: this is a plain text with the Matlab structures more relevant for the simulation. It contains the configuration structure together with several intermediate outcomes and the main M(G)RAIM output structure. This structure changes with the algorithm selected but it contains:
  - Integrity flags per user and epoch
  - Accuracy/HPL value in meters per user and per epoch
  - Number of satellites per constellation per user and epoch
  - Number fo faults monitores (only in MRAIM mode)
- **simulation_data_XXXX_HPL_vec/matrix**: these are .csv files with the information about HPL value in a vector or matrix (for user grid mode) per user and epoch. Please note that in MGRAIM mode these files are fulfilled with 0 since no PL is computed.

6.2.1.2.2 Single user mode

When the tool is configured in a single user mode, giving an specific location on the Earth surface, the tool provides the following plots in addition to the aforementioned plain text file.

The tool depicts the estimated accuracy at 95% of confidence for the given user epoch by epoch for the MGRAIM mode. This accuracy takes into account the estimated GNSS constellation geometry, the integrity information and the error models to estimate which would be the expected performances along the time window introduced.

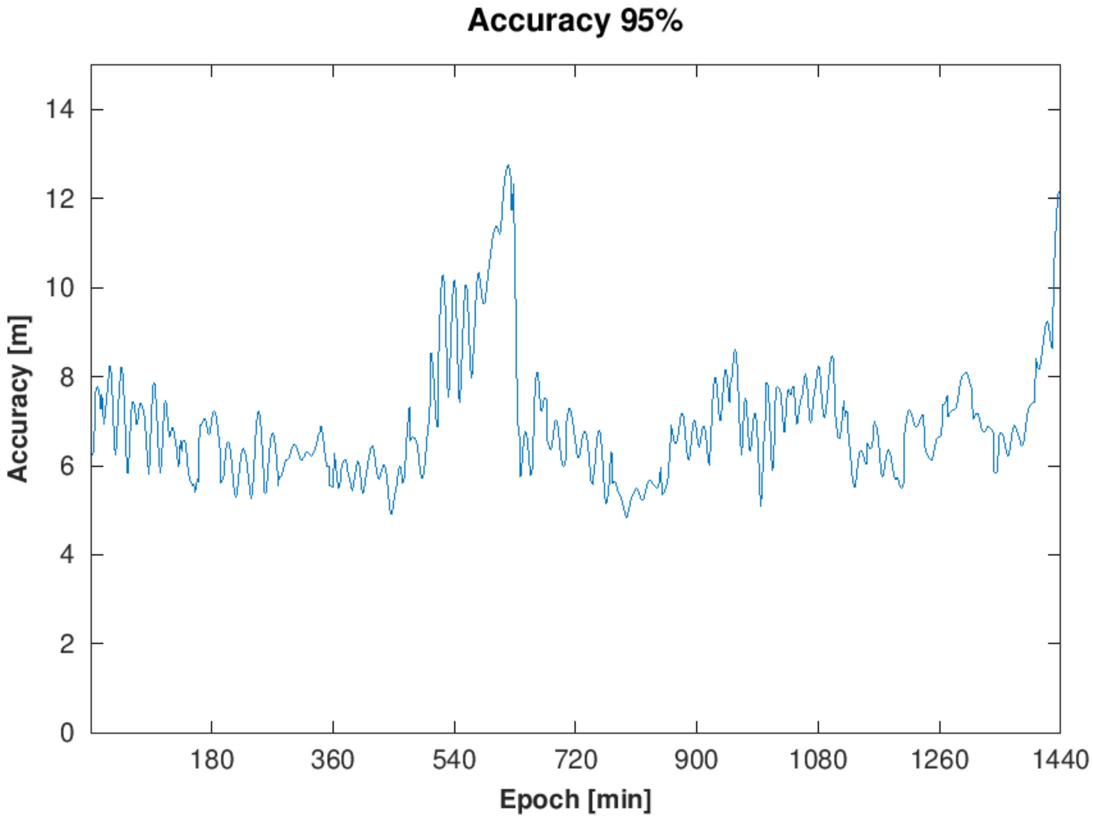


Figure 6-4. M(G)RAIM Performance Prediction prototype. Example of ACC95 along time

This figure parametrization is:

- Horizontal axis depicts to the epoch elapsed in minutes since the beginning of the simulation.
- Vertical axis depicts the Accuracy at 95% estimated by the algorithm

The tool depicts the HPL for the given user epoch by epoch for the MRAIM mode. This accuracy takes into account the estimated GNSS constellation geometry, the integrity information and the error models to estimate which would be the expected performances along the time window introduced.

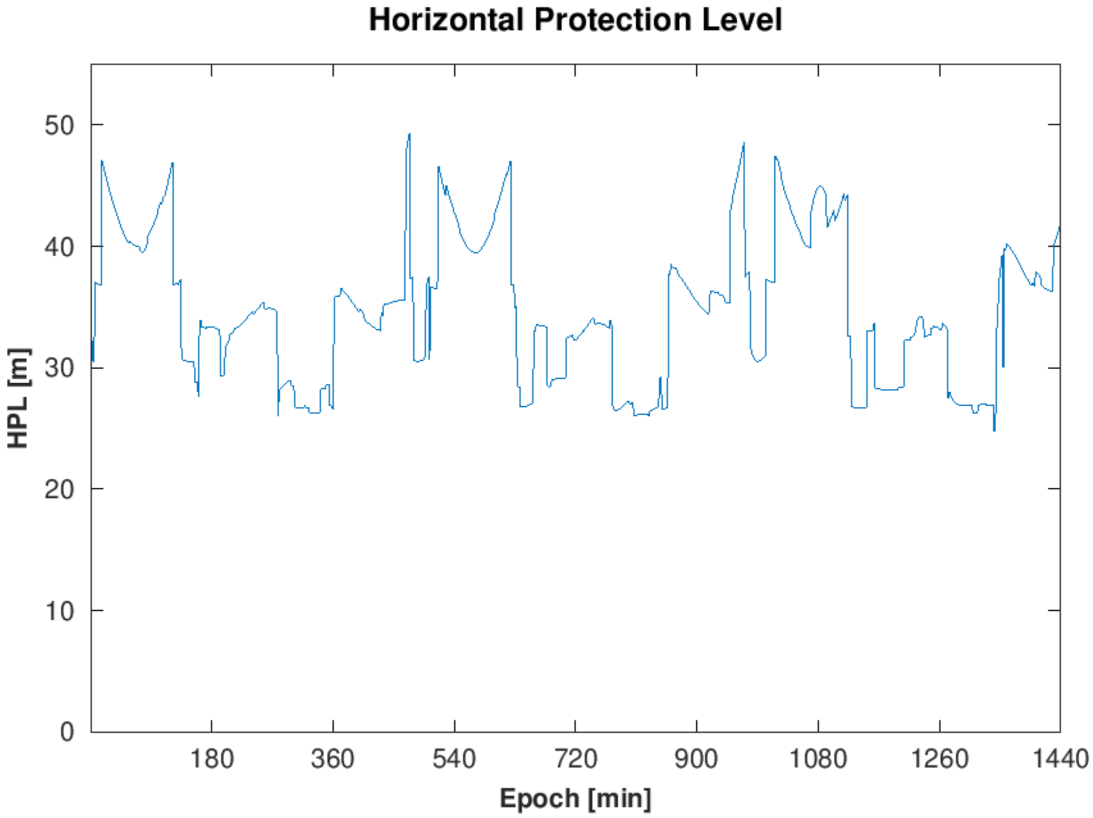


Figure 6-5. M(G)RAIM Performance Prediction prototype. Example of HPL along time

This figure parametrization is:

- Horizontal axis depicts to the epoch elapsed since the beginning of the simulation in minutes.
- Vertical axis depicts the HPL estimated by the algorithm according to the configuration.

The tool depicts the estimated integrity status for the given user epoch by epoch. This integrity status takes into account the estimated GNSS constellation geometry, the integrity information and the error models to estimate if any alarm will be risen during the operation.

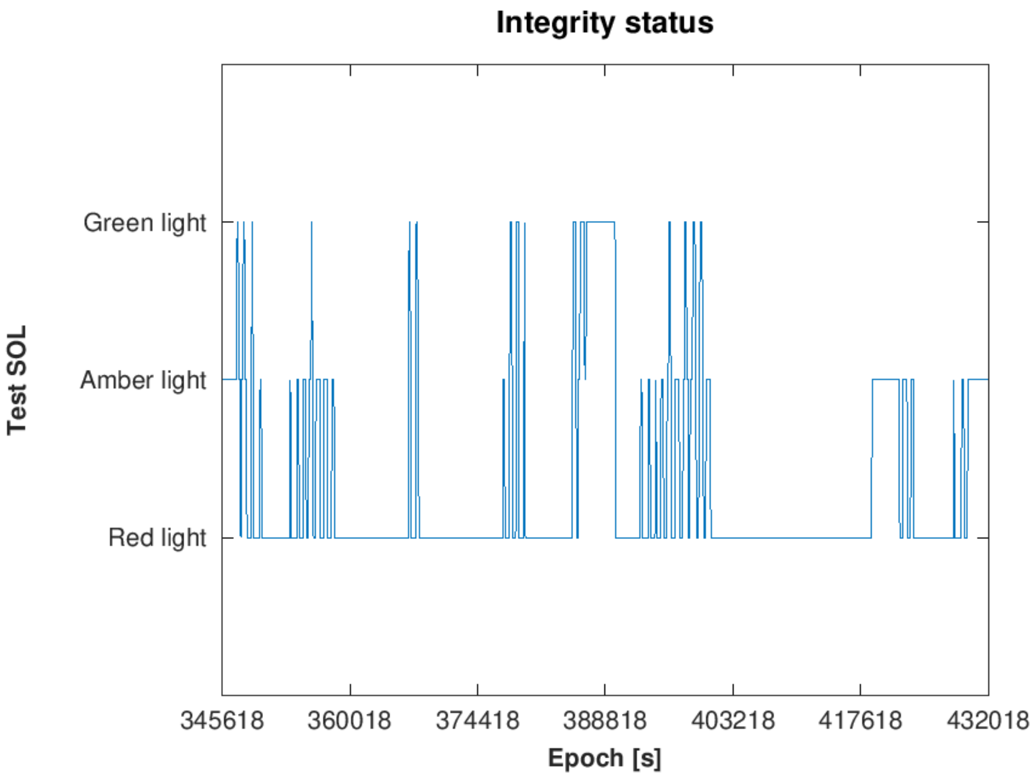


Figure 6-6. M(G)RAIM Performance Prediction prototype. Example of test SOL along time

This figure parametrization is:

- Horizontal axis depicts to the epoch elapsed since the beginning of the simulation in minutes.
- Vertical axis depicts the integrity status given by the traffic light concept where:
  - 2 corresponds to “green light”
  - 1 corresponds to “amber light”
  - 0 corresponds to “red light”

Finally, the tool depicts the estimated number of satellites available for the positioning solution for the given user epoch by epoch. This number of satellites takes into account the estimated GNSS constellation geometry and the integrity information to perform the estimation.

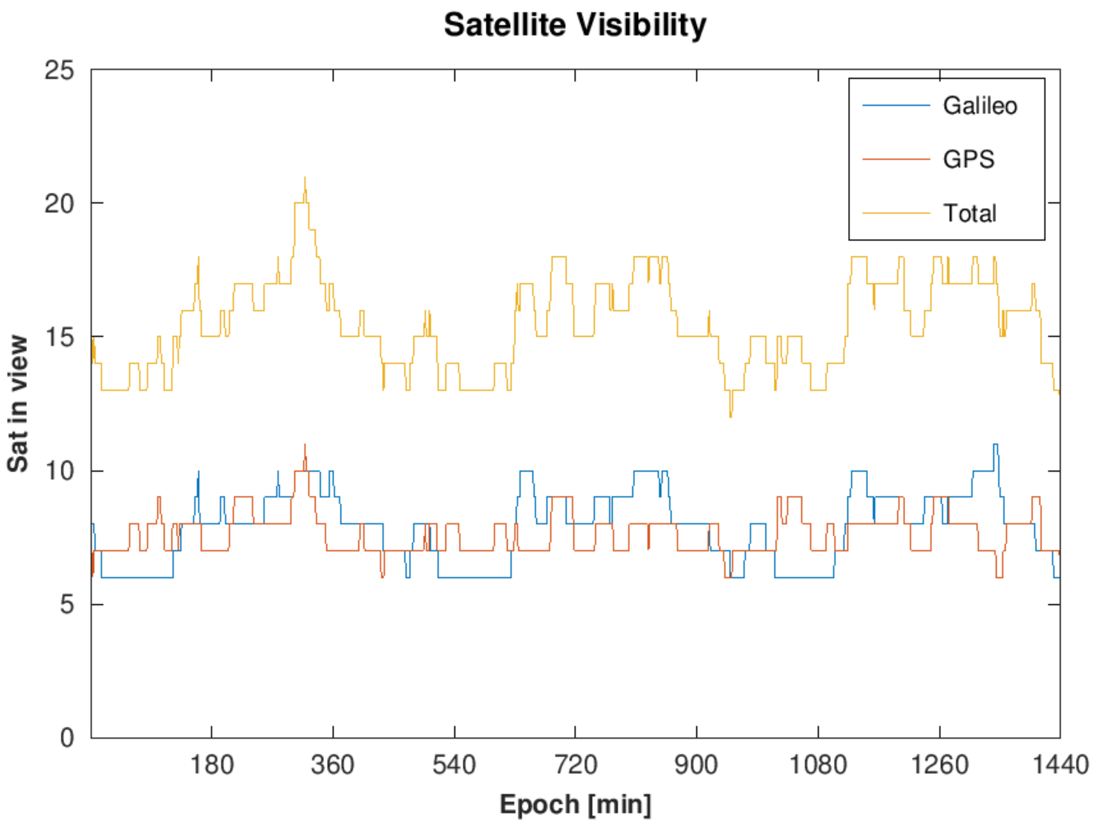


Figure 6-7. M(G)RAIM Performance Prediction prototype. Example of number of estimated satellites along time

This figure parametrization is:

- Horizontal axis depicts to the epoch elapsed since the beginning of the simulation in minutes.
- Vertical axis depicts the number of available satellites according to the depicted legend, which includes GPS/Galileo satellites and the total number.

6.2.1.2.3 Grid user mode

Finally, in user grid mode the tool depicts similar information in a map format in addition to the plain text files. However, in this case the information cannot be provided for a long time and one statistical value for the distribution of each user has to be selected

The tool depicts the estimated 95 percentile of the Accuracy at 95% of confidence for the grid of users for the MGRAIM mode. This accuracy considers the estimated GNSS constellation geometry, the integrity information and the error models to estimate which would be the expected performances along the time window introduced.

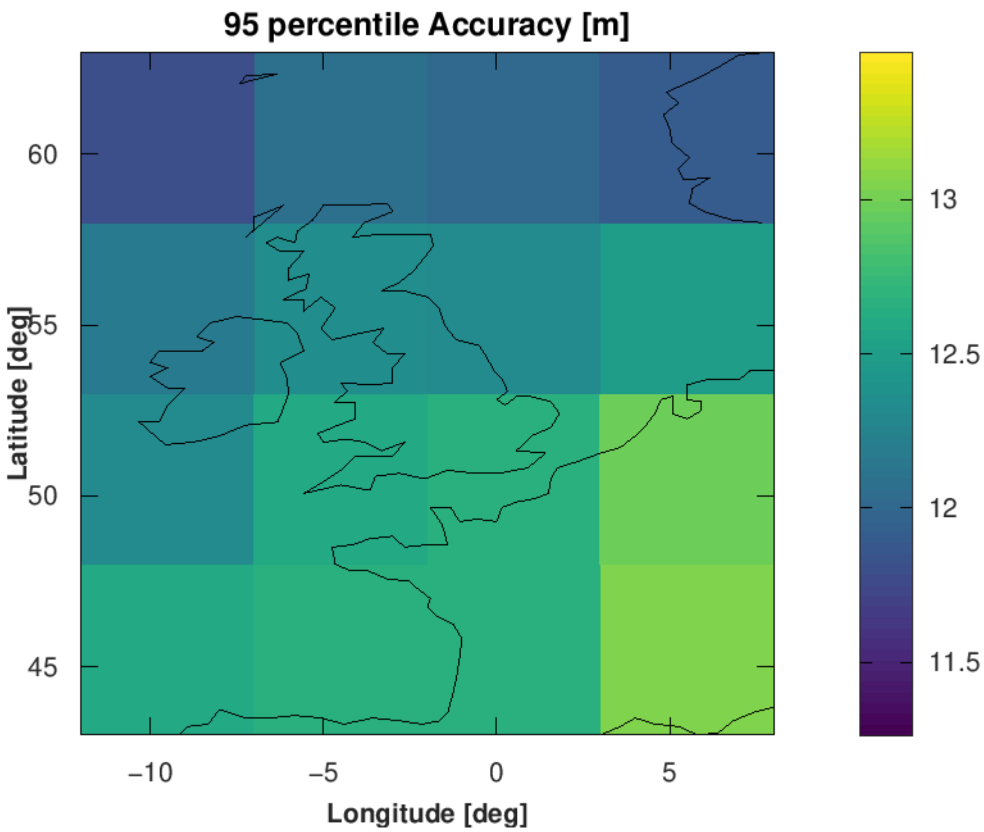


Figure 6-8. M(G)RAIM Performance Prediction prototype. Example of 95 percentile for the Acc95 over UK

This figure parametrization is:

- Horizontal axis depicts the longitude of the user.
- Vertical axis depicts latitude of the user.
- Colour code depicts the 95 percentile of the Accuracy 95% for each user

The tool depicts the estimated 99.8 percentile of the HPL for the grid of users for the MRAIM mode. The percentile 99.8 has been selected to assess the HPL at the availability requirement for all the navigation phases. This HPL takes into account the estimated GNSS constellation geometry, the integrity information and the error models to estimate which would be the expected performances along the time window introduced.

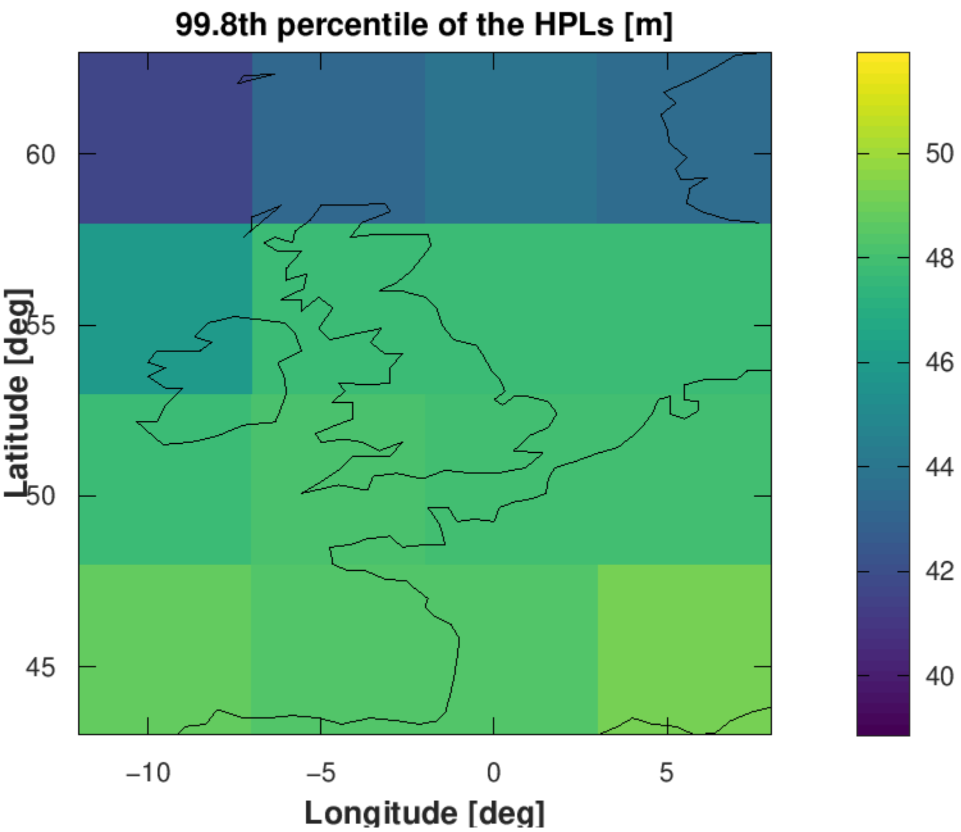


Figure 6-9. M(G)RAIM Performance Prediction prototype. Example of 99.8 percentile for the HPL over UK

This figure parametrization is:

- Horizontal axis depicts the longitude of the user.
- Vertical axis depicts latitude of the user.
- Colour code depicts the 99.8 percentile of the HPL for each user

Finally, the tool depicts the availability for the grid of users for the MRAIM mode. This availability takes into account the estimated HPL and the integrity flags and compare them against the requirements of the navigation phase to provide an indication of the percentage of epochs that navigation will be available with the performance required.

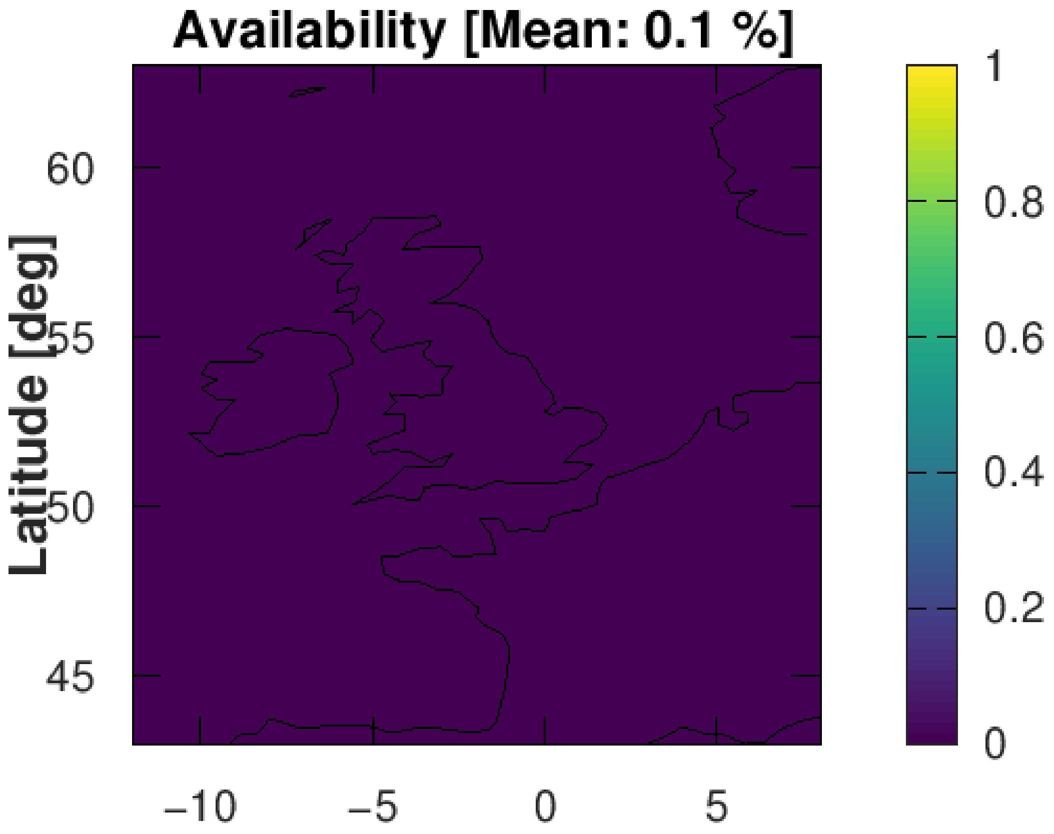


Figure 6-10. M(G)RAIM Performance Prediction prototype. Example of availability over UK

This figure parametrization is:

- Horizontal axis depicts the longitude of the user.
- Vertical axis depicts latitude of the user.
- Colour code depicts the availability percentage for each user

6.2.2 Running the Tool

To run the tool, access the main folder (inspire_svs) and from there the “RAIM_SVS_main.m” shall be executed. This function takes the following input parameters in this order:

- Simulation path: Absolute path to the path where the configuration input file is contained
- Execution mode: Integer from 1 to 4 to indicate the kind of processing desired.
  - 1 for M(G)RAIM processing for one single scenario
  - 2 for PVT processing only without integrity algorithm for a single scenario
  - 3 for M(G)RAIM processing for one single scenario but making a sensitivity analysis for a single parameter
  - 4 for M(G)RAIM processing for several Test Cases and Subcases
- Simulation Configuration: Absolute path to the simulation configuration file
- Test subcase indicator
- Ephemeris filex2: Absolute or relative path to the input ephemeris file required, one per constellation and Galileo first if double constellation is used.

However, creating the simulation config files, store them in one folder each and run the main script with the aforementioned input parameters could be very time consuming for those situations where several cases want to be executed.

In order to ease these execution cases, two scripts have been created as user interface for running several cases in a batch mode.

To launch the application, it is first necessary to configure the configuration files to be analysed. To do this, the user must access the simulations folder, select the desired scenario, and go to input, where the configuration functions are located as mentioned above. An image of this configuration file can be seen in Figure 6-11.

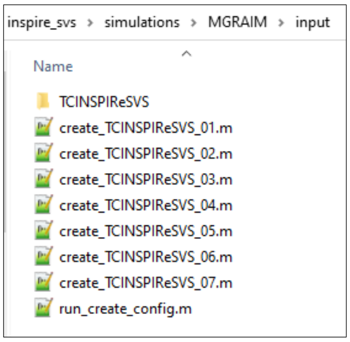


Figure 6-11. inspire_svs input configuration files location

By opening the scenario configuration file under the name <create_TCINSPIReSVS_'sc'>.m in Octave, this can be modified. If more scenarios want to be generated the user has to copy the file and paste it in the same folder with a different 'sc' number and modify the variables to obtain the desired scenario, an example is shown in Figure 6-12. Please note that test case is identified as the text after the first "-" character and subcases identifier are always the string after the first "_" character.

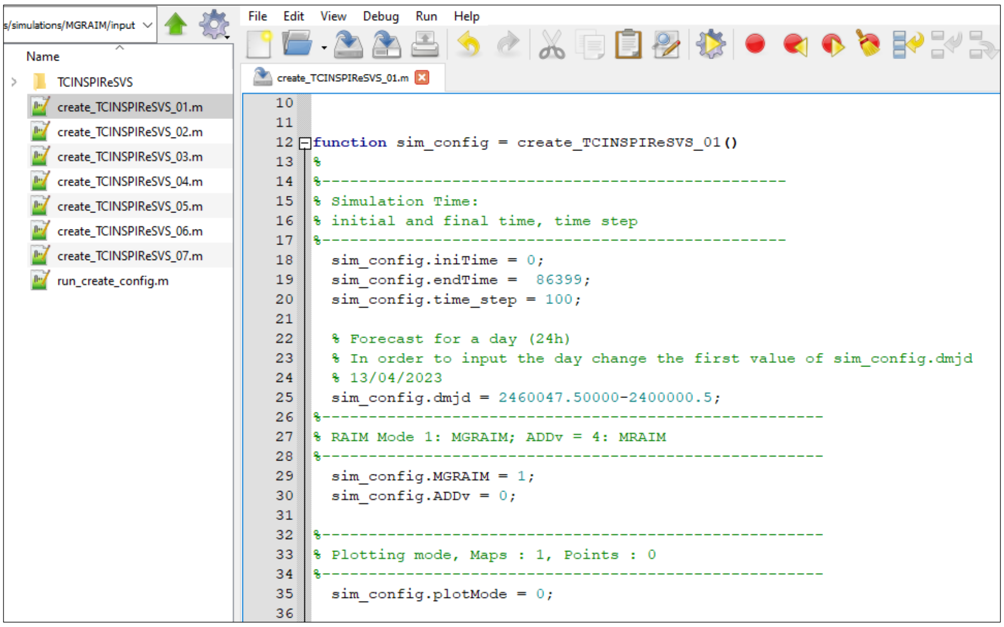


Figure 6-12. Configuration file

To create the scenarios in the desired format, the function run_create_config.m must be used, and the scenario has to be added in the file. The part of the code that should be copied and paste is shown in Figure 6-13, by changing the names of the test case and the scenario, several scenarios can be launched at the same time.

As an example, the following variables:

- tc = 'TCINSPIReSVS_'sc' ';
- sim_config = create_TCINSPIReSVS_' sc' ();
- configuration_file = strcat('.\','simulations\','SIM_1\','input\',test,'\', tc);

```
%%%%%%%%%%%%%%%%%%% create_TC-INSPIRe-01 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Case 1, Diferenciate subcases with delim = "-"
tc = 'TCINSPIReSVS_01';
[test,subcase] = strtok(tc,"_")
disp(tc)

sim_config = create_TCINSPIReSVS_01();

configuration_file = strcat('.\','simulations\','MRAIM\','input\',test,'\', tc);

if exist(configuration_file)~= 7
  mkdir(configuration_file);
end
configuration_file = strcat(configuration_file, '\sim_config_', tc);
save(configuration_file, 'sim_config');
```

Figure 6-13. run_create_config file

The function "run_create_config.m" will be launched from the main folder of the inspire_svs tool. To do this, the first thing to do is to add to path the selected directories and subdirectories as shown in Figure 6-14.

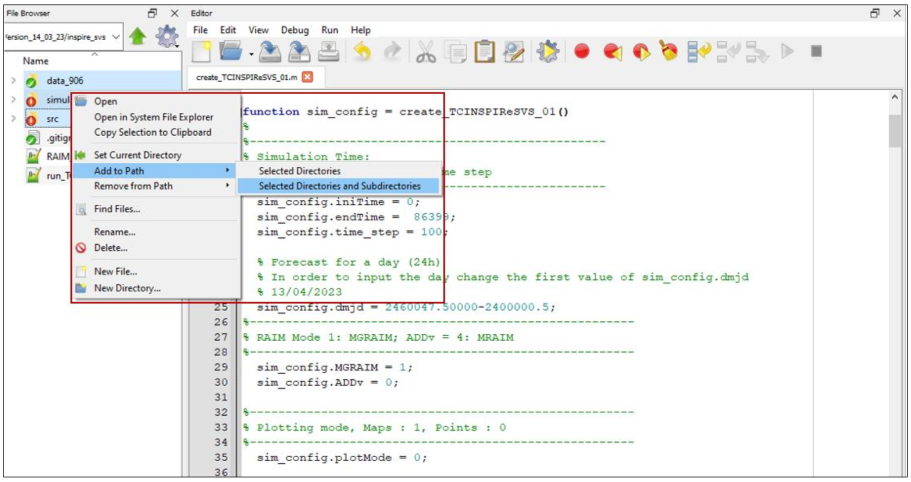


Figure 6-14. inspire_svs add to Path Directories

Then, to run several cases in a batch mode the user may open the executable run_TC on Octave. In this function the variable 'simulation_location' must be modified with the name of the folder of the scenario to be evaluated, as well as the scenarios evaluated in the variables 'tests.TC.name and 'tests.TC.cases' shown in Figure 6-15.

As an example, the following variables:

- simulation_location = '.\simulations\SIM_1\';
- tests.TC.name = 'TCINSPIReSVS'
- tests.TC.cases = {' TCINSPIReSVS_'sc' ';' TCINSPIReSVS_'sc' '}

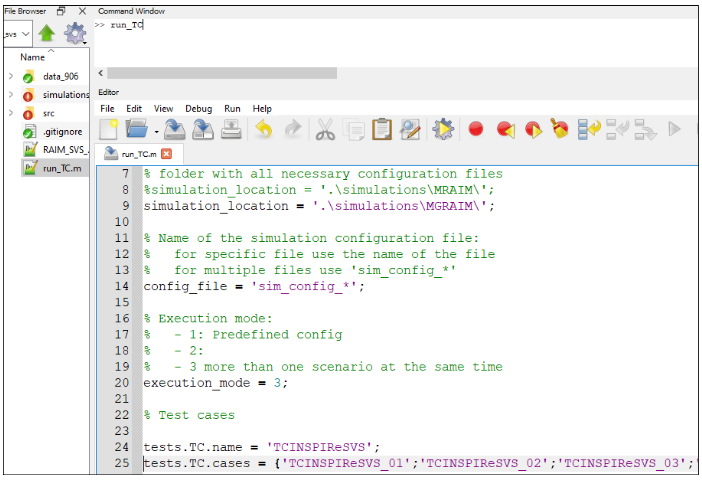


Figure 6-15. run_TC function

The desired results can be found in the output folder as mentioned in the beginning of the user manual.

7 IDENTIFICATION OF STEPS AND TIMESCALES FOR DEVELOPMENT AND IMPLEMENTATION OF AN OPERATIONAL TOOL

This section details the roadmap for the development of an operational M(G)RAIM Performance Prediction tool.

Taking into account the M(G)RAIM algorithm design [RD.1][RD.2] and the requirements identified for the operational Performance Prediction Tool in section 3.2. following sections details the activities that should be performed in order to put in place an operational tool and their timescale.

Please note that T0 will be in this section the kick-off of the service development. development for each stage. Please note that Performance Prediction tool will be developed in two stages:

1) Upgrade the prototype tool developed in this project to a functional, online, service that anyone can access. Its purpose would be mainly educational, to raise awareness of integrity at sea, and to inform today's mariners of the capability that their receiver is likely to provide.

2) Develop the Provision Scheme for an operational prediction service, along with the IALA / IMO process to get changes made to maritime equipment. This second stage will take into account the final implementation of the M(G)RAIM algorithms if they are finally incorporated into maritime receivers.

7.1 Operational Performance Prediction Tool activities

This chapter contains the main actions identified to implement an operational Performance Prediction Tool from the prototype already developed.

7.1.1 Action #1. Incorporation of M(G)RAIM proposed solution

Objective: The objective of this action is foster the incorporation of the M(G)RAIM proposed solution into maritime receivers.

Justification: It could be obvious to mention, but the usability of a potential Performance Prediction Tool for maritime users is linked directly with the penetration of the proposed M(G)RAIM algorithms designed in INSPIRe project [RD.1][RD.2].

Performances are given, both in terms of availability and size of protection level, for the proposed maritime on-board solution, assuming among other features, the implementation of one of the two algorithms analysed in this project. Therefore, maritime users shall implement these algorithms to find the Performance Prediction Tool useful.

In order to do so, it should be promoted the penetration of the M(G)RAIM proposed solution into maritime receivers via IEC standardisation, IALA guidelines or any other maritime regulatory material that could help this penetration. Afterwards, it should be assessed if the development of an operational Performance Prediction Tool, the second stage of the development, makes sense or the scope should be readapted to include the existing algorithms, regardless they are M(G)RAIM ones or any others.

In this action should be distinguished the two algorithms proposed. MGRAIM algorithm is a simpler algorithm where most of the checks are already implemented by the receivers and the geometry screening is the additional feature that should be included. Therefore, its penetration is expected much easier and the auxiliary tool could help to foster its usage.

However, the MRAIM implies a different integrity concept and would imply significant changes in the maritime integrity approach. For this algorithm is where has to be evaluated if an operational tool may makes sense.

Action type: Promotion and Standardisation activity.

Owner: This work should be done by the maritime authorities and the INSPIRe consortium.

Criticality: The criticality of this action is classified as high because after its completion a go/no-go decision should be taken.

Timeframe: This activity shall be carried out before the service development and will last for at least ten years, starting at T0_ stage1 and ending at T0_stage1 +10yrs.

Recommendation: Promotion of M(G)RAIM solution should start as soon as possible since the time scope for maritime regulatory material modification or development is usually long and take not less than 2 years. In addition, manufacturers would not implement the M(G)RAIM solution unless clear advantages are observed or regulation imposes it.

7.1.2 Action #2. Service provision analysis

Objective: The objective of this action is analyse the service provision scheme for the Performance Prediction Tool, including the stakeholders involved in the service provision, the liabilities and the interface among them.

Justification: This activity aims to analyse the service provision of a safety Maritime Performance Prediction service for the algorithm designed in INSPIRe project [RD.1][RD.2].

M(G)RAIM algorithms are designed for safety purposes in the context of maritime navigation, and therefore, their implementation is subject to some verification control that would assess if a receiver equipped with that algorithm is safe for maritime navigation. Taking this into account, this activity should assess and define the role of a Maritime Performance Prediction service and the most suitable scheme for its provision.

Depending on the outcomes of this analysis, the Performance Prediction tool could be used to evaluate the compliance with the navigation requirements of certain operations, in certain areas over a specific time. Mariners user will have an indication of the expected performances with a certain level of confidence. In this case, then it should be analysed if there were some kind of liabilities in the provision of such as performance forecast, that would allow maritime users to claim in case wrong prediction.

Action type: Service definition activity.

Owner: This work should be done by the maritime authorities that should define the specific role of this service taking into account the integrity concept in maritime domain.

Criticality: The criticality of this action is classified as high because the liabilities may impose additional requirements to the tool development.

Timeframe: The end of this activity will set the starting point of the second stage service development (i.e., T0_ stage2) and will last for a year, ending at T0_ stage2+12m.

Recommendation: The outcomes of this activity shall be, above all, the role of this tool in the maritime navigation procedures. In case this tool is provided only as an auxiliary tool to estimate approximately the performance of M(G)RAIM requirements will be much more relaxed.

7.1.3 Action #3. Prediction Tool core processing development

Objective: The objective of this action is upgrade the current developed prototype into an operational tool, following the coding standards required.

Justification: Currently, M(G)RAIM prediction tools is developed as a prototype. In order to provide an operational tool, the core forecast module should be coded according to the requirements defined by Action #2. Service provision analysis.

This action will develop and implement all the requirements detailed in section 3.2.2 following the prototype design in section 4.1 and the appropriate coding standards, without taking into account interface requirements. Current protype implementation simplifies some of the processing and interfaces but the high-level scheme, the input and outputs will remain the same for an operational tool.

These interfaces may change along the Prediction Tool operation, for example due to a change of the message format, and therefore the development of the core processing should be a separated activity.

In addition, the auxiliary tool developed in the first stage will be evolved to become an operational tool with the latest changes considered when M(G)RAIM are implemented in maritime receivers.

Action type: Technical software development activity.

Owner: This work should be done by the service developers

Criticality: The criticality of this action is classified as high since is the core activity for the Performance Prediction Tool development.

Timeframe: This activity may be performed in 6 months starting at T0_ stage1 for the first stage and T0_ stage2 for the operational tool.

Recommendation: It is recommended to wait until high level provision scheme is defined in Action #2. Service provision analysis in order to develop the core tool function according to the most suitable standards. Otherwise, reengineering may be needed.

7.1.4 Action #4. Development of Performance Prediction Tool interfaces

Objective: The objective of this action is to develop all the interfaces required to comply with section 3.2.3 requirements.

Justification: Currently, M(G)RAIM prediction tools is developed as a prototype that takes all input parameters in a file format. However, section 3.2.3 requirements and functional requirements of section 3.2.2 require different interface than static files.

In particular, there should be defined two different groups of interfaces, the one available to the mariner user to introduce its desired configuration and obtain the performance forecast, and the GNSS healthy related interfaces. In particular, the following interfaces should be developed:

- **GNSS healthy interfaces,** please note that this interfaces could take place between the stakeholders identified in Action #2. Service provision analysis:
  - **GNSS Navigation interface**: Tool requires the closest available GNSS constellation ephemeris to the configured date. These ephemerides should be obtained from a network of receivers decoding real data for the forecast, and from historical data for “past-forecast” mode (i.e. Navigation RINEX).
  - **GNSS Health Status:** The operational tool should take as input the NANUs, NAGUs or equivalent messages that provide information about the GNSS constellation and satellite health status. In addition, this interface should consider as inputs augmentation system information, if used, about GNSS health information. These messages should be decoded on real time for the forecast, and from historical data for “past-forecast” mode (i.e. NANUs/NAGUs historical data or ftp servers)
  - **Error models:** These models could be provided by a user configuration or taken from augmentation system signal error estimations, making assumption for the

propagation of the model in the future. For "past-forecast" mode augmentation messages shall be read from historical data, (i.e. ftp servers).

- **User interfaces**: The tool shall consider at least the following configuration parameters to be developed aligned with the Action #2. Service provision analysis outcomes: User location / User grid definition; Date and expected time window; Constellation(s) to be used; Satellites to be used; M(G)RAIM configuration parameters and navigation phase requirements. It is expected that this configuration parameters will be provided via web GUI (Graphical User Interface), where also the output information can be displayed in form of plots and maps. In addition, this interface should consider the automatic processing or reports in form of pdfs or other text format.

These interfaces may change along the Prediction Tool operation, for example due to a change of the message format, and therefore the development of the core processing should be a separated activity.

Action type: Technical software development activity.

Owner: This work should be done by the service developers.

Criticality: The criticality of this action is classified as high since is the core activity for the Performance Prediction Tool development.

Timeframe: This activity may be performed in 6 months starting at T0_stage1 .

Recommendation: It is recommended to wait until high level provision scheme is defined in Action #1. Incorporation of M(G)RAIM proposed solution

Objective: The objective of this action is foster the incorporation of the M(G)RAIM proposed solution into maritime receivers.

Justification: It could be obvious to mention, but the usability of a potential Performance Prediction Tool for maritime users is linked directly with the penetration of the proposed M(G)RAIM algorithms designed in INSPIRe project [RD.1][RD.2].

Performances are given, both in terms of availability and size of protection level, for the proposed maritime on-board solution, assuming among other features, the implementation of one of the two algorithms analysed in this project. Therefore, maritime users shall implement these algorithms to find the Performance Prediction Tool useful.

In order to do so, it should be promoted the penetration of the M(G)RAIM proposed solution into maritime receivers via IEC standardisation, IALA guidelines or any other maritime regulatory material that could help this penetration. Afterwards, it should be assessed if the development of an operational Performance Prediction Tool, the second stage of the development, makes sense or the scope should be readapted to include the existing algorithms, regardless they are M(G)RAIM ones or any others.

In this action should be distinguished the two algorithms proposed. MGRAIM algorithm is a simpler algorithm where most of the checks are already implemented by the receivers and the geometry screening is the additional feature that should be included. Therefore, its penetration is expected much easier and the auxiliary tool could help to foster its usage.

However, the MRAIM implies a different integrity concept and would imply significant changes in the maritime integrity approach. For this algorithm is where has to be evaluated if an operational tool may makes sense.

Action type: Promotion and Standardisation activity.

Owner: This work should be done by the maritime authorities and the INSPIRe consortium.

Criticality: The criticality of this action is classified as high because after its completion a go/no-go decision should be taken.

Timeframe: This activity shall be carried out before the service development and will last for at least ten years, starting at T0_ stage1 and ending at T0_stage1 +10yrs.

Recommendation: Promotion of M(G)RAIM solution should start as soon as possible since the time scope for maritime regulatory material modification or development is usually long and take not less than 2 years. In addition, manufacturers would not implement the M(G)RAIM solution unless clear advantages are observed or regulation imposes it.

Action #2. Service provision analysis in order to develop the core tool function according to the most suitable standards. Otherwise, reengineering may be needed.

7.1.5 Action #5. Deployment of monitoring network stations (Optional)

Objective: The objective of this action is to develop and additional module could monitor the real performances and compare it against the forecasted ones, in order to fine tuning and refine the used error models.

Justification: Currently, M(G)RAIM prediction tools is developed as a prototype that takes all input parameters in a file format. In particular, maritime error models are provided from pre-computed models or are extrapolated from real time information from augmentation systems, if used.

An additional module could be developed to monitor the real performances and compare it against the forecasted ones, in order to fine tuning and refine the used error models. This module will help then to improve the configured models without augmentation and also will improve the extrapolation models from augmentation messages information.

In addition to the refine function, the interfaces of this module may be also defined if this monitoring station network is deployed (or reused) with M(G)RAIM enabled receivers. These network station could also provide recorded information and the monitoring module could post-process the algorithm. Finally, this activity should define how previous models are overwritten with the outcome of the refinements since it should be noted that reference stations may not provide a representative enough error from the maritime environment.

Action type: Technical software/hardware development activity.

Owner: This work should be done by the service developers.

Criticality: The criticality of this action is classified as low since the refinement of the error models could be performed by many other approaches, and also could be configured by the user.

Timeframe: This activity may be performed in 6 months starting at T0_stage1+6m.

Recommendation: It is recommended to develop this activity once the service have started its Testing phase, since it is an optional module that requires the system already in place, at least in a EOP.

7.1.6 Action #6. Performance Prediction Tool Test Bed

Objective: Finally, the objective of this action is to develop a Test Bed to assess the functioning of the tool prior to its operational phase.

Justification: Similar to any operational service related with the safety of navigation, the Performance Prediction Tool shall be assessed by a Test Bed in order to analyse its functioning under operational environment.

This activity is key to solve any undetected problem in the development phase before taken any commitment, if any.

Action type: Technical software/hardware development activity.

Owner: This work should be done performed as defined in Action #2. Service provision analysis by the entity that is going to host the service.

Criticality: The criticality of this action is classified as high since it is the previous step before the service becomes operational where everything is tested.

Timeframe: This activity may be performed in 12 months starting at T T0_stage1+6m.

Recommendation: It is recommended to develop this activity considering the same stakeholders that are going to develop the operational system according to Action #1. Incorporation of M(G)RAIM proposed solution

Objective: The objective of this action is foster the incorporation of the M(G)RAIM proposed solution into maritime receivers.

Justification: It could be obvious to mention, but the usability of a potential Performance Prediction Tool for maritime users is linked directly with the penetration of the proposed M(G)RAIM algorithms designed in INSPIRe project [RD.1][RD.2].

Performances are given, both in terms of availability and size of protection level, for the proposed maritime on-board solution, assuming among other features, the implementation of one of the two algorithms analysed in this project. Therefore, maritime users shall implement these algorithms to find the Performance Prediction Tool useful.

In order to do so, it should be promoted the penetration of the M(G)RAIM proposed solution into maritime receivers via IEC standardisation, IALA guidelines or any other maritime regulatory material that could help this penetration. Afterwards, it should be assessed if the development of an operational Performance Prediction Tool, the second stage of the development, makes sense or the scope should be readapted to include the existing algorithms, regardless they are M(G)RAIM ones or any others.

In this action should be distinguished the two algorithms proposed. MGRAIM algorithm is a simpler algorithm where most of the checks are already implemented by the receivers and the geometry screening is the additional feature that should be included. Therefore, its penetration is expected much easier and the auxiliary tool could help to foster its usage.

However, the MRAIM implies a different integrity concept and would imply significant changes in the maritime integrity approach. For this algorithm is where has to be evaluated if an operational tool may makes sense.

Action type: Promotion and Standardisation activity.

Owner: This work should be done by the maritime authorities and the INSPIRe consortium.

Criticality: The criticality of this action is classified as high because after its completion a go/no-go decision should be taken.

Timeframe: This activity shall be carried out before the service development and will last for at least ten years, starting at T0_ stage1 and ending at T0_stage1 +10yrs.

Recommendation: Promotion of M(G)RAIM solution should start as soon as possible since the time scope for maritime regulatory material modification or development is usually long and take not less than 2 years. In addition, manufacturers would not implement the M(G)RAIM solution unless clear advantages are observed or regulation imposes it.

Action #2. Service provision analysis to exploit synergies.

7.1.7 Action #7. Maritime user engagement

Objective: The objective of this action is to promote the Performance Prediction Tool service for maritime users

Justification: After the Performance Prediction Tool service is developed for maritime users, mariners will need to realise of the benefits of the tool. It is expected that usage of the tool would not be mandatory prior any operation, and therefore benefits of the tool should be highlighted to mariners.

The main advantage of such a tool for mariners is the forecast capability in order to assess the level of performance for intended operation, in the given location, at the expected time window, increasing the safety of the operations since mariners would have an indication of how much they can trust in the positioning provided by GNSS. This would facilitate the operation since mariners will not set off unless they are sure they can perform the full operation without any risk. Obviously, these advantages are strictly related with the Action #2. Service provision analysis since the mandatory grade of these algorithms will drive the added value on the eyes of the mariners.

Action type: Promotion activity

Owner: This work should be done by the maritime authorities and the INSPIRe consortium.

Criticality: The criticality of this action is classified as medium because it is not a key activity for the service development, but it is for its usage and usefulness.

Timeframe: This activity may be performed in at least 18 months starting at T0_ stage1.

Recommendation: It is recommended to keep in mind this activity for the whole development of the Performance Prediction Tool service in order to get mariners feedback as soon as possible and engage them at first operational stages.

7.2 Operational Performance Prediction Tool Roadmap

Finally, the last stage of this identification is the development of a roadmap based on the aforementioned information. The expected development roadmap is detailed in the following figure.

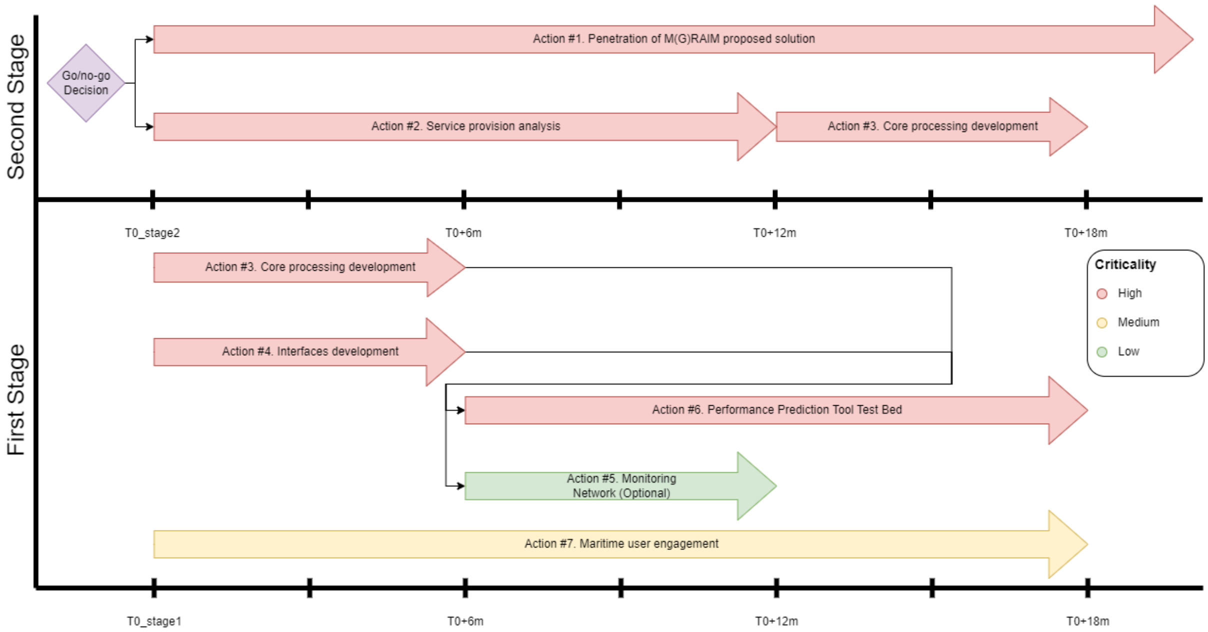


Figure 7-1. Operational Performance Prediction Tool Roadmap.

Actions have been classified by their criticality, indicating the relationship among the actions and the expected timeframe.

8 HIGH LEVEL ESTIMATED COST REPORT

This section provides a high level estimated cost for an operational M(G)RAIM Performance Prediction tool including the development, implementation, and operations, highlighting assumptions and data sources.

Table 8-1, shows the high-level estimation for the development of the prototype tool based on the main actions identified to implement an operational Performance Prediction Tool described in Section 7 above. Be advised that the figures contained in this table are estimated taking into account the current proposal of Performance Prediction Tool development and is aligned with the hypothesis of this tool is provided as an auxiliary tool. In case of significant change in the development approach, the estimated cost shall be re-estimated.

Table 8-1 High-level estimate cost

Task	Estimated cost	Justification
Action #1. Incorporation of M(G)RAIM proposed solution	£300k+hardware	This action aims to develop technical analysis and dissemination activities to foster the penetration of the M(G)RAIM algorithms.
Action #2. Service provision analysis	£150k	This action only analyses the liabilities and service provision scheme for the Performance Prediction Tool. Estimated cost for one-year desk research project
Action #3. Prediction Tool core processing development	£150k + validation	This action is for the upgrade from the prototype for the operational core tool. The level of validation required will increase the cost
Action #4. Development of Performance Prediction Tool interfaces	£200k	Interfaces include receiving the GNSS signal/messages in real-time and user/web interfaces
Action #5. Deployment of monitoring network stations (Optional)	£50k/station £100k (central facility)	This includes the deployment of stations to compare real performances against forecasted ones to refine the tool and error models
Action #6. Performance Prediction Tool Test Bed	£100k deployment +£50k per year	Test Bed cost has been estimated with the cost of previous operational Test Bed deployed by GMV
Action #7. Maritime user engagement	£30k per person and a year of effort	This includes dissemination and maritime engagement activities to engage users in the usage of the Prediction tool

Operational cost of the tool, once developed, would depend on the service provision approach. If the tool is provided as it is then the operational cost is negligible. However, in case any commitment is made for the quality of the service, then operational cost will increase for the maintenance effort, the provision of periodic performance report, the implementation of a user help desk, etc.