Rovins

Operation Guide

iXblue

Revision History

Edition	Date	Comments
A	07/2019	Creation
B	03/2020	Alignment phases updated

Copyright

Disclaimer

iXblue specifically disclaims all warranties, either expressed or implied, including but not limited to implied warranties about merchantability and fitness for a particular purpose with respect to this product and documentation. iXblue reserves the right to revise or to make changes or improvements to this product or documentation at any time without notify any person of such revision or improvements.
In no event shall iXblue be liable for any consequential or incidental damages, including but not limited to loss of business profits or any commercial damages, arising out of the use of this product.

Trademarks

Microsoft, MS-DOS and Windows are registered trademarks of Microsoft Corporation.
Intel and Pentium are registered trademarks and Celeron is a trademark of Intel Corporation.

Export Control

This product is subject to export control regulations. Please refer to the commercial offer or contact iXblue for details about the applicable export control regulations and restrictions.

Rovins Documentation

The following documents give all the information you need in order to understand and to use your product.

- **Rovins Technical Description** *(ref.: MU-ROVINSTD-AN-001*)
  - Rovins and iXblue technology presentation
  - Technical specifications
  - Certification and qualification, life cycle
  - Mechanical, electrical and communication interface description
- **Rovins Installation & Setup Guide** *(ref.: MU-ROVINSISG-AN-001)*
  - Conventions
  - Physical and electrical installation
  - Connecting to the Web-Based Graphical User Interface
  - Setup the Rovins
  - Contacting iXblue support
- **Rovins Operation Guide** *(ref.: MU-ROVINSOG-AN-001)*
  - Introduction to the Inertial Navigation System
  - Start-up Phases
  - Web-Based Graphical User Interface description
  - Configuring the navigation parameters & managing the external information
  - Viewing the system information
  - Recording data
- **Rovins Interface Library** *(ref.: MU-ROVINSIL-AN-001)*
  - NMEA frames
  - Digital input and output protocols
  - Pulses interfaces specification
  - Control commands
- **Rovins Quick Start Guide**
  - Pack content verifying
  - Installing and connecting Rovins
  - Configuring and operating Rovins
- **SEACON 12 PIN TI 1M Pigtail Cable - Product Description** (Ref.: MU-PDCABLES-AN-001)
  - cable and pinout of the SEACON 12 pins Pigtail Cable
- **SEACON 19 PIN TI 1M Pigtail Cable - Product Description** (Ref.: MU-PDCABLES-AN-002)
  - cable and pinout of the SEACON 19 pins Pigtail Cable
- **SEACON 26 PIN TI 1M Pigtail Cable - Product Description** (Ref.: MU-PDCABLES-AN-003)
  - cable and pinout of the SEACON 26 pins Pigtail Cable
- **Subsea Products - Illustrated Part Catalog** *ref.: MU-SUBSEADP-AN-001*
  - Detailed part list
  - Alphanumerical Index
- **Application Note - INS+DVL Calibration** *(ref.: MU-DVLINS-AN-001)*
  - Configuring the calibration
  - Calibrating the DVL+INS

- **Application Note - Installation and Configuration of AHRS and INS for Seabed Mapping Measurements** (*ref.: MU-HEAVAPN-AN-001*)
  - > Using heave compensation on seabed mapping
  - > Effect of vessel transient movements

Rovins Operation Guide Overview

This document must be read and understood prior to using the product.
The manufacturer shall in no case be held liable for any application or use that does not comply with the stipulations in this manual.

The Rovins Operation Guide is divided into several parts:

- **Part 1: Introduction to the Inertial Navigation System**
  This part gives information about the presentation of the inertial navigation system.
- **Part 2: Start-up Phases**
  This part gives details on the start-up phases, alignment phases and recommended trajectories.
- **Part 3: Web-Based Graphical User Interface Description**
  This part gives detail on the Web-Based Graphical User Interface.
- **Part 4: Configuring the Web-Based Graphical User Interface**
  This part gives detail on how to configure the Web-Based Graphical User Interface.
- **Part 5: Configuring the Navigation Parameters**
  This part gives details on how to configure starting mode, altitude mode and current model.
- **Part 6: Managing the External Information**
  This part gives the configuration parameters to help you fixing the Rovins.
- **Part 7: Viewing the System Information**
  This part gives detail on where to find the detailed status, the navigation data and the events.
- **Part 8: Recording Data**
- **Appendix A**: **External data rejection criteria**

Abbreviations and Acronyms

ACC	Accelerometer
CTD	Conductivity, Temperature, Depth sensor
DVL	Doppler Velocity Log
EGNOS	European Geo-stationary Navigation Overlay Service
GALILEO	European Satellite Navigation System
GGA	Essential fix data which provide 3D location and accuracy data
GLONASS	Global Navigation Satellite System (operated by the Russian Space Forces)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System (operated by the United States Department of Defense)
GST	GPS Pseudo-range Noise (PRN) statistics (The GST message is used to support Receiver Autonomous Integrity Monitoring)
GUI	Graphical User Interface
HRP	Heading, Roll, Pitch
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IP	Internet Protocol
LVA	Lever Arms
PPS	Pulse Per Second
RTK	Real Time Kinematic
SD	Standard Deviation
UTC	International acronym for Coordinated Universal Time (CUT)
UTM	Universal Transverse Mercator
VTG	Vector Track and speed over Ground
ZDA	Time and Date (The ZDA message identifies UTC time, day, month, and year, local zone number, and local zone minutes)
ZUPT	Zero velocity UPdaTe

Table of Contents

1 Introduction to the Inertial Navigation System

Rovins is an Inertial Navigation System (INS) that provides heading, roll, pitch, speed, position and heave surge sway information to the user, with or without external sensor data.

1.1 Inertial Navigation System Principles

INS Data flow

Figure 1 details the data flow inside the Rovins, from sensor acquisition to user data outputs in Web-Based Graphical User Interface and protocols:

- The FOG, accelerometers and temperature sensors are sampled at 400 Hz.
- An inertial sensor assembly (ISA) block is generated to synchronize this data set.
- The thermal compensation is applied to this data flow to get sensor blocks that are no longer sensitive to thermal changes.
- This data set is compensated at 400 Hz from coning/sculling dynamic effects due to discrete integration of the sensors, and from accelerometer lever arms that generate centrifuge accelerations inside the IMU block. It is then downscaled to 200 Hz to get IMU delta rotation and delta speeds.
- The IMU data is then provided to the algorithm to compute user data at 200 Hz and this data set is used for Web-Based Graphical User Interface display at 1 Hz and for user output protocols, which rate is configurable from 0.1 Hz to 200 Hz.

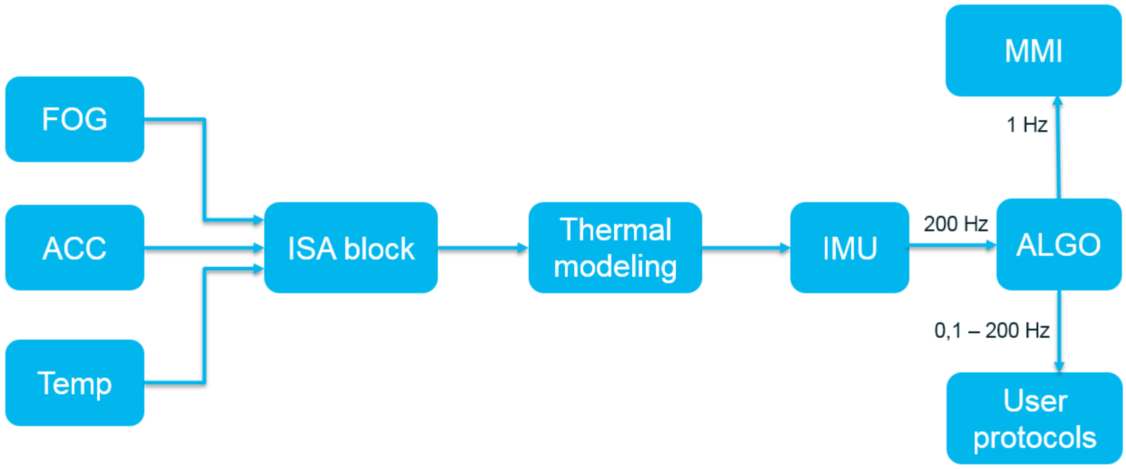


Figure 1 - Inertial Navigation System Data Flow

INS Algorithm

Figure 2 details the algorithm architecture used in Rovins to compute user data from IMU delta rotation and delta speed information:

- The delta rotation and delta speed coming from the IMU are used to integrate Rovins motion, based on current attitude, speed and position, to compute next attitude, speed and position. This is performed with or without external sensor input.
- When external sensors are available, they are first pre-filtered in the rejection filter to make sure they are consistent with the Rovins current position, speed and attitude.
- If they are consistent, they are used by a Kalman filter to estimate current position, speed and attitude error and correct the user data and the estimated INS internal sensor errors.

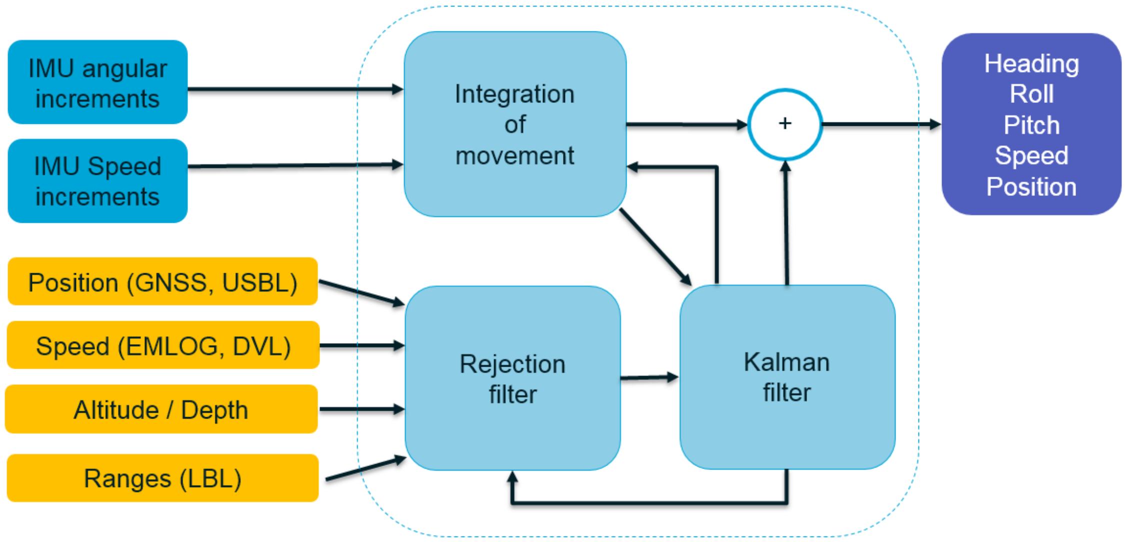


Figure 2 - Inertial Navigation System Algorithm

Integration of Movement

The algorithm converts angular increments and speed increments computed by the IMU into user navigation data by integrating these values as described in Figure 3:

- The IMU delta-rotations are compensated from craft rate and earth rotation and used to update the current attitude.
- The IMU delta-speed are projected from Rovins body frame to geographical frame using the current attitude, compensated from local computed gravity and Coriolis force to update current geographical speed.
- Position is updated using geographical speed.

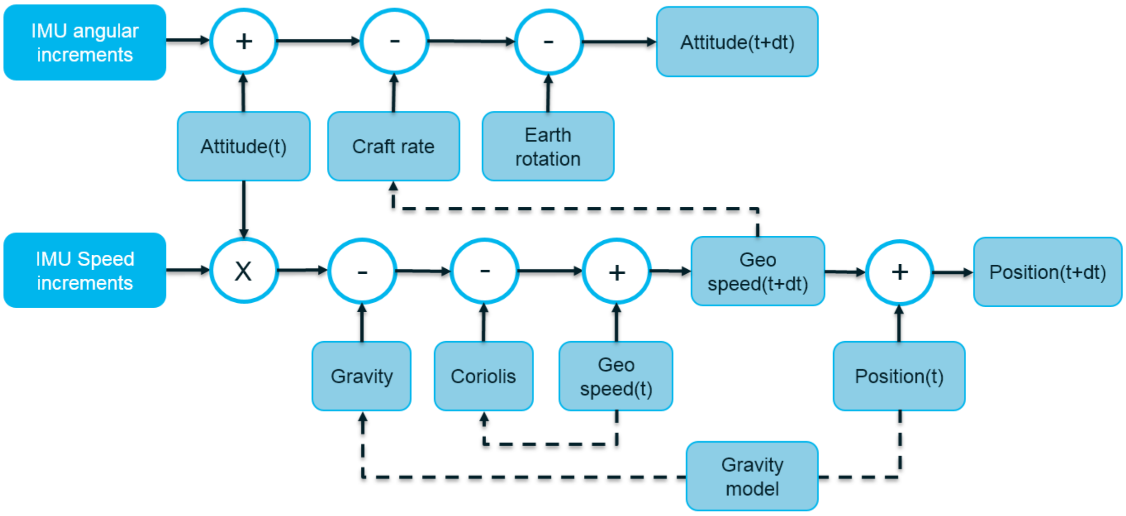


Figure 3 - Integration of movement

1.2 Kalman Filter

The Kalman Filter is a Bayesian probabilistic filter that models integration of movement errors and predict future state error statistics from current state to compare it to external observation and determine integration error and update model parameters. The Kalman Filter typically estimates:

- Attitude errors
- Position error
- Speed error
- Internal sensor errors (FOG and accelerometer biases, scale factors, etc.)

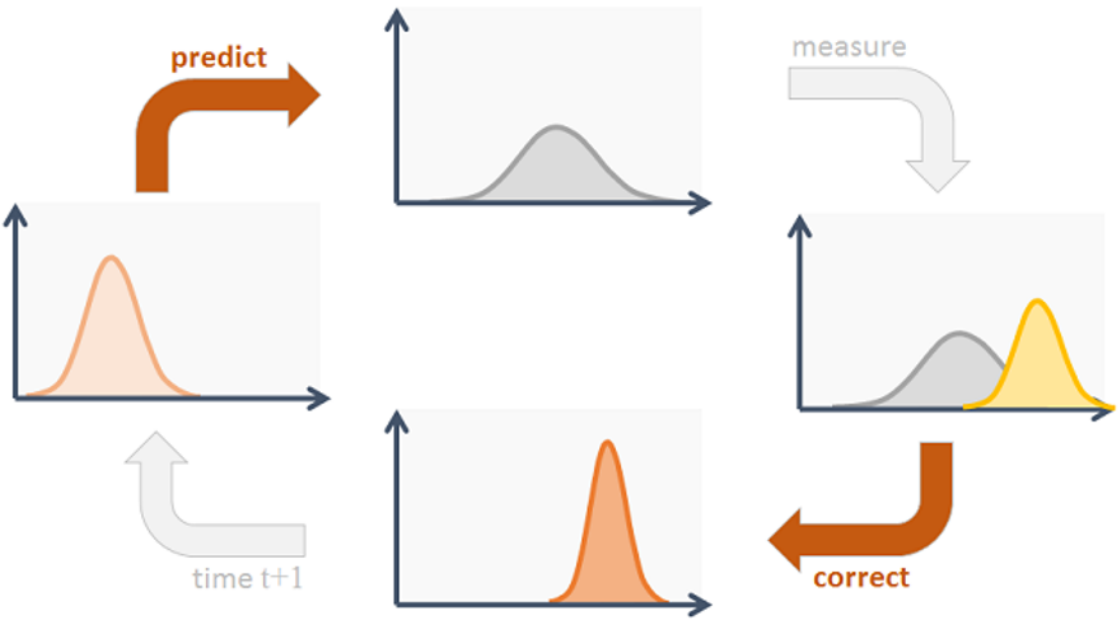


Figure 4 - Kalman Filter Steps: predict, measure, correct

This works when external observations are available.

External observations must be accurate. If they are not, the Kalman Filter may be corrupted. This means that both the configuration of the external sensor (lever arms, timestamping) and its error estimation (standard deviation provided by the sensor or set by the user) must be correct.

1.3 Propagation of Errors in Pure Inertial Mode

1.3.1 Horizontal Plane

The accuracy of data computed by the pure inertial system is dependent:

- on the accuracy of accelerometers and gyroscopes sensors
- on the capacity of the Kalman Filter to increase the sensor accuracies
- on the initial attitude, velocity and position errors obtained after the coarse alignment

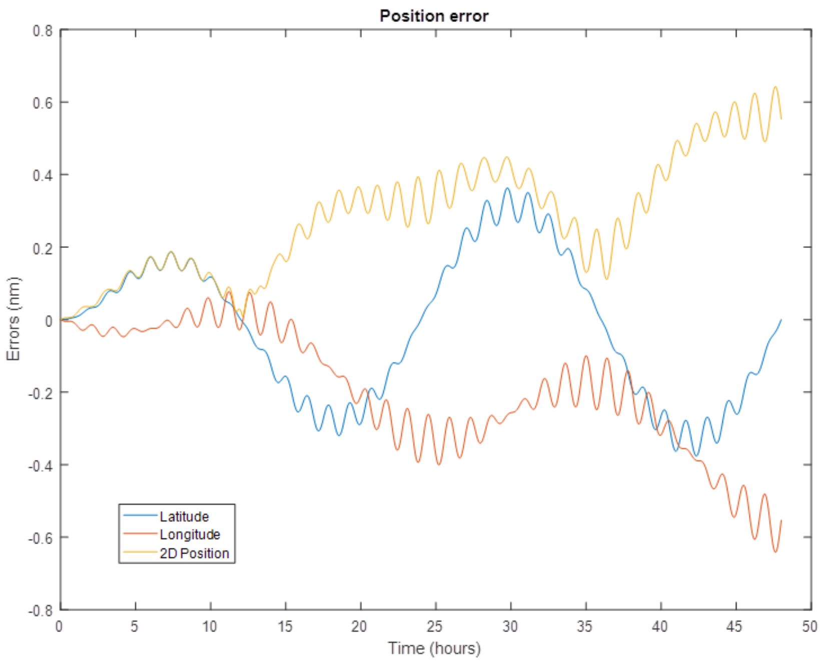
All sensors have errors (no matter how small they are). Since the gyroscopes and accelerometers data are integrated over time and since the velocity, position and attitude computations form a closed loop, all these errors propagate with time and influence each other.

Error propagation can be divided into 3 different categories:

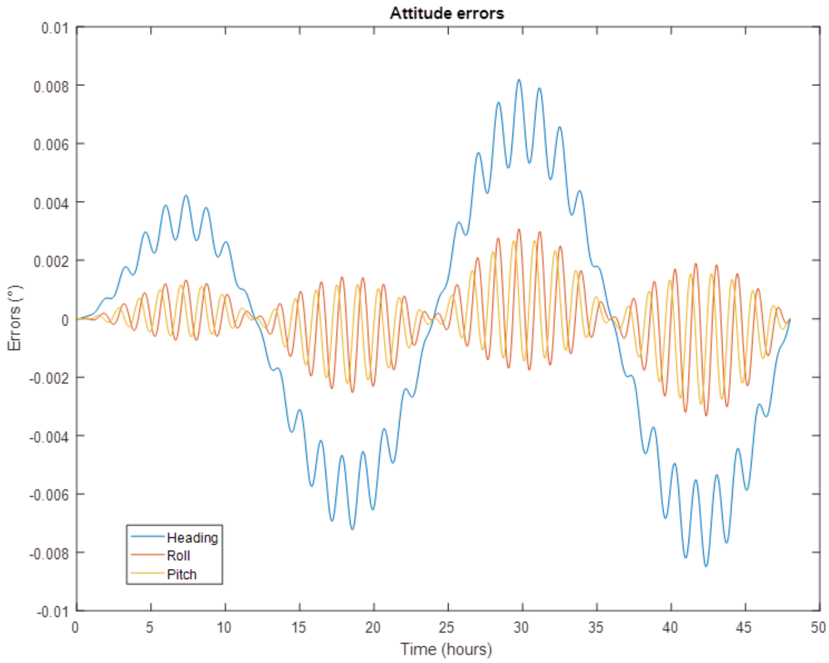
- Schuler oscillation (84,4 min period)
- 24h oscillation (24 h period)
- Drift (only on longitude data)

In pure inertial, without external sensor observations, the navigation equation integration will accumulate accelerometer and gyrometer errors in time and generate speed, attitude and position errors. In these conditions, latitude error oscillates with Shuler Period (84 minutes) and Earth period (24h). The error amplitude depends on the INS sensor class but is bounded. The longitude error also oscillates with the same periods, plus an additional linear drift due to composite polar gyrometer bias and scale factor error. The oscillation amplitude and the linear drift speed depend on INS sensor class and this error is not bounded due to the linear part of the drift. The linear drift is due to longitude error generated by gyrometer bias along the polar axis.

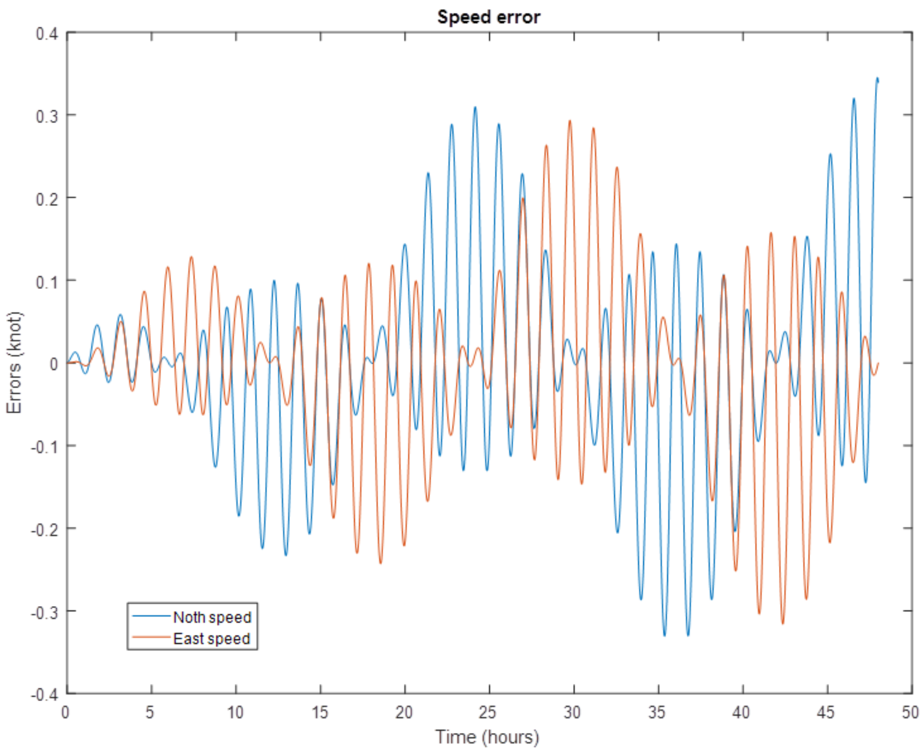
The resulting 2D position error combines latitude and longitude errors. It is not bounded as the longitude error:



Heading and roll/pitch errors oscillate with both earth period and Shuler period. The roll and pitch error is mainly driven by acceleration errors and thus Shuler effect. The heading error is more affected by gyro errors that vary with Earth period.



North and East speed error also oscillate with Earth and Shuler periods, due to both acceleration errors and attitude errors, but they are bounded.



1.3.2 Vertical Axis

The estimation of altitude cannot be done by free inertial means: the error would increase exponentially. The altitude of Rovins is stabilized (either by external sensor data or artificially) to prevent this exponential growth of the altitude error. The stabilization of the product altitude is configured with the altitude computation mode.

The following altitude modes are available:

- **Stabilization** (recommended for surface ship): The stabilization mode is selected when the update of the mean altitude is not needed and the altitude drift to be avoided during long GNSS drop-outs. In this mode, the altitude drift will be maintained small around a mean value by filtering out the low-frequency components of the altitude variation computed by Rovins.

- **GPS**: in this GPS altitude mode, Rovins will use GNSS altitude and vertical speed sensors.
  In navigation mode, GNSS data is filtered by the algorithm. Rovins will use the quality indicator in the GGA telegram to evaluate the reliability of the GNSS position. Refer to the GPS input protocol description in the Rovins Interface Library document.
  If the GST telegram is received, Rovins will use this data instead of the quality indicator. This quality indicator information will be used to reject GNSS spikes, resulting in smooth position data. The smaller the standard deviation (SD) on altitude is, the better the spike rejection will be and the Rovins computed altitude will follow more closely the GNSS altitude.
  If the GNSS signal is lost and no 3D-speed sensor is received, the altitude drift will be maintained small around a mean value by switching to Stabilization mode (as described above). The mean value is the value of Rovins when the last valid aiding measurement was received. Rovins will exit stabilization mode as soon as altitude SD and vertical speed SD are within a given criterion and when GNSS is back ON and valid.

- **Hydrograhy**: This hydrography mode is used solely with RTK GNSS. In this case, the goal is to reject GNSS jumps that are associated with poor altitude fixes and will degrade product altitude computation (i.e.: multibeam imagery in Hydro applications). The altitude is the combination of GNSS altitude mode with an added feature of quality mode rejection. In this mode Rovins will use GNSS altitude and vertical speed to compute altitude. It operates in the following manner:
  If the GST telegram is received, altitude standard deviation is retrieved in the data string. If not, the quality factor in the GGA telegram is converted in altitude standard deviation (SD).
  When Q=4 (RTK mode) then the GNSS altitude in GGA string is used by Rovins to compute height. For the other cases, when this condition is not met (i.e., Q = 0, 1, 2, 3, 5, 6) the product will stabilize the altitude to the last valid value. Rovins will exit stabilization mode as soon as altitude SD and vertical speed SD are within given criteria. This will happen in practice when GNSS is back to mode 4 (RTK). If GNSS is lost (i.e., under a bridge), the same altitude stabilization applies.

- **Depth** (recommended for subsea application with depth sensor): In this mode, depth output is computed using subsea positioning system (i.e., USBL, depth sensor) or/and vertical speed sensor if available.
  If a depth sensor is available, the attitude provided by USBL is not used to avoid using any noisy data. As long as depth underwater sensor is available, Rovins filters this information based on sensor standard deviation. In case of sensor drop-out, if no 3D speed sensor is received, the depth output value is stabilized around the last value received as in stabilization mode, until sensor data becomes available.

In all these modes, the default altitude convention used by Rovins is the mean sea level altitude (MSL). Ellipsoid WGS84 height can also be selectable in the Output port configuration from the Web-Based Graphical User Interface (refer to the Rovins Installation & Setup Guide).

1.4 Rejection Filter

To prevent from corrupting the Kalman filter with inconsistent data that do not follow the Kalman filter sensor models, a rejection filter is added in front of the Kalman filter.

This filter will check the consistency between Kalman filter prediction and external sensor information.

When the sensor data is consistent with the Kalman filter prediction (the distance between sensor observation and Kalman prediction is in the same order of magnitude as the respective standard deviations), the observation is validated and feeds the Kalman filter.

When the distance is larger, it is either attenuated before feeding the Kalman, or when it is too large, it is rejected and will not be passed to the Kalman filter. This allows maintaining a stable Kalman filter even when external sensors exhibit transient errors (multi-path GNSS, spurious speed error on speed sensor, etc.).

For each external sensor, the rejection filter can be set in three modes:

- Automatic: it behaves as described above, rejecting outliers and accepting consistent observations
- Always true: the rejection filter is by-passed and all external sensor observations will feed the Kalman filter
- Always false: the external sensor data will not be used at all

For more details on rejection criteria, please refer to Appendix A.

1.5 Current Model

The algorithm uses a dedicated model to manage the water current estimation in time and distance. This current estimation is used to link the measured water speed information from EMLog to INS speed.
The more confidence the algorithm will have on current stability, the tighter the coupling will be between INS estimated speed and water speed measurement.

Confidence in previously estimated current will change in time and in traveled distance: when no observation allowed to re-estimate the current for a long time or a long traveled distance, the algorithm will degrade its confidence in current estimation.
As soon as new observations allow to re-estimate it, it will be able to converge again on current confidence, for example when both GNSS and EMLog are received together.
Maintaining a good current estimation allows to significantly reduce the INS navigation error oscillating at Shuler period and Earth rotation period, and this can be done by optimized setup on current model maximum standard deviation and time/distance correlation time.
In a very stable zone where current is known as quite constant, the setup can be typically 0.3 m/s in 3 h and 10 km. This means that after 3 h or 10 km of navigation, current would only change by 0.3 m/s RMS.
In an unstable area, where current could change quickly of more than 1 knot, the setup can be typically 1 m/s in 1 h and 3 km.
This setup will be more robust and avoid misleading the algorithm on current stability but will be less efficient to filter out navigation oscillating errors.

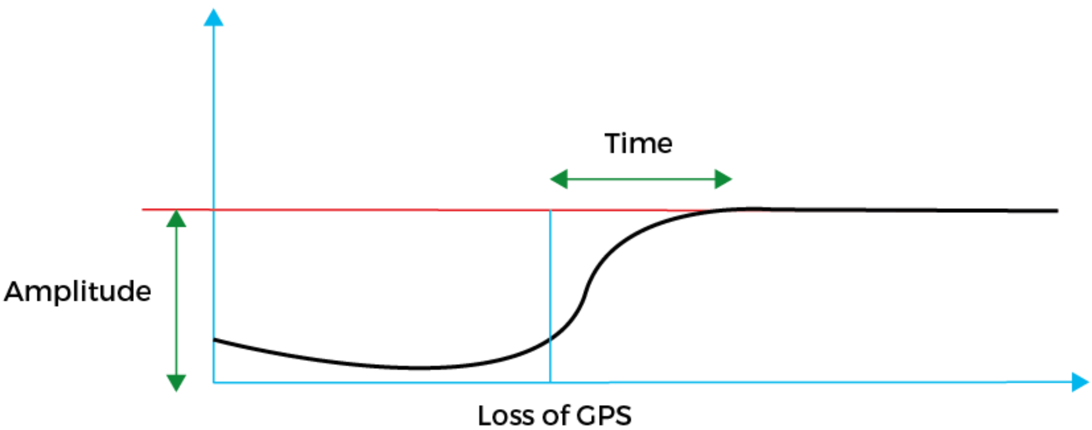


Figure 5 - Current model

1.6 External Sensor Data Age Management

Rovins is using external sensor data in the Kalman filter to compare it to the same data type calculated by the Rovins. To do this we need to compare data that are concomitant, for example to compare GNSS position to Rovins position at the same time.

When external sensor data is timestamped, the Rovins computes external sensor data age by comparing current time inside Rovins with external data sensor timestamp. It then uses this age to retrieve the position or speed in the Rovins logs and computes the position or speed error by comparing this internal estimation to external sensor data at that time.

When external sensor data is not timestamped, the Rovins assumes a null age and thus uses current position or speed to compare external data to internal estimation and compute the error that will feed the Kalman filter.

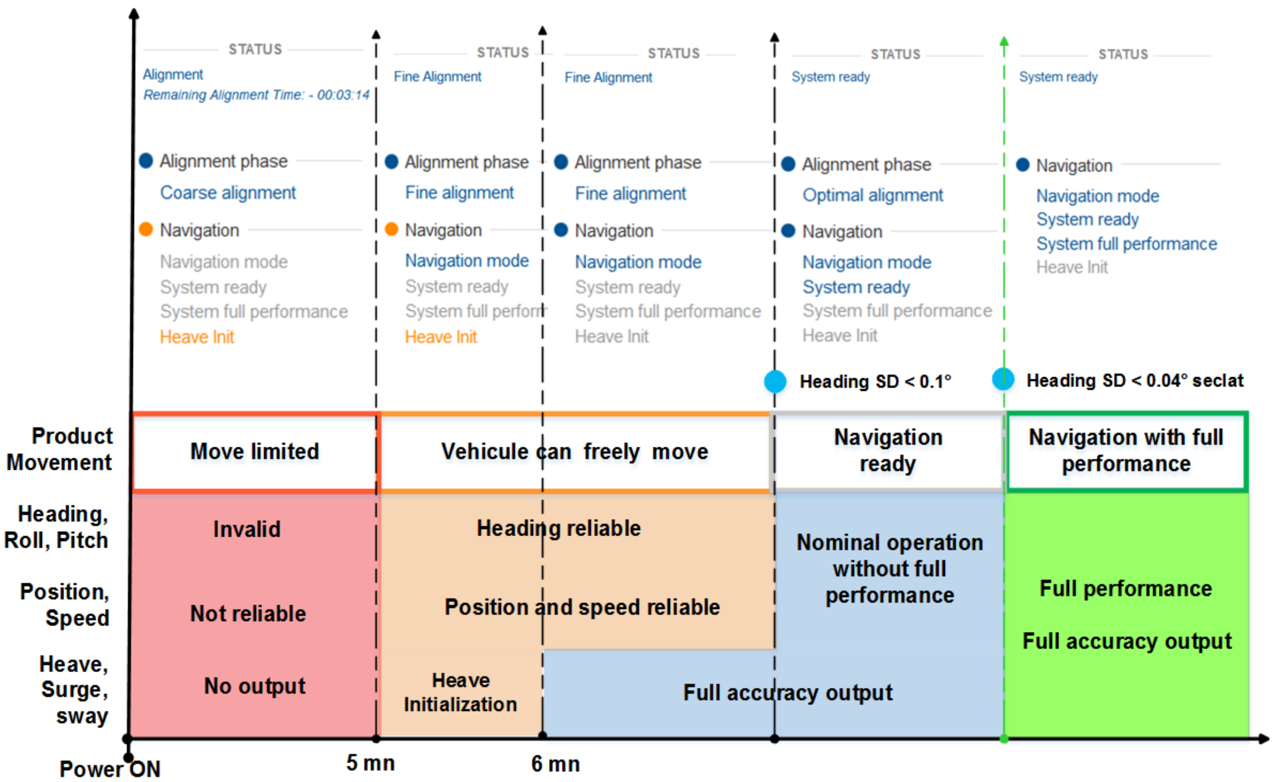
Thus latency in non-time stamped aiding data may cause the data to be rejected or the data may corrupt the Kalman filter.

2 Start-Up Phases

2.1 Alignment Process

The alignment process starts as it is described on the following figure with the different alignment types displayed on the Web-Based Graphical User Interface and the type of moves and output data during this time.

Status & Detailed Status System displayed



The different phases of the Rovins alignment are:

- Coarse alignment: at the end, navigation data are available
- Heave filter initialization: at the end, heave, surge and sway data are available
- Fine alignment: system is auto-calibrating to improve performances. The legacy 'Fine alignment' phase is raised when heading standard deviation gets below 0.1° (no seclat). When fine alignment is completed, the system is ready, it does not reach its full performance.
- Optimal alignment: equipment performance on heading, roll and pitch has reached an optimal performance. The system is ready to navigate but it has not reached the specified heading performance yet.
- When optimal alignment is completed, the system is ready and gives all the data with full performance.

2.2 Start-Up Modes

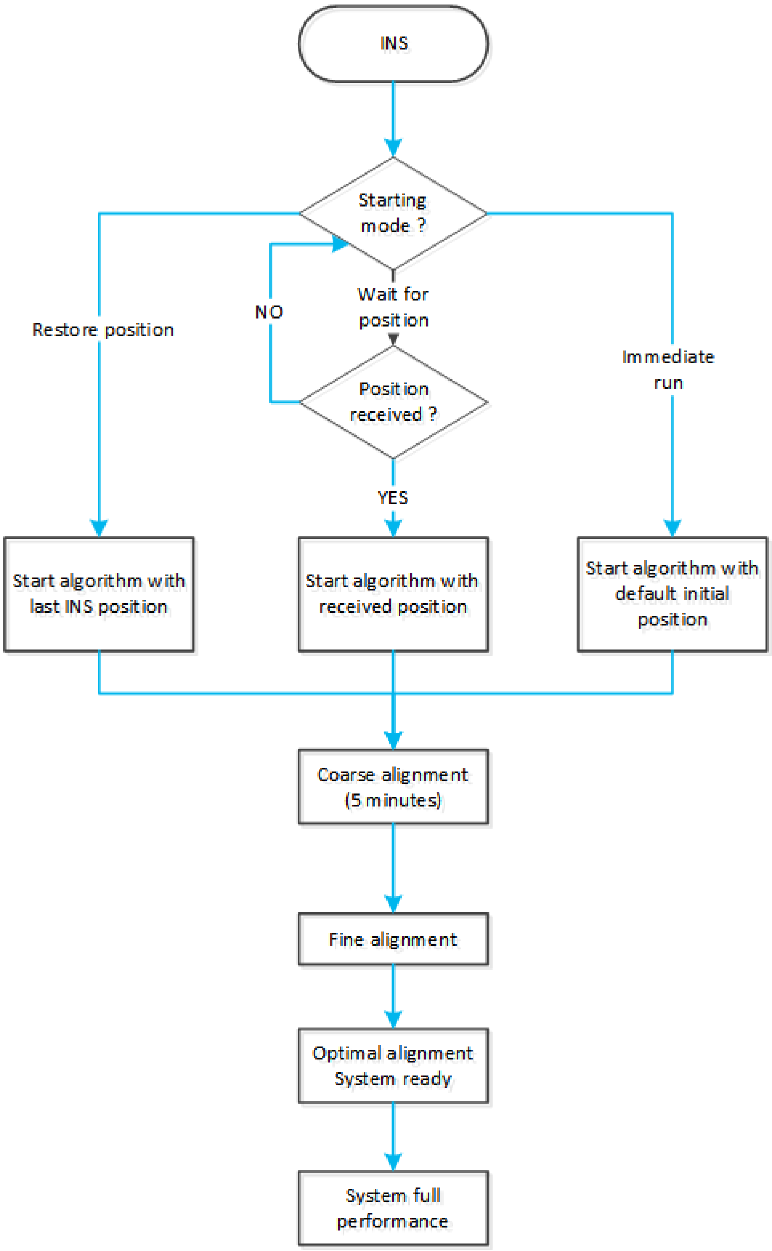


Figure 6 - Start-up modes for Rovins

2.2.1 START-UP

Rovins starts 20 s after power is applied (there is no ON/OFF switch), it then performs a self-test phase.

During this phase:

- The system is muted and cannot receive commands.
- There is no data displayed on the Web-Based Graphical User Interface in the CONTROL page and the blue disc flashes.

At the end of this phase, the system starts transmitting data and can receive commands

2.2.2 Wait for Position (recommended)

In the case of “Wait for position” starting mode, the Rovins waits for at least one valid position input data from any of these active position sensors to start the alignment sequence.
No data is displayed on the Web-Based Graphical User Interface.
‘Wait for position’ status is displayed.
The position standard deviation used after ‘Wait position’ mode is the standard deviation specified by the external position sensor or by the manual position fix used to exit this mode.
When the system is set to “wait for position” start-up mode, but no external positioning sensor (GNSS for instance) is configured, then the product will behave like if it were set to “immediate run” start-up mode, that is to say, start immediately, using the last position used in SETUP - POSITION FIX menu.

2.2.3 Immediate run

In the case of “Immediate run” starting mode, Rovins uses the manual position and altitude stored in the system to start the initial alignment process immediately, without waiting for any sensor. In this mode, the initial position standard deviation is set to 50 m by default.

2.2.4 Restore Position

in this mode, Rovins restores the position saved during the preceding power outage then initializes the algorithm with this position. Rovins static alignment starts with the last known position with the default standard deviation.

2.2.5 Emulation Mode

Emulation mode is an algorithm starting mode where DSP input sensor data is simulated instead of being captured from the sensor board.

This is useful in a demo unit where sensors are not available, but it may also be used in a real unit with sensors.

Simulated sensor values will correspond to a static system at current user latitude, with a fixed heading of 45° and a roll and pitch of 0°. Once you select this mode you need to restart the product. The position used to start the algorithm in this mode shall be the same as the initial position stored for 'Immediate Run' mode, with 50 m standard deviation. No data are displayed on the Web-Based Graphical User Interface.

'Emulation mode' is displayed orange in the system detailed status.

Difference between Simulation and Emulation mode

Unlike in simulation mode (activated in the SETUP menu of the Web-Based Graphical User Interface), the system goes through a complete starting sequence in emulation mode.

For more information on the simulation mode, refer to the Rovins Installation & Setup Guide.

2.3 Coarse Alignment

Important

Coarse alignment phase is a key phase. If the conditions described below are not observed during this phase, performance can be degraded. It is better to restart the Rovins and perform the alignment again.

Principle

During this phase, Rovins is estimating for initial attitude(leveling) and heading (north seeking) using a dedicated algorithm, before switching to standard navigation algorithm.

Output Data

During this phase heading, roll and pitch data are computed and sent but are not accurate and flagged “not valid”. Heading is not sent during alignment for certain telegrams (i.e.: HETHS) to be compliant with NMEA standard.

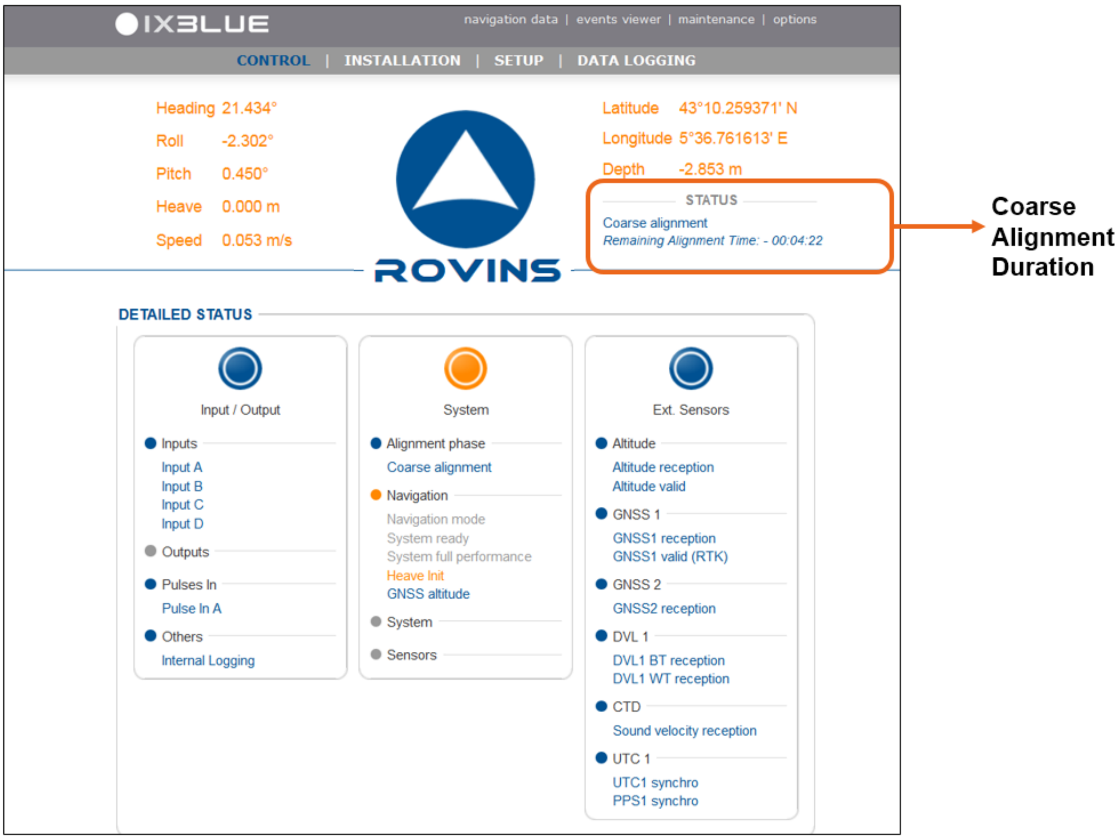
Start/Duration

After powering Rovins on, the coarse alignment starts for 5 minutes.

- With a speed sensor:
  - Initial position (GNSS, manual position)
  - Speed inputin case of manual position
  - No operational constraints on navigation
- Without speed sensor
  - Initial position (GNSS, manual position)
  - Ideally static, or constant steady heading and speed.

End of phase

The coarse alignment duration is displayed by the "Remaining Alignment Time" message in the STATUS area of the Web-Based Graphical User Interface until the end of the coarse alignment. At the end of the coarse alignment, Rovins will automatically switch to the fine alignment.


IXBLUE
navigation data | events viewer | maintenance | options
CONTROL | INSTALLATION | SETUP | DATA LOGGING
Heading 21.434°
Roll -2.302°
Pitch 0.450°
Heave 0.000 m
Speed 0.053 m/s
ROVINS
Latitude 43°10.259371' N
Longitude 5°36.761613' E
Depth -2.853 m
STATUS
Coarse alignment
Remaining Alignment Time: - 00:04:22
Coarse Alignment Duration
DETAILED STATUS
Input / Output
Inputs
Input A
Input B
Input C
Input D
Outputs
Pulses In
Pulse In A
Others
Internal Logging
System
Alignment phase
Coarse alignment
Navigation
Navigation mode
System ready
System full performance
Heave Init
GNSS altitude
System
Sensors
Ext. Sensors
Altitude
Altitude reception
Altitude valid
GNSS 1
GNSS1 reception
GNSS1 valid (RTK)
GNSS 2
GNSS2 reception
DVL 1
DVL1 BT reception
DVL1 WT reception
CTD
Sound velocity reception
UTC 1
UTC1 synchro
PPS1 synchro

2.4 Initialization of the Heave Filter

Principle

Heave measurement is used to compensate for vertical movement due to sea waves in application such as multi-beam or sonar imagery.

Heave is obtained from a double mathematical integration of the vertical geographical accelerometer data. To avoid this data to drift, it is filtered (i.e. high pass filter). The heave filter is designed to measure periodic vertical movement of a surface vessel related to the average sea level.

Heave measured at a specific monitoring point is the addition of the heave measured at the unit location and the heave induced by the rotations (roll & pitch) applied to the lever arms from the unit to the specific monitoring point. The same filtering method applies to the surge and sway, respectively, the two horizontal filtered displacements.

For more details refer to Application Note - Installation and Configuration of AHRS and INS for Seabed Mapping Measurements (Ref.: MU-HEAVAPN-AN-001).

Output Data

There is no output data during the coarse alignment. During the heave filter initialization phase, the heave, surge and sway outputs have not reached full accuracy.

Condition

Heave performance depends on the amplitude and frequency of the waves.

Important

To ensure heave performance at any location of the subsea vehicle, its center of gravity must be enabled and configured in the Web-Based Graphical User Interface, refer to Rovins Installation & Setup Guide.

Start-Duration

Heave initialization occurs when the unit is started (or restarted). The heave initialization phase is performed in parallel of the coarse alignment phase.

End of Phase

The heave initialization ends after 6 minutes. Once the heave filter completes its initialization, it will accurately measure any variations of Rovins positions in the three directions (heave, surge and sway).

The Heave Init. status is displayed **orange** in the Web-Based Graphical User Interface when it is in progress.

When it is displayed grey, this heave initialization is completed.

Delayed heave

Rovins can output two distinct heave measurements :

- Real Time Heave which provides heave in real time mode
- Smart Heave™ provides a measurement of heave with a 100 s fix delay. This data will give the best accuracy in all sea conditions.

The type of the heave measurement and protocol are defined for each output port through the Web-Based Graphical User Interface. Refer to the Rovins Installation & Setup Guide.

2.5 Fine Alignment

Principle

After coarse alignment phase, Rovins is ready for navigation and switches to the “fine alignment” phase. This mode is an auto-calibration mode.
In this mode, the Kalman Filter is activated and it will use both inertial sensors and external sensors to compute optimal estimates of errors (i.e.: ACC & FOG bias), attitude, heading, speed and position.
Residual accelerometer and gyro biases are estimated after each reboot by the Kalman Filter, after the coarse alignment. They are not saved into Rovins to avoid storing bad values. This could happen if “fine alignment” is performed with erroneous GNSS lever arms or incorrect speed log heading misalignment or several other reasons.
INS Kalman filter will continuously estimate internal sensor biases in navigation mode as long as external sensor data (e.g.: GNSS, EM Log,…) is available.
As a consequence, we can say that as long as the Rovins is aided, it is fine aligning, even if the flag has been replaced by the “System Ready” flag that does not mean that fine alignment is over.

Output Data

During the fine alignment, heading is reliable, position and attitude are computed.

Start-Duration

Depending on the navigation pattern and aiding sensor accuracy, the full accuracy on heading, roll, pitch, speed and position can take typically 15 to 45 minutes. To follow the fine alignment progression, you can monitor the heading standard deviation in the navigation data page.
As for any inertial sensor, error estimations from the Rovins Kalman filter depends on two things, first, the quicker and larger the effects of the errors are, the better you can estimate them, second, the source of error shall be identified.
The first will depend on the time dedicated for the alignment, some errors are quick (Schuler oscillations) some are slower (24 h oscillation or polar drift).
The second will depend on movements of the vessel, being static, heading error and X/Y gyro bias have the same effect on the errors, but a heading change allows to set them apart. Some optimal trajectories and time will allow getting even better performances from your sensors.

End of phase

Fine alignment and optimal alignment complete when heading standard deviation is below 0.1°.
Rovins switches to the “fine alignment” phase to improve accuracy on attitude, position and speed by having the Kalman filter estimate the residual biases of accelerometers and gyroscopes. The legacy ‘Fine alignment’ phase is raised when heading standard deviation gets below 0.1° (no seclat).
When fine alignment is completed, the system is ready, it does not reach its full performance.

To view the several views following the type of status on the Web-Based Graphical User Interface, refer to the section "Alignment Process"

2.5.1 Alignment at shore

Fine alignment can also be performed if Rovins is not installed on-board a moving vehicle, for example in a laboratory.
The procedure for successful fine alignment in such case is described below.
Even if static, Rovins requires an input of position and/or speed to achieve fine alignment. This can be done with the following options:

- By connecting a GNSS sensor to Rovins, with the GNSS sending valid data to Rovins.
- By simulating input of GNSS data into Rovins with a software simulator. The input data can be kept constant, and should be equal to the real position of the system.
- Without any external input (no sensor connected, no simulator used), by using the ZUPT mode (i.e.: Autostatic, Position). In such a case, initial manual input of Rovins geographical position is required.

Once Rovins has been set as described above, fine alignment is performed by setting Rovins with different orientations typically 90 degrees apart.
From the initial orientation, the recommended procedure is to leave Rovins still for 30 minutes, then perform a 90 degrees rotation clockwise, then let Rovins still for 30 more minutes.

2.5.2 Recommended fine alignment trajectories

Alignment is required each time the system is powered on or restarted.

Important

There is no need to shut the system down and the system can stay permanently powered. It does not require restarted unless incorrect information is sent to the system and corrupted the Kalman filter. There will be no impact on the life expectancy of the unit, as there are no moving parts to wear out when powered on.

A good alignment would start by switching on the Rovins at quay as early as possible.
Then, trajectory would consist in 2 heading change of at least 60 deg with a typical duration of 30 minutes to 1 hour in between phase.
Such trajectories allow the Kalman filter assessing all sources of errors of the system, correcting them and achieving optimal performances at the end of the fine alignment process. In particular the internal residual gyrometer and accelerometer biases on horizontal X/Y axis are computed.

Such alignment is not required to get the Rovins datasheet performance, but will provide optimal performance.

2.6 Optimal alignment

Principle

Optimal alignment indicates that the system is at its best attitude performances.

Output Data

Heading is reliable, position and attitude are computed.
Full accuracy output are available for heave, surge and sway.

Start-Duration

Optimal alignment starts after the fine alignment.

To view the several views following the type of status on the Web-Based Graphical User Interface, refer to the section "Alignment Process"

End of Phase

The optimal alignment is completed when standard heading is below to 0.04° seclat and with Navigation mode set.

The Optimal alignment status is displayed **orange** in the Web-Based Graphical User Interface when it is in progress.
When it is displayed grey, this alignment is completed.

2.7 System Full Performance

Principle

During navigation, Rovins uses its own inertial sensors together with external sensors, when they are available, to provide optimal estimates of position, speed, attitude and heading. When no external sensor is available, Rovins switches automatically to “pure inertial mode” and keeps providing position, speed, attitude and heading estimates

Output Data

Rovins is ready for navigation with optimal performances.

Start Duration

The “System Full Performance” status is raised after optimal alignment completes.

End of Phase

The System Full Performance status disappears:

- when Rovins restarts
- when the connection is lost

To view the several views following the type of status on the Web-Based Graphical User Interface, refer to the section "Alignment Process"

3 Web-Based Graphical User Interface Description

The Web-Based Graphical User Interface is a user-friendly interface and is composed of one main window which displays the menus to be selected and all the information of your product.

3.1 Control Page

The Control page is the first page displayed after launching the Web-Based Graphical User Interface. It is composed of several areas:

- the **menu area** which displays all the menus of the Web-Based Graphical User Interface. Refer to section 3.2 to get details on the menus.
- the **data area** which displays the Rovins navigation data, the geographic coordinates and the system status. System status is described in the section 7.1.
- the **logo**. It is always visible whichever the selected menu is. It gives visual information about the system status thanks to the associated color code and provides a quick access to the detailed status.
- the **compass area** which displays the heading in degrees from 0 to 360° by main steps of 20° and sub-steps of 10°. Fine outer graduations are displayed by steps of 2°. An internal fine heading rose displays heading steps between 0 and 10.

The Control page is available any time by clicking on the logo of the Web-Based Graphical User Interface.

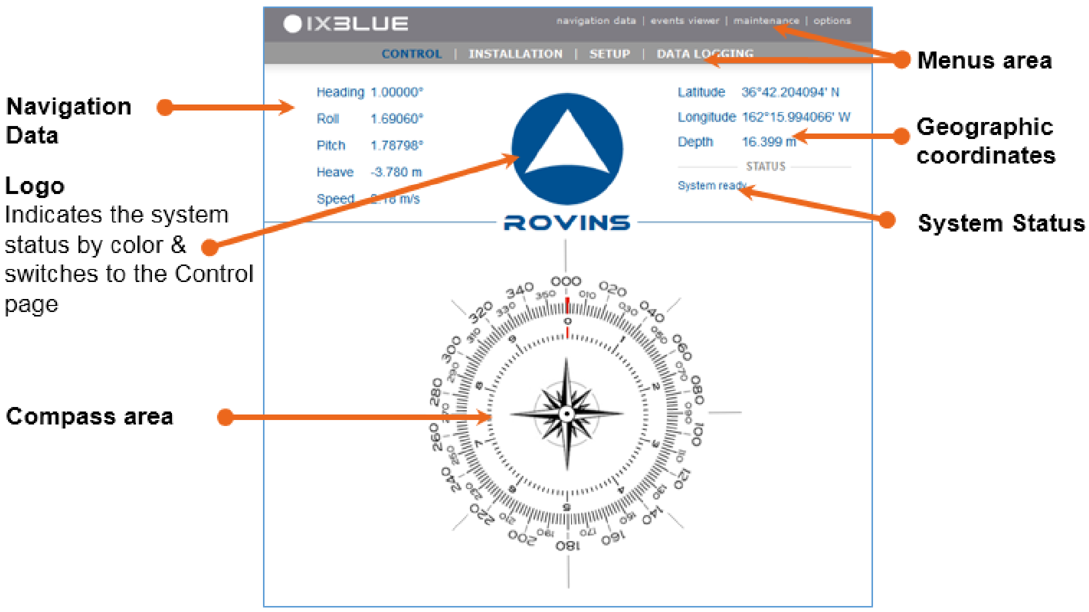


Figure 7 - Main page of the Web-Based Graphical User Interface

When clicking on the logo, the real-time information is displayed with the detailed status:

- **Input/Output**: Input, Output, Pulses
- **System**: Navigation, System, Sensors
- **Ext. Sensors**: displays the status of the Rovins external sensors

Refer to the Rovins Interface Library for the explanation of the status.

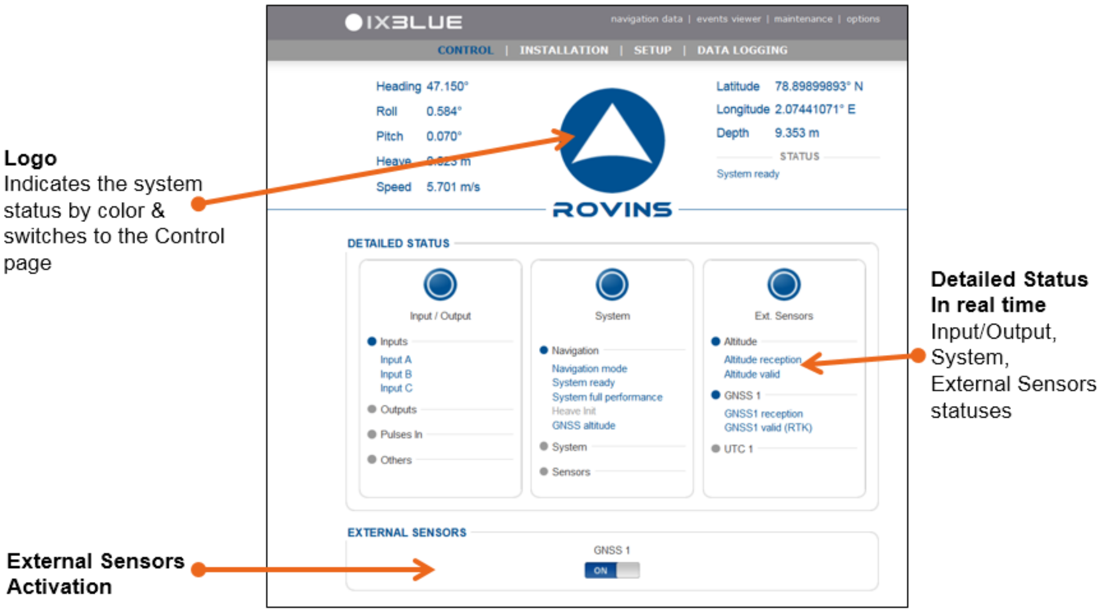


Figure 8 - Control page of the Web-Based Graphical User Interface

3.2 Menus

Many menus are available in order to configure and monitor the product as shown on the figure below.

Figure 9 - Menus of the Web-Based Graphical User Interface

- **MAIN MENU BAR**
  > **CONTROL** displays information on the product and navigation & status information. This page is the default page displayed when the Web-Based Graphical User Interface is launched.

  > **INSTALLATION** displays a drop-down sub-menu to configure the installation parameters:
    - MECHANICAL PARAMETERS
    - INPUTS
    - OUTPUTS
    - NETWORK CONFIGURATION

  > **SETUP** displays a drop-down sub-menu to set specific parameters during a mission:
    - POSITION FIX
    - NAVIGATION PARAMETERS
    - WARNING CONFIGURATION
    - DVL CALIBRATION
    - SETTING MANAGEMENT
    - SIMULATION MODE
    - PASSWORDS
    - ADVANCED POSITION FILTERING
- **DATA MENU BAR**
  > **navigation data** to access to all the data values. Information is displayed in a pop-up window.

  > **events viewer** to get a list of all events (errors, status or events messages) that have occurred. Information is displayed in a pop-up window.

  > **maintenance** to access to maintenance information and/or restart the unit.

  > **options** to set specific options of this interface.

3.3 Data resolution

The data on the Web-Based Graphical User Interface are displayed with the following resolution:

Data type	Resolution after the decimal point	Example
Latitude, Longitude °	8 digits	48.12839644°
Latitude, Longitude ° '	6 digits	48° 07.703786’
Latitude, Longitude ° ' "	4 digits	48° 07’ 42.2272’’
All other real data	3 digits	N/A

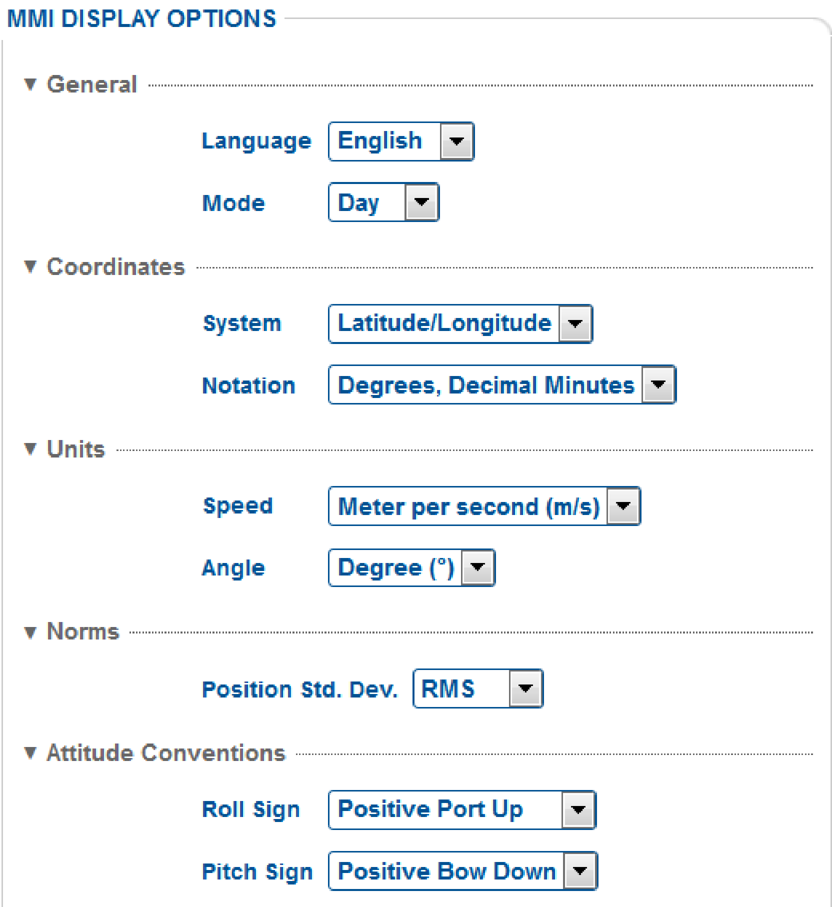
4 Configuring the Web-Based Graphical User Interface

At first delivery, the Web-Based Graphical User Interface parameters are set to their default values. The parameters can be modified to fit your needs.

4.1 Selecting the Web-Based Graphical User Interface language

These settings only affect the text of the Web-Based Graphical User Interface.
It will not translate the options, the selections or the protocols names.

1. Click on the **options** menu. The following options are displayed.

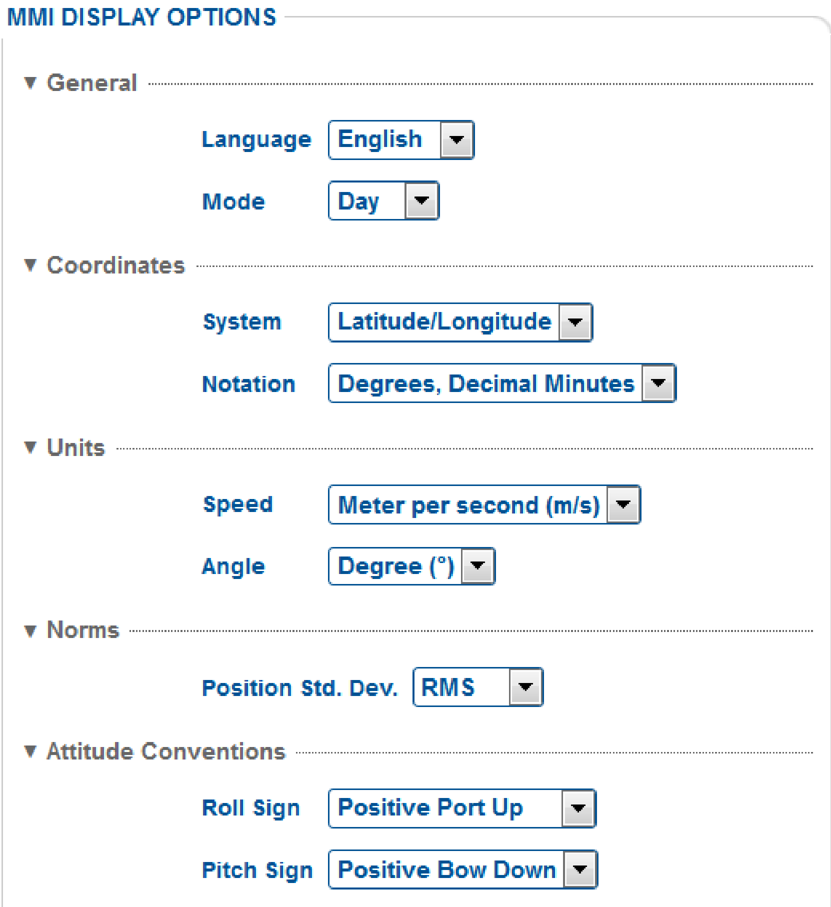


2. In the **General** area, select the right language in the Language drop-down list: French or English.

3. Click on the **OK** button. The text of the web-based user interface is then displayed with the selected language.

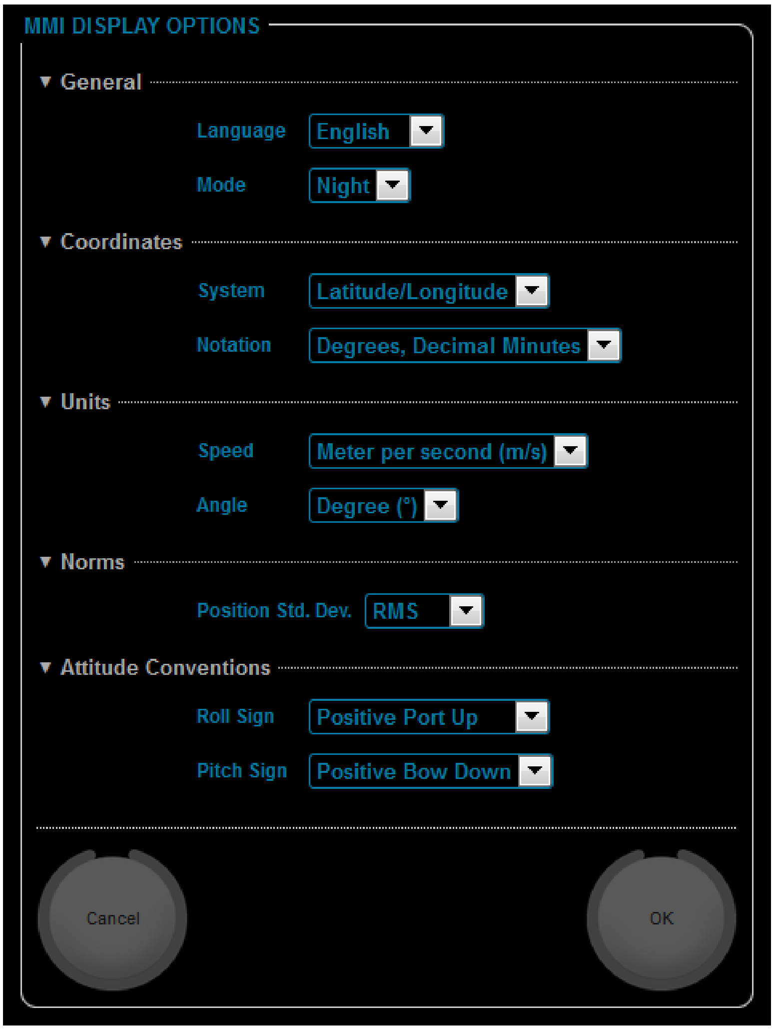
4.2 Selecting the Day or Night Mode Displays

1. Click on the **options** menu. The following options are displayed.



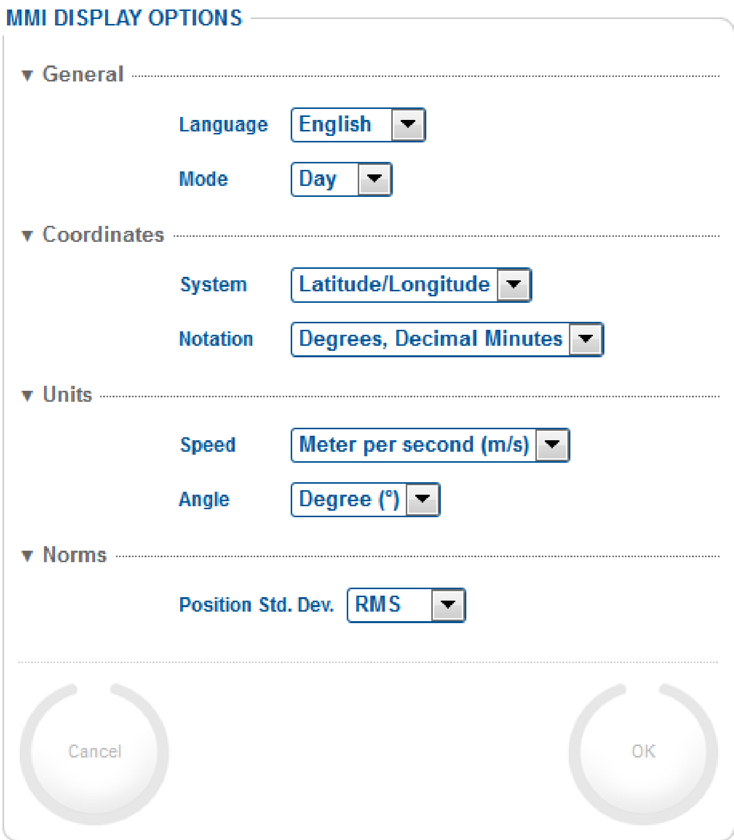
2. In the **General** area, select **Day** or **Night** in the **Mode** drop-down list.

3. Click on the **OK** button. When the Night mode is selected, the web-based user interface is displayed as follows:


MMI DISPLAY OPTIONS
General
Language
English
Mode
Night
Coordinates
System
Latitude/Longitude
Notation
Degrees, Decimal Minutes
Units
Speed
Meter per second (m/s)
Angle
Degree (°)
Norms
Position Std. Dev.
RMS
Attitude Conventions
Roll Sign
Positive Port Up
Pitch Sign
Positive Bow Down
Cancel
OK

4.3 Selecting the System Coordinates

1. Click on the **options** menu. The following options are displayed.



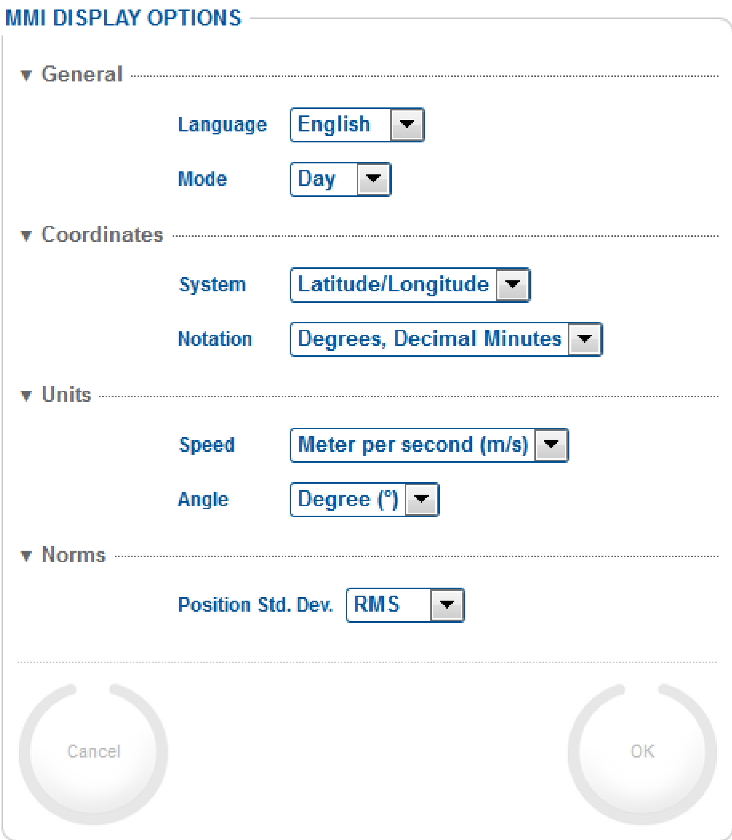
2. In the Coordinates area, select the type of coordinates in the System drop-down list:
   - **Latitude/Longitude**
   - **UTM** (UTM Northing, UTM Easting) position representations, in meters (WGS84)
   - **Polar Lat./Long**. It is recommended for the navigations close to the poles. In this case the reference is a point of the equator instead of the North pole.
   - **UPS**: Universal Polar Stereographic
   - **OSGB**: Ordnance Survey Great Britain
   - **MGRS**: Military Grid Reference System
   - **GEOREF**: World Geographic Reference System
   - **ECEF**: Earth Centered Earth Fixed

3. **For Latitude / Longitude or Polar Lat. /Long. System**, select the type of notation in the notation drop-down list:
   - Decimal Degrees
   - Degrees, Decimal Minutes
   - Degree, Minute, Seconds

4. Click on the **OK** button.

4.4 Selecting the Speed and Angle Units

1. Click on the **options** menu. The following options are displayed.



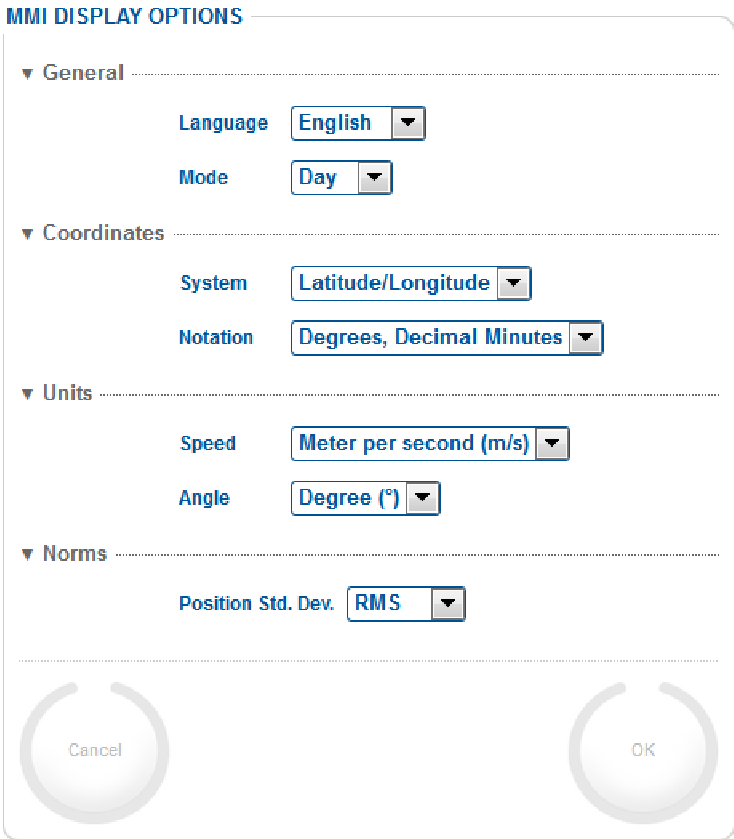
2. In the **Units** area, select the units in the **Speed** drop-down list:
   - **Knot (kn)**: Knot
   - **Meter per second (ms)**: meter/second

3. Select the angle in the **Angle** drop-down list:
   - **Degree (°)**: for degree
   - **Mil (mil)**: angle unit used in land defense applications

4. Click on the **OK** button.

4.5 Selecting the Position Error Convention

1. Click on the **options** menu. The following options are displayed.

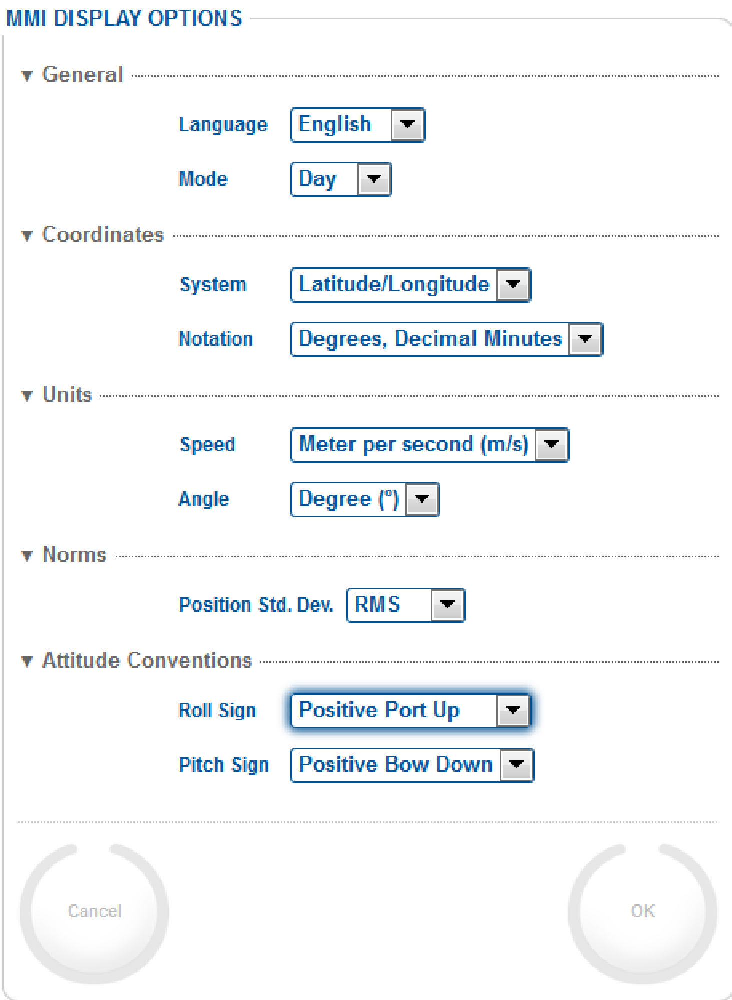


2. In the **Norms** area, select the position error convention for all standard deviations computed by the Rovins in the **Position Standard Deviation** drop-down list:
   - RMS
   - CEP 50 (0.67 x RMS)
   - CEP 95 (2 x RMS)

3. Click on the **OK** button.

4.6 Selecting the Attitude Conventions

1. Click on the **options** menu. The following options are displayed.



2. In the **Attitude Conventions** area, select the convention in the **Roll Sign** drop-down list:

- **Positive Port up**
- **Positive Port down**

3. Select the convention in the **Pitch Sign** drop-down list:

- **Positive Bow down**
- **Positive Bow up**

4. Click on the **OK** button.

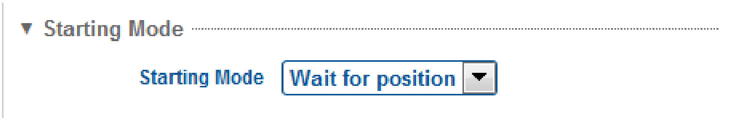
5 Configuring the Navigation Parameters

5.1 Configuring the Starting Mode

To get details on the starting modes, refer to the section 2.

1. Click on the **SETUP** menu then select the **NAVIGATION PARAMETERS** option. The Navigation Parameters page is displayed.

2. In the **Starting Mode** area, select the starting mode from the list:



- **Wait for position** (default and recommended)
  Rovins does not check whether a position sensor (GNSS) has been configured and unconditionally wait for at least one valid GNSS position input, or a manual position fix.
- **Immediate Run**
- **Restore position**: in this mode, Rovins recovers the position saved during the preceding power outage then initializes the algorithm with this position. Rovins static alignment starts with the last known position with the same position standard deviation as before shutdown.
- **Restore attitude**
- **Emulation mode**

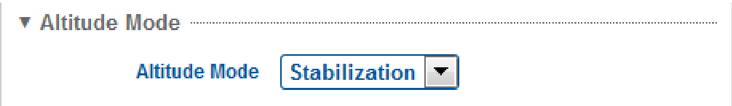
3. Click on the **OK** button to save the settings.

5.2 Configuring the Altitude Mode

To get details on the altitude modes, refer to the section 1.3.2.

1. Click on the **SETUP** menu then select the **NAVIGATION PARAMETERS** option. The Navigation Parameters page is displayed.

2. In the **Altitude Mode** area, select the altitude mode from the list:



- **Stabilization**
- **GPS altitude**
- **Hydro altitude**
- **Depth sensor** (recommended for subsea with depth sensor)

3. Click on the **OK** button to save the settings.

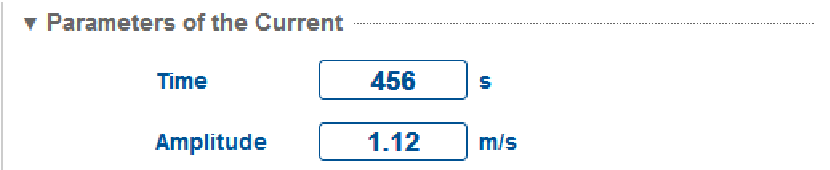
5.3 Configuring the Current Model

To get details on the current model, refer to section 1.5.

This option is displayed only if DVL sensor is configured.

1. Click on the **SETUP** menu then select the **NAVIGATION PARAMETERS** option. The Navigation Parameters page is displayed.

2. In the **Parameters of the current** area, enter the parameters:



- Time: time constant of the current model
- Amplitude: maximum standard deviation of the current used in the filter

These settings are used when EM Log speed is input into the system.

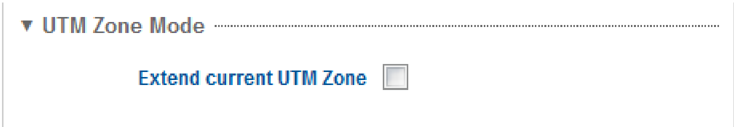
3. Click on the **OK** button to save the settings.

5.4 Enabling the Extension of the UTM Zone

A check box allows the user to extend the current UTM zone to keep linear UTM coordinates and to avoid automatic zone computation as done by Rovins in standard mode.

1. Click on the **SETUP** menu then select the **NAVIGATION PARAMETERS** option. The Navigation Parameters page is displayed.

2. In the **UTM Zone Mode** area, tick the **Extend current UTM Zone** box:



Rovins continues to give the UTM position referring to the original zone, even if the vehicle has over-passed the bounds of the original area.

3. Click on the **OK** button to save the settings.

6 Managing the external information

Rovins requires some external information at start-up and when possible during navigation. When external information (position, speed, time) is not available, Rovins uses only its internal sensors (accelerometers, FOG, clock) to estimate navigation data. In this configuration speed is less accurate and position can drift (see Rovins Technical Description for performances).
To avoid this, position, speed and time fixes can be sent to the Rovins, this can be done in various mode:

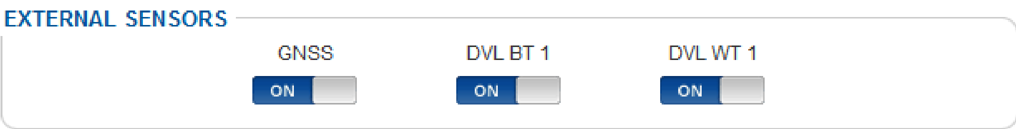
- External sensor connection
- Manual information

6.1 Enabling the External Sensors

Rovins receives data from external sensors, this data is displayed in the Navigation data window (refer to section 7.2).
In order to prevent incorrect or corrupted external aiding data degrading the performance of the product, external sensor data first passes through a rejection filter, before being incorporated into Rovins main computation and Kalman filter.

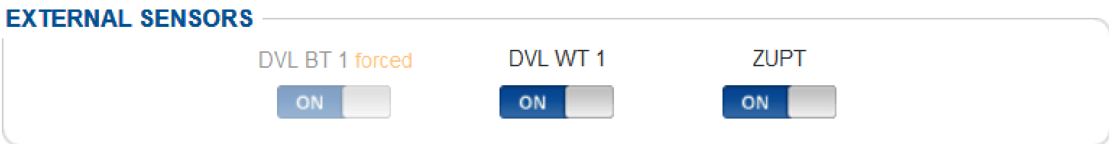
External data acceptance can be:

- Automatic: left to the Rovins rejection filter to decide whether to accept it or not: recommended mode, the external sensor is displayed ON.



- Forced in: forced mode bypasses the system rejection filter meaning all data, including potentially incorrect data is used by the system. Forced mode is not recommended as bad external sensor data will no longer be rejected and could corrupt the Kalman filter.

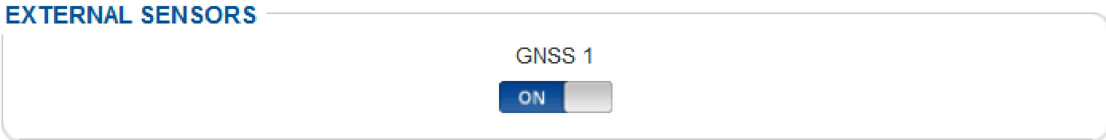
If an external sensor is set in Forced mode (in the input configuration page), the related ON/OFF button is inactive and no action is possible on this button.



- Disabled: using the toggle box to switch the external sensor OFF (per default, after configuration of a new sensor): the box is displayed OFF. When toggled off the external sensor data will not be used in the Rovins Kalman filter computations.

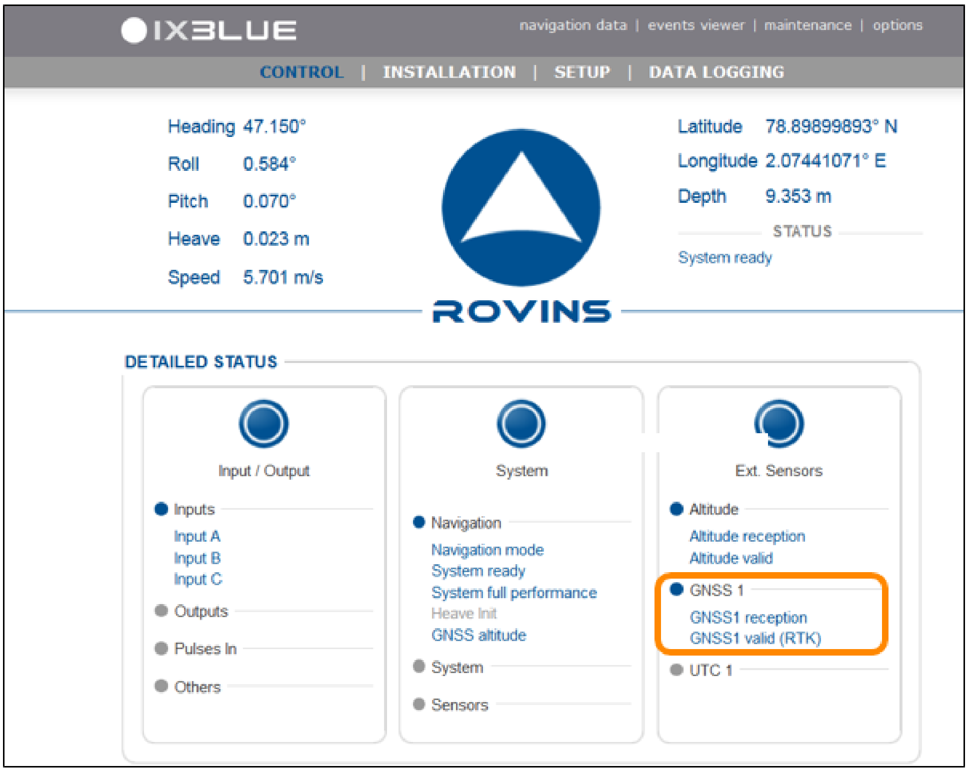
To use an external sensor data, the external sensor should be:

- Activated: switched and displayed "ON" on the CONTROL page



- Or forced in by the rejection filter:

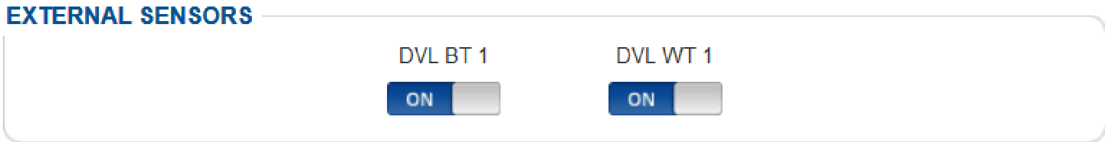
- Valid: valid status in the External Sensors Detailed Status



Procedure

1. Click on the logo.

2. To **enable the external sensor**, click on the parameter of the external sensors (s) **until displaying ON**.



The sensor data will be used by the Kalman filter.

3. To **disable the external sensor**, click on the parameter of the external sensors (s) **until displaying OFF**.
The sensor data is no more used by the Kalman filter.

6.2 Inputting manually information to Rovins

Whenever Rovins is started, the initial position is required.
Failure to input a correct initial position will generate inconsistent heading value, and the algorithm will be corrupted if the position given is too far from the real one.
Position initialization is done either using a sensor fix (GNSS) or input initial position.

Important

If a GNSS is connected, activated and GNSS fixes are valid, the position is used continuously.

There are several ways to input manual data:

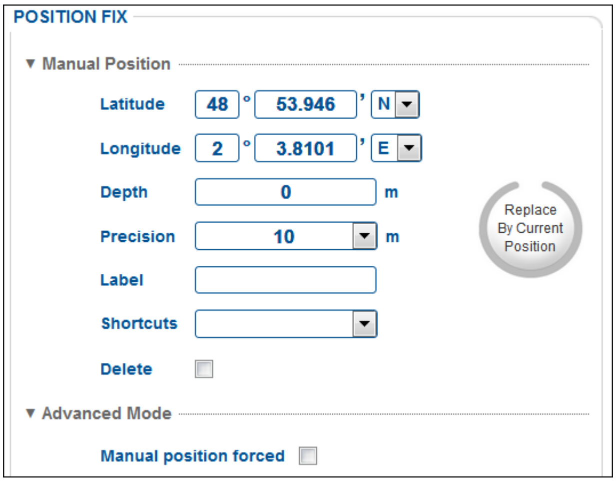
- Position:
  - initial position: this position is saved in the Rovins
  - position fix: this position is not saved in the Rovins
  - position ZUPT
- Speed:
  - ZUPT

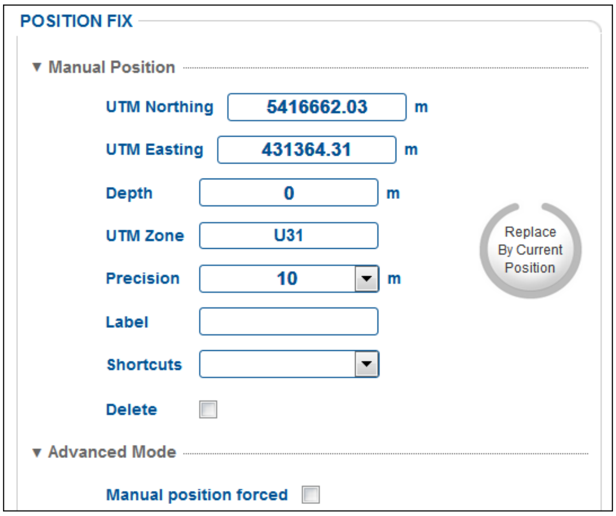
ZUPT mode shall only be used when the Rovins is static. Activating ZUPT mode when Rovins is moving could corrupt the Kalman filter and degrade navigation performance.

6.2.1 Inputting the Manual Position Fix

The position fix sent to the system is used only as an individual fix that is managed by the Kalman as GNSS position. The position fix is not saved in the non-volatile memory.
This is used to send a position fix during operation. It allows you to start the Rovins when the starting mode is "Wait for position".

1. Click on the **SETUP** menu then select the **POSITION FIX** option. The following page is displayed according to the position representation:





2. In the **Manual position** area, select or enter the following parameters:
   - For Latitude/longitude system coordinates
     - > **Latitude**: Latitude in either degrees, or (degrees, decimal minutes) or (degrees, minutes, seconds) + hemisphere: N (North) or S (South)
     - > **Longitude**: Longitude in degrees, or (degrees, decimal minutes) or (degrees, minutes, seconds) + E (East) or W (West)
     - > **Altitude**: in meters.
     - > **Precision**: standard deviation for the Kalman on input latitude, longitude and altitude, to be chosen in a drop-down list from 0.1 to 1000 m.
     - > **Label**: defining a text label for this position allows it to be kept locally on the computer (i.e., the position is kept in a cookie)
     - > **Shortcuts**: to use a position already defined and labeled
     - > **Delete box**: check this box to delete the position saved with the entered label
   - For UTM system coordinates
     - > **UTM Northing**
     - > **UTM Easting**
     - > **Altitude**: in meters.
     - > **UTM Zone**: letter + number of the UTM zone
     - > **Precision**: standard deviation for the Kalman on input latitude, longitude and altitude, to be chosen in a drop-down list from 0.1 to 1000 m.
     - > **Label**: defining a text label for this position (waypoint system) allows it to be kept locally on the PC (i.e., the position is kept in a cookie)
     - > **Shortcuts**: to use a position already defined and labeled

3. If you want to take the current position into account by avoiding to type the current coordinates, just click on the **Replace by current position** button.

4. Click on the **OK** button to take this updated position into account. This information will be used by the Kalman filter to improve its position estimation.

5. In the Advanced area, tick the **Manual position forced** box to force the manual position fix that is normally going through the rejection filter. When the position is forced, the rejection is bypassed.

6. Click on **OK** button to save the settings then click on **OK** to validate.

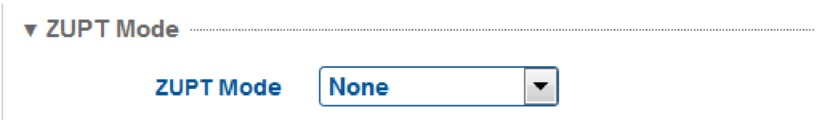
6.2.2 Configuring the ZUPT Mode

Zero velocity update modes may be used when Rovins is kept static without any external sensor connected.
In this mode, fake speed (or position) information is input to Rovins in order to improve the estimation of attitude and heading, to prevent the estimated position and speed from drifting and to perform fine alignment.

It is highly recommended to check that the product is not in “ZUPT” mode in normal operation, when other sensors are available. The ZUPT switch must be OFF, see on the next page.

1. Click on the **SETUP** menu then select the **NAVIGATION PARAMETERS** option. The Navigation Parameters page is displayed.

2. In the **ZUPT Mode** area, select the ZUPT mode from the list:



- **None**: no zero velocity update.
- **Static 10 m/s**: the fake sensor is sending to Rovins a speed value of 0 m/s with a standard deviation of 10 m/s. The acquisition mode is « Always True » which means that Rovins will always consider this information valid. The ZUPT flag will always be valid. This mode can be set when Rovins is used as a gyrocompass and no external aiding sensor are connected (i.e., GNSS).
- **Static 0.1 m/s**: the fake sensor is sending to Rovins a speed value of 0 m/s with a standard deviation of 0.1 m/s. The acquisition mode is « Always True » which means that Rovins will always consider this information valid. The ZUPT flag will always be valid.
- **Autostatic**: the fake sensor is sending to Rovins a speed value of 0 m/s with a standard deviation of 0.01 m/s. Rovins will exit this mode if the measured rotation rate of any gyro is greater than 10°/h. In this case the ZUPT flag will change from valid to invalid.

It is highly recommended to use Autostatic and Autostatic bench mode, only in the laboratory/workshop environment.

After a Zero Velocity Update sequence, it is highly recommended to deactivate the Zero Velocity Update mode.

3. Click on the **OK** button to save the settings.

4. **To enable the ZUPT mode**, click on the iXblue logo. The control page is displayed with the status.

5. Click on the ZUPT parameter until displaying ON.

6. To disable the ZUPT mode click on the ZUPT parameter until displaying OFF.

7 Viewing the System Information

7.1 Viewing the Status Messages

Two types of status messages are available on the Web-Based Graphical User Interface

- STATUS: displays status information on the top right of the window.
- DETAILED STATUS displays in the center of the window
  - > the Input/Output,
  - > System,
  - > and External sensors status.

The color of the logo gives you information on the Rovins status.

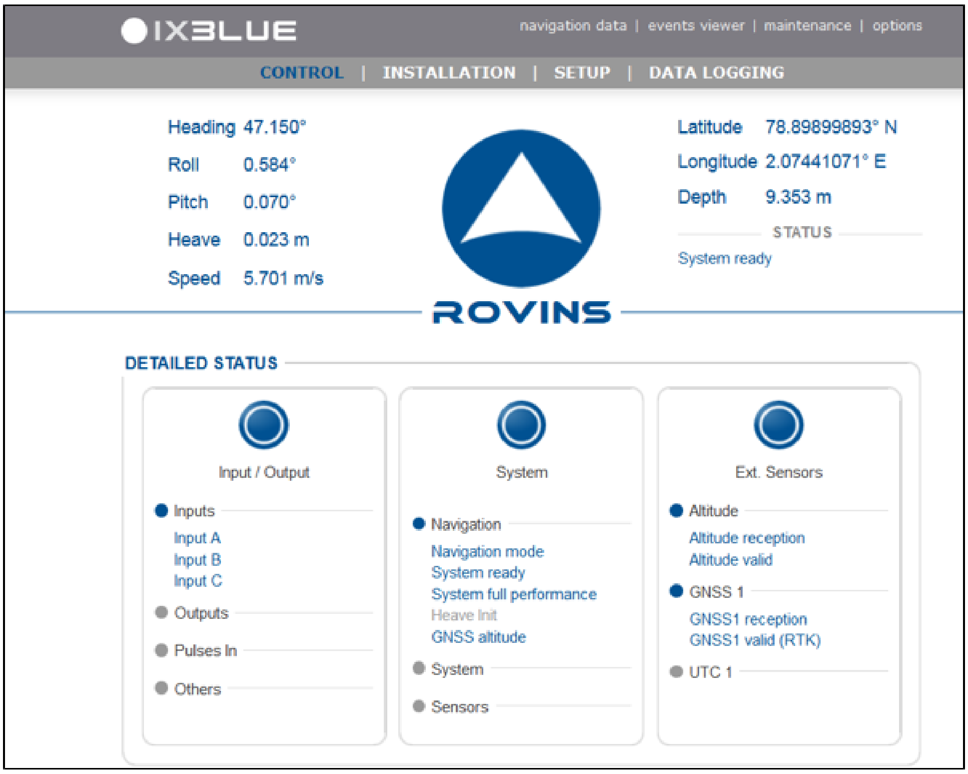


Figure 10 - Web-based Graphical User Interface

Logo color

When a problem occurs, the color of the disc changes and the detailed status window is automatically displayed with the equipment in fault.
For troubleshooting, refer to Rovins Maintenance Manual.

Status Messages

Message displayed in blue means that is an information message
Message displayed in orange means that is a warning message
Message displayed in red means that is an error message

Message	Meaning
System initializing	Rovins is in the initialization phase
Alignment	Rovins is in its coarse alignment phase for 5 minutes.
Fine alignment	Is set when standard deviation heading < 0.1° with Navigation mode
System ready	Rovins is ready for navigation with optimal performances
System warning	There is a system warning
Waiting for position	The system is waiting for a position to start
System error	An error has occurred
Connection Lost	The Ethernet connection with Rovins is lost

Detailed Status

Detailed status displayed in blue means that is an information message
Detailed status displayed in orange means that a warning status is displayed for 3 seconds. This remains true whatever the protocol frequency.
Detailed status displayed in red means that an error status is displayed for 10 seconds. This remains true whatever the protocol frequency.
The Web-Based Graphical User Interface displays the status in real-time.
To get the detailed status description, refer to the Rovins Interface Library document.

7.2 Viewing the Navigation Data

Navigation data computed and received by Rovins and data received from the external sensors are displayed in the Navigation Data pop-up window (see figure below).
Click on the **navigation data** menu on the top menus of the Web-Based Graphical User Interface.

Figure 11 - Navigation data pop-up window

Data displayed in the Navigation Data pop-up window

Sensor data

- GNSS data:
  - > Latitude, Longitude and Altitude data.
  - > Std Dev.: it corresponds to the standard deviation of the latitude data.
  - > Time: it is the validity time of the last GNSS data. In the case of GNSS drop-out, or GNSS shielding, GNSS data is not updated and the last valid data from the GNSS are displayed.
  - > Mode: it corresponds to the quality factor. Refer to the Rovins Interface Library document to get the definition of the quality factor.
  - > Delay: it indicates the drift between last GNSS frame reception time and validity time contained in that frame. It should be less than 200 ms in typical cases. Values larger than 1 s or negative values usually come from a bad time synchronization configuration (PPS + Time instead of Time + PPS, or large network propagation time for example).
- CTD data: Sound of speed data (from SVP or CTD)
- Depth sensor data:
  - > Depth in meters.
  - > Time: it is the validity time of the last depth sensor data.

- DVL data:
  - > The Bottom track speeds: these are the speed inputs from the sensor, measured at sensor position in the sensor reference frame X1, X2, X3.
  - > The Water track speed data directly input from sensor, measured at sensor position in the sensor X, Y, Z reference frame.
  - > Range to bottom
  - > Sound speed in DVL: speed of sound used by DVL for its speed computation
  - > Time: it is the validity time of the last DVL data.
- EM Log data:
  - > Longitudinal Speed: it is the speed in knots
  - > Time: it is the arrival time of the last log EM data
- LBL data:
  - > Beacon N°
  - > Beacon Latitude, Longitude and Depth
  - > Beacon Range
  - > Time: it is the validity time of the last LBL data.
  - > Delay
- USBL data:
  - > Beacon ID and Transponder code (Tp Code)
  - > Beacon Latitude, Longitude and Depth
  - > Delay in seconds
  - > Time: it is the validity time of the last USBL data.

Computed data

- Heading & Attitude data with their associated standard deviations
- Position data with their associated standard deviations
- North, East, Vertical, Norm speeds in knots with their associated standard deviations
- North and East currents in m/s with their associated standard deviations

Time data

- Run time (since last powering on)
- UTC time and last UTC synchronization time, if available

7.3 Viewing the Events Messages

Event viewer records all important events and system messages that occurred since the last system reboot.

The system status and the error messages generated by Rovins can be followed in the events viewer window by clicking on the **events viewer** menu. See hereafter an example of event viewer messages.

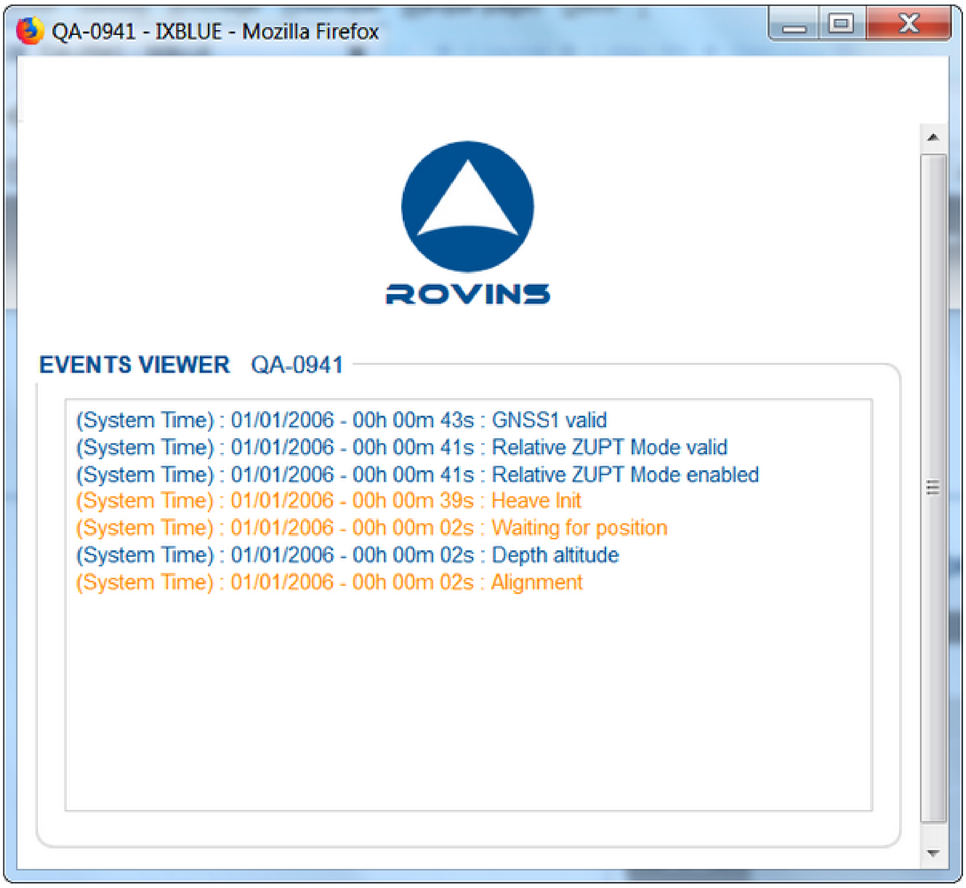


Figure 12 - Events viewer window

8 Recording Data

iXblue provides an external dedicated tool to log system outputs: iXblue Multilogger.
This tool and its user guide are available on the Rovins flash drive.

iXblue CONTACT - SUPPORT

For non-URGENT support:

- by email: support@ixblue.com
- using the form on the iXblue web site www.ixblue.com

For 24/7 URGENT SUPPORT:

- North America / NORAM
  +1 617 861 4589

- Europe Middle-East Africa Latin-America / EMEA-LATAM
  +33 1 30 08 98 98

- Asia Pacific / APAC
  +65 6747 7027

A Appendix: External data rejection criteria

When an observation of external data is performed data will be accepted, rejected or attenuated by the Kalman filter.

For example, when a GNSS position is received, the distance δ between INS position and GNSS position is calculated.

- If the distance is smaller than 3 times the quadratic sum of GNSS position standard deviation and Rovins standard deviation the position is accepted.
- If the distance is greater than 5 times the quadratic sum of GNSS position standard deviation and Rovins standard deviation the position is rejected.
- If the distance is within 3 to 5 times the quadratic sum of GNSS position standard deviation and Rovins standard deviation, the position is attenuated by a factor μ.

These criteria can be written as follows:

$$\mu = \begin{cases} 1 & if\ \delta < 3\sqrt{\sigma_{INS}^2 + \sigma_{GPS}^2} \\ 1 - \dfrac{\left[\dfrac{\delta}{\sqrt{\sigma_{INS}^2 + \sigma_{GPS}^2}}\right] - 3}{2} & if\ 3\sqrt{\sigma_{INS}^2 + \sigma_{GPS}^2} < \delta < 5\sqrt{\sigma_{INS}^2 + \sigma_{GPS}^2} \\ 0 & if\ \delta > 5\sqrt{\sigma_{INS}^2 + \sigma_{GPS}^2} \end{cases}$$

After GNSS position is taken into account, the new standard deviation of Rovins position is calculated as follows:

$$\sigma_{INS}^2 = \frac{\sigma_{INS}^2 \cdot \dfrac{\sigma_{GPS}^2}{\mu}}{\sigma_{INS}^2 + \dfrac{\sigma_{GPS}^2}{\mu}}$$

When GNSS sensor data is accepted, $\mu = 1$, and GNSS standard deviation is taken as: σ_{GPS}. We hence find the standard formula for the new Rovins standard deviation at the output of the Kalman filter:

$$\sigma_{INS} = \sqrt{\frac{\sigma_{INS}^2 . \sigma_{GPS}^2}{\sigma_{INS}^2 + \sigma_{GPS}^2}}$$

When GNSS sensor data is rejected, $\mu = 0$.

GNSS standard deviation is taken into account with the following value:

$$\frac{\sigma_{GPS}}{\mu}$$

which tends to an infinite value when $\mu = 0$.
So rejecting an external sensor is equivalent to associating an infinite standard deviation to the GNSS position.

When GNSS data is attenuated, $0 < \mu < 1$.
GNSS standard deviation is taken into account with the following value:

$$\frac{\sigma_{GPS}}{\mu} > \sigma_{GPS}$$

So attenuating an external sensor is equivalent to increasing the standard deviation associated with this sensor.
The same criteria described above is applicable to all types of external aiding data.

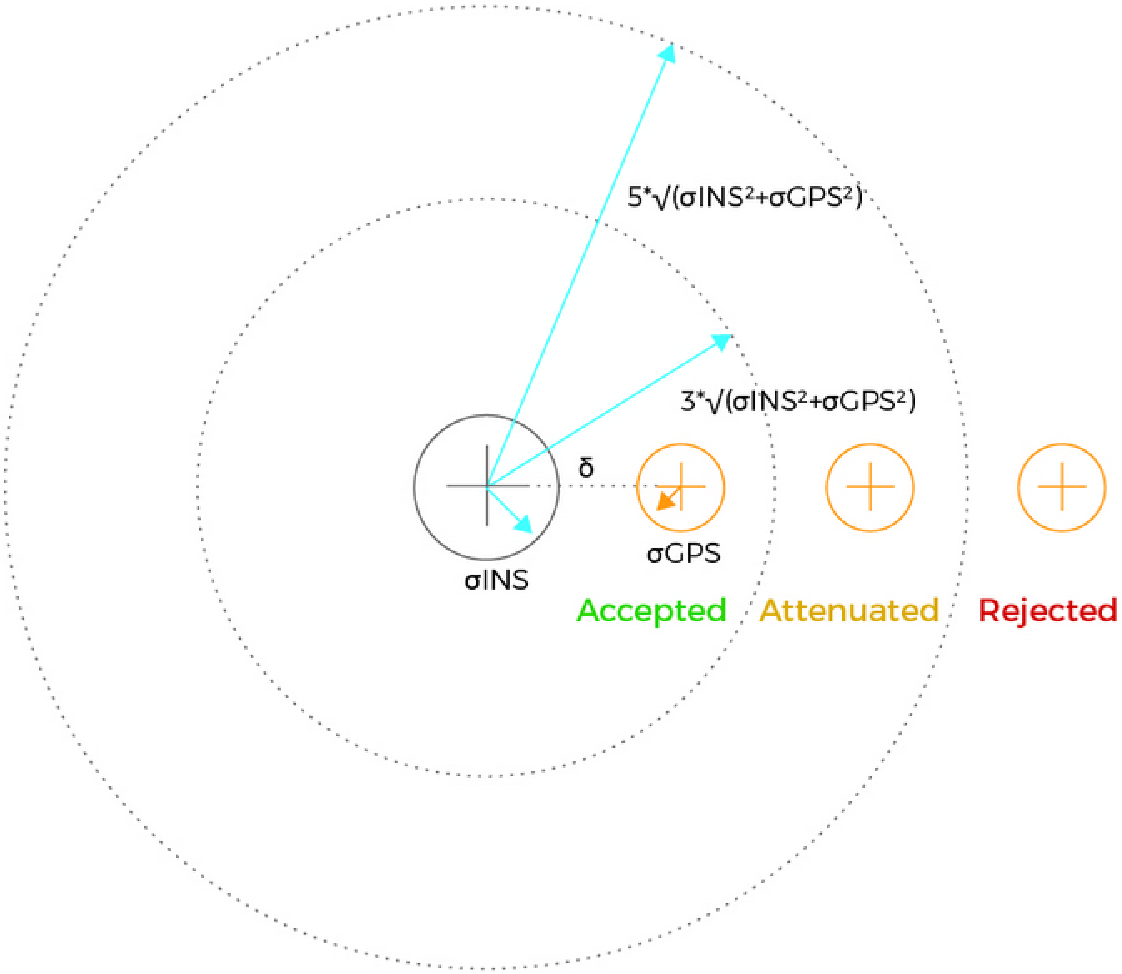


Figure 13 - Rejection criteria schematic

PAGE INTENTIONALLY LEFT BLANK