Survey Grade INS

Use in automotive applications

Operating handbook

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SBG SYSTEMS

This operating handbook aims to guide users during sensor installation and configuration in automotive environments.

You don't need the sbgCenter to configure the products, only the web interface is required.

Mechanical installation

When used in automotive application, the INS performs some velocity assumptions: No lateral velocity is allowed and therefore, a good sensor installation is a key point to follow.

For an optimal installation, please make sure these few **critical** points are respected:

- Unit is **rigidly fixed** to the vehicle and GNSS antennas
- Unit is not exposed to high vibrations. In some applications such as motor-sport, mechanical dampers may be used to mitigate vibration effects.

Vehicle reference frame

The vehicle coordinate frame is defined as follows:

- X axis points to the front of the car
- Y axis points Rightward.
- Z axis points downward.

Note: For the Navsight version, names "sensor" and "IMU" in this document refer to Ekinox-I, Apogee-I, or Horizon-I units (IMU block only), distinctly from the Navsight Processing unit (or P.U).

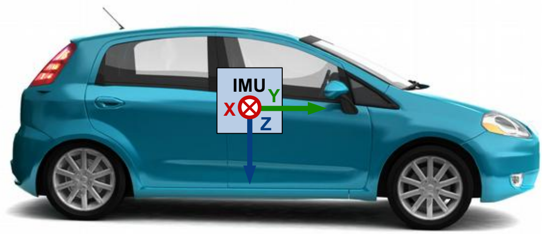
Sensor Orientation in the vehicle

The sensor can be placed in any orientation in the vehicle. When IMU axes do not match exactly with the vehicle coordinate frame, a two step software alignment method can be performed, as explained below.

> **Note:** Once the unit is aligned (mechanically or by software), the vehicle reference frame is used to express all lever-arms and setup the product accordingly.

Step 1: Axis Misalignment

In the first step, you basically need to check in which direction each IMU axes point. Next example shows IMU X axis is turned left, IMU Y axis is turned in vehicle Front direction and Z is turned down.



Step 2: Fine Misalignment (optional)

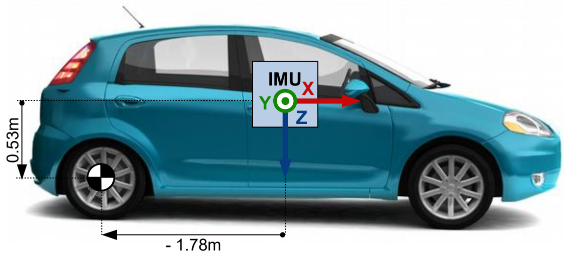
This step can be used to compensate for small angles in case the sensor is not aligned within 1 degree with the vehicle coordinate frame. The angles are expressed in terms of Euler Roll, Pitch and Yaw residuals.

An easy way to measure roll and pitch misalignment is to park the car and read roll and pitch angles. Then park the car again at the same location but reverse direction, and read again the roll and pitch angles. By averaging the two measurements, you will remove any effect of the road inclination and just have IMU to car misalignment residuals.

> **Note:** The alignment precision in the vehicle should be less than 2°. The Extended Kalman Filter is able to take into account the residual angle errors if the user configuration is not perfect.

Centre of Rotation Lever Arm (Primary Lever Arm)

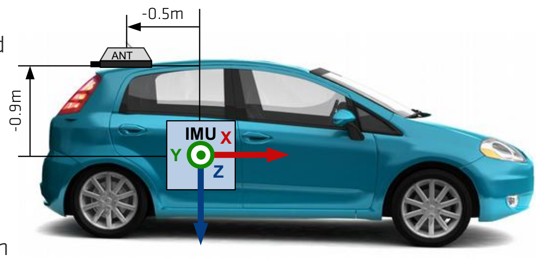
Once the sensor is installed in the car, the Center of Rotation should be identified. This is most often located at the rear Axle. The Primary Lever Arm which is the signed distance **FROM** the IMU, **TO** the Center of Rotation should be measured within a 5cm accuracy.



GNSS Antenna installation

For single antenna systems, the main installation requirement is to have a rigid installation between GNSS antenna and the IMU.

The antenna should be installed somewhere with a clear view of sky (typically on the roof of the car).



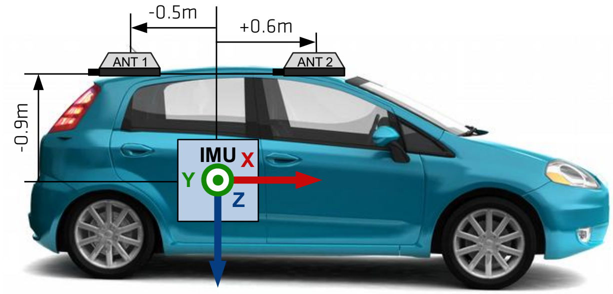
Once installed, the GNSS lever arm should be measured. It is the signed distance, expressed in the vehicle coordinate frame, **FROM** the IMU center of measurements, **TO** the GNSS antenna. It must be measured within **5cm accuracy**.

Dual GNSS antenna placement

Dual antenna systems installation will require special care in order to obtain optimal performance:

- Both antennas must be **fixed** with respect to the to the inertial unit
- Both antennas must be **turned the same way** (connectors oriented in same direction)
- Both antennas must have the **same optimal view of sky** (avoiding signal masks due to the vehicle structure)
- **Same cables** with same length must be used for both antennas. Prefer no splitter, or make sure they are adapted.
- Baseline of **at least 1 meter between both antennas** is recommended for optimal performance

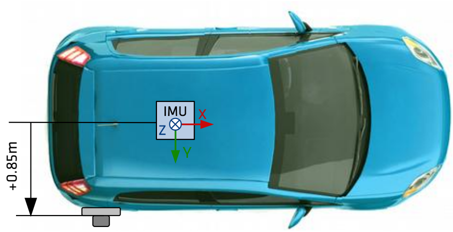
Once installed, the two GNSS antenna lever arms must be measured. These are the signed distances, expressed in the vehicle coordinate frame, **FROM** the IMU, **TO** the GNSS antenna. It must be measured within **5cm accuracy**.

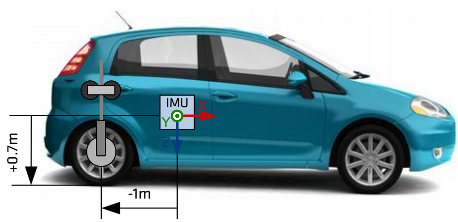


Odometer placement

Odometer has to be placed on a **non steering wheel** (rear wheel in most applications).

The Odometer lever arm has to be measured. It is the signed distance, expressed in the vehicle coordinate frame, **FROM** the IMU **TO** the Odometer. It has to be measured with 5cm accuracy, and should be lower than 10m for best performance.





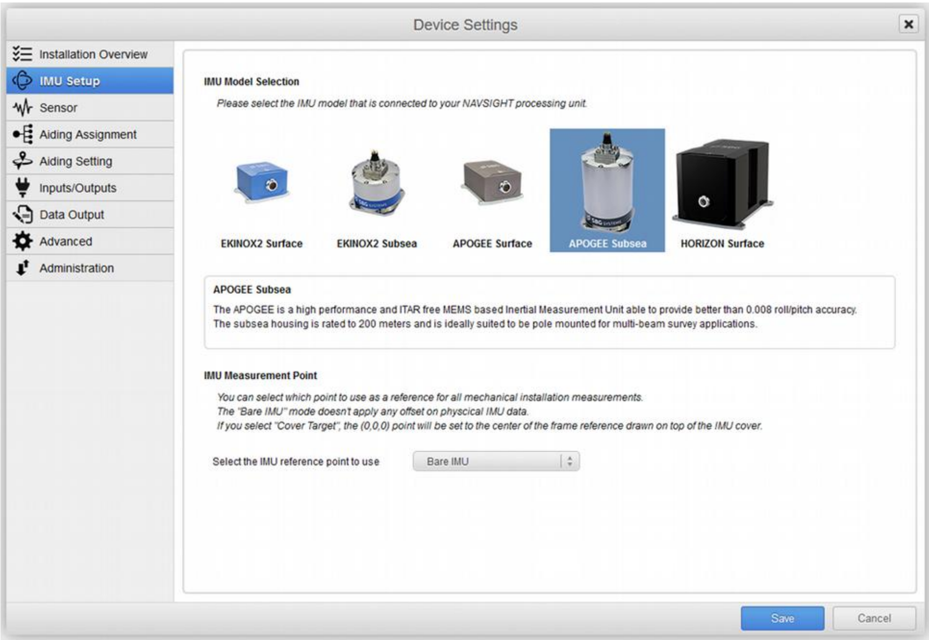
Software configuration

All Navsight configuration is done through the web interface.

Note: At the first access or if the device firmware has been updated, the sensor will cache the entire embedded website to optimize the responsiveness. This preload operation may take up to two minutes depending on your system configuration.

IMU Setup (Navsight series only)

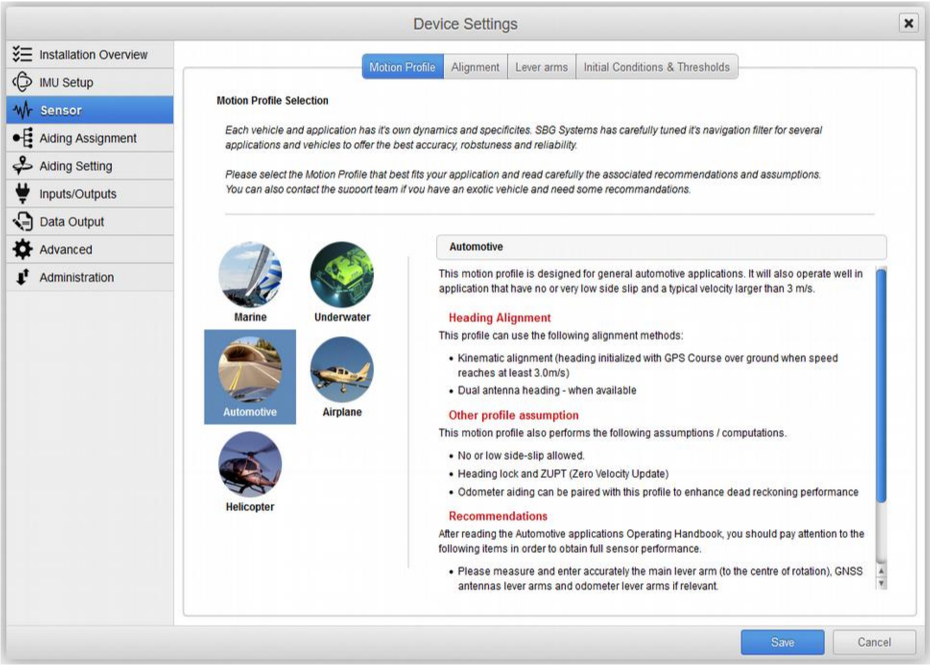
Select the IMU you'll be operating with your Navsight processing unit, both Ekinox and Apogee ranges are available, in surface or sub-sea housing:



Sensor

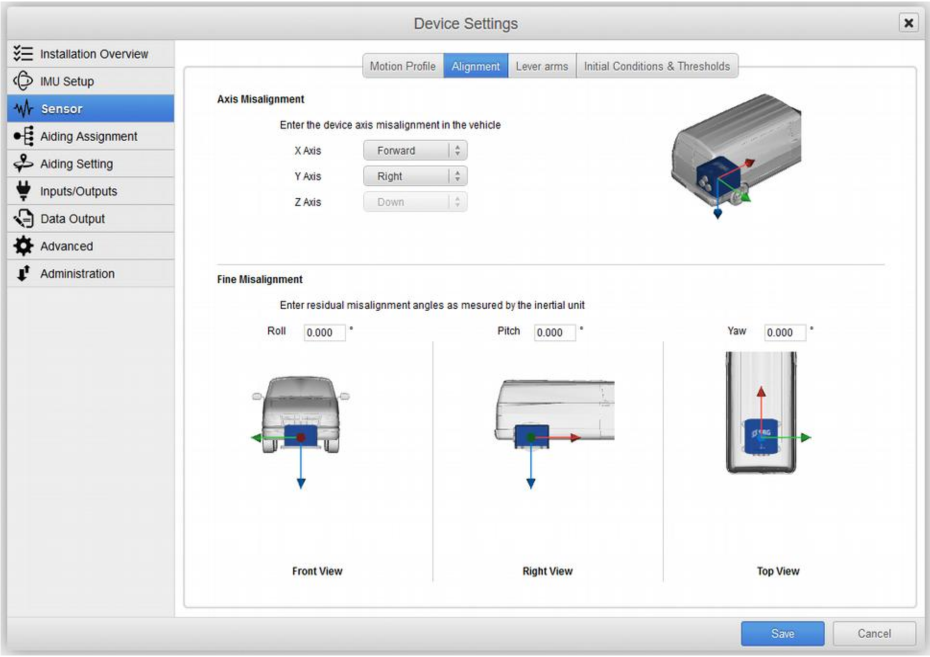
Motion profile

Conventional vehicles should use the "Automotive" motion profile.



Misalignment

Here you have to configure the IMU misalignment in the vehicle coordinate frame. The nice looking frame will help you through these steps.



Axis Misalignment

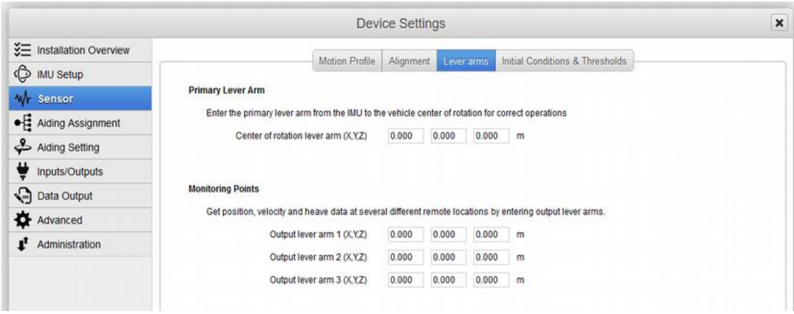
First, you need to enter the axis misalignment settings, by entering the sensor X and Y axes direction in the vehicle frame.

Fine Misalignment (Optional)

In a second time, you can enter the residual roll, pitch and yaw angles if the sensor is not fully aligned with the vehicle frame after the Axis misalignment step

Lever Arms

This panel allows you to enter the Center of Rotation location and three monitoring points.



Primary Lever Arm

Enter here the lever arm **from** the sensor **to** the center of rotation in Vehicle reference frame,

Monitoring Points

You can configure three monitoring points to output all orientation and position data.

> These values can also be changed directly in the Setup Overview section. These values are measured from the IMU reference point selected (see Misc. section).

Aiding Assignment

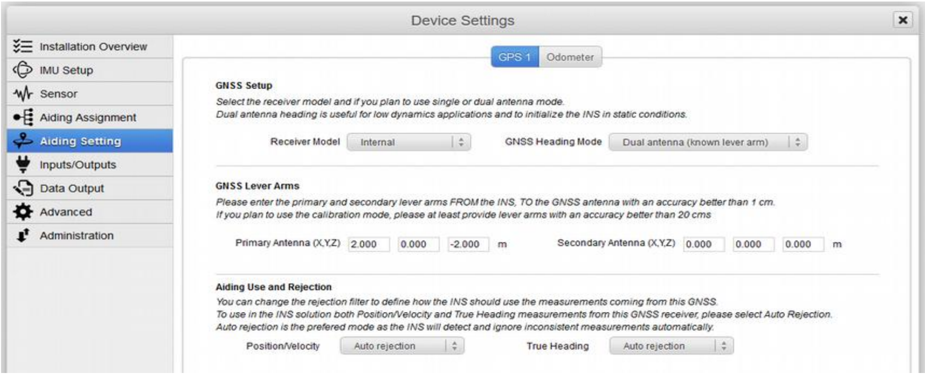
You can enable one or two GNSS on this panel, you can choose whether you want to use the internal GNSS or not.

You can enable or disable the odometer, if you have the opportunity to use one it may significantly improve the dead reckoning performance.

Note: If an external GNSS receiver is used, make sure to select the source of the PPS signal on the right input synchronization. In case of an internal GNSS receiver, you can activate here the RTCM reception for RTK operations.

GNSS configuration

Please check the following points to ensure a correct GNSS configuration:



GNSS Setup

Choose this parameter for external receiver, otherwise keep "Internal". Depending on the GNSS you are using (NMEA, Novatel, Trimble or Septentrio), you can refer to the corresponding manual to know how to configure the GNSS.

If two antennas are used you have to define the lever arm for the second one. But you can also choose "auto lever arms" in GNSS Heading Mode to let the Kalman Filter estimate the antennas lever arms through a specific calibration run.

> **Note:** When using Dual Antenna (Auto Lever Arm), the heading will not be calculated until the calibration is performed. The secondary antenna lever arms are necessary to calculate the GNSS heading.

GNSS Lever arms

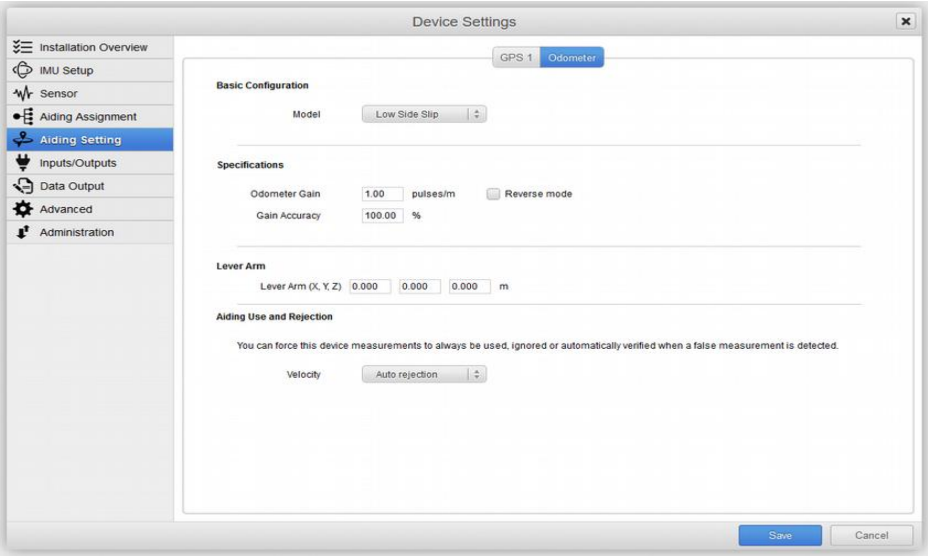
Set up the lever arm of the GNSS depending on its position on the aircraft (GNSS Antenna installation).

Aiding Use and Rejection

Auto rejection is advised for all measurements. This mode automatically detects if a measurement can be trusted or not.

Odometer configuration

If you are using an odometer and activated it in Aiding Assignments, you will see a thumbnail called “odometer” in the Aiding Settings panel.

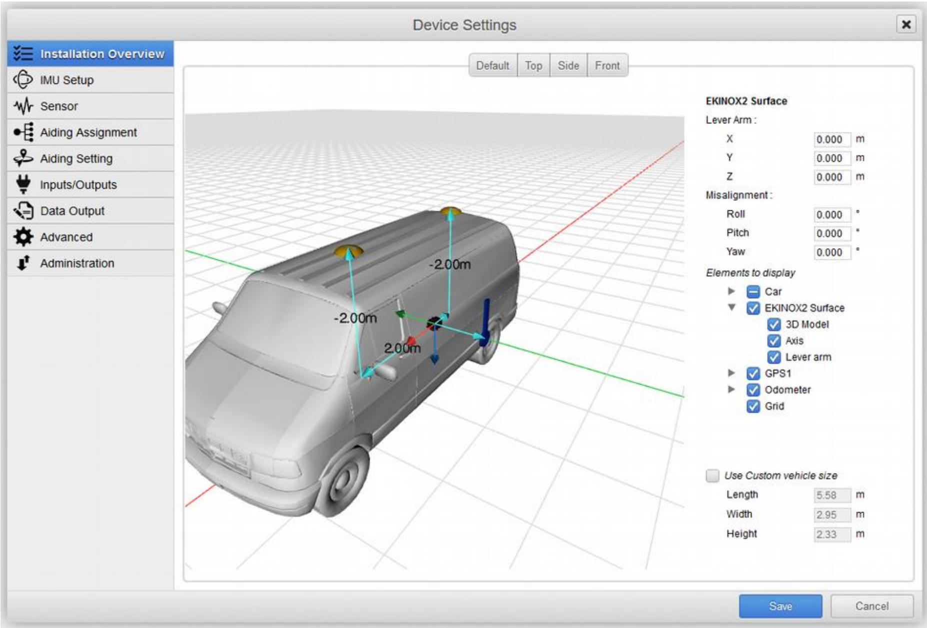


1. First, the odometer gain should be roughly entered in terms of pulses per meter. This parameter will be then automatically tuned by the Kalman filter to optimize the dead reckoning performance. Depending on your hardware configuration, the “reverse” mode can be use to reverse the velocity value in order to fit with an actual velocity direction. Initial gain error in percent should also be entered in this section: this defines how much the Kalman filter needs to estimate the Odometer's gain. Put 100% if you want it to be completely estimated, or 20% if you find your odometer is very accurate. If you are not sure, 50% is a good default value
2. Set up here the Odometer lever arm depending on its position with respect to IMU location (Odometer placement).
3. Auto-rejection is advised so the Kalman filter determines the confidence of this parameter by itself.

Note: SBG Systems strongly recommends to always use a gain accuracy of 100% to let the INS estimate and correct the odometer gain. This estimation is done very quickly and accurately by the Kalman filter during good GNSS reception.

Installation Check

The whole configuration can easily be checked in the Setup Overview section. It features a 3D display that can be modified by simply clicking on an item, then changing the orientation or lever arm values. Any change will be directly visible.



GNSS lever arm and alignment calibration procedure

The Ekinox, Apogee, Navsight and Quanta series include a very intuitive and accurate calibration procedure that simplifies a lot the installation while allowing highest performance level.

As a rule of thumb, measuring GNSS antenna lever arms can be very complex in typical situations where the IMU is installed inside the vehicle cabin and the GNSS antennas are located outside. Moreover, a dual antenna setup is even more complex due to the fact that a good knowledge of the mechanical alignment is required to allow proper measurement of the lever arms.

Considering this challenge, the automated calibration procedure developed allows the user to:

- Enter rough GNSS lever arm for the primary GNSS antenna – within 5 – 10cm
- If the vehicle dynamics are sufficient, let the system determine automatically the secondary antenna lever arm – nothing to enter
- In case of lower dynamics, enter a rough estimation of secondary lever arm – within 5 – 10cm.
- Run a one time calibration procedure to refine the GNSS lever arms
- Store parameters in the non-volatile memory to obtain highly accurate measurements in following missions.

Note: For a 20 minute calibration, RTK and dynamics are required. Low dynamic or non RTK applications can take longer to perform a calibration (1 hour).

Step by step calibration procedure

Step 1: define rough GNSS lever arms in configuration page

In the GNSS aiding settings, you have the possibility to select the GNSS heading mode between three options:

- Single antenna mode
- Dual antenna mode (auto lever arm)
- Dual antenna mode (known lever arm)

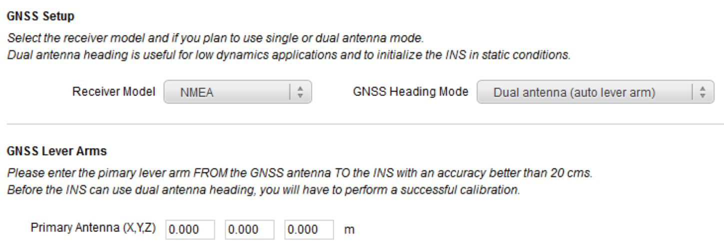


Figure 1: GNSS aiding configuration page

In the first two options, only the primary GNSS antenna lever arm can be entered. The third option requests a user first guess for the secondary antenna lever arm.

Step 2: Start the calibration

Before starting the calibration, it is recommended to place the vehicle in a good GNSS environment to enable best performance. Although it is not required, we recommend the calibration procedure to be performed with high precision GNSS like PPP or RTK as it will provide faster results, with a better confidence.

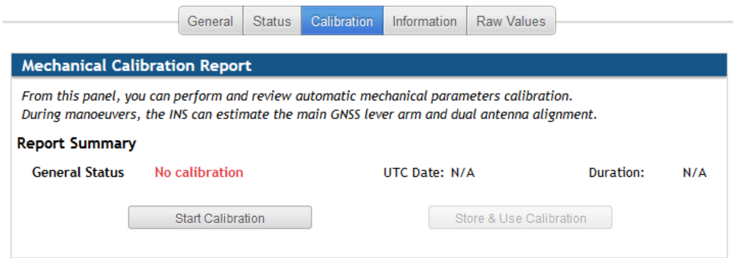


Figure 2: Default calibration page with no calibration applied

From the web page, in the calibration tab, you can simply start the calibration by pressing “Start Calibration” or “Restart Calibration” button.

This will cause the Extended Kalman filter to restart in a specific mode that enables estimation of GNSS parameters.

Step 3: Running calibration and check progress

Once started, the calibration status will typically do into “Waiting” state. In order to actually run the calibration, we need to operate the Kalman filter in Full navigation mode, which means we need heading, and position resolved.

In case the setting “Auto lever arm” has been set, please note that the system will not be able to initialize the heading in static condition, so the EKF will transition to Full navigation only after a short period of motion in forward direction.

Once the calibration is started and the vehicle is operated a sufficient speed (higher than 2.5m/s), the calibration status will transition to “running” mode. Two progress bars now display the calibration progress: one for the primary GNSS lever arm estimation, and one for the dual antenna heading alignment (linked to the secondary lever arm). The more dynamics we can get, the faster the calibration will be.

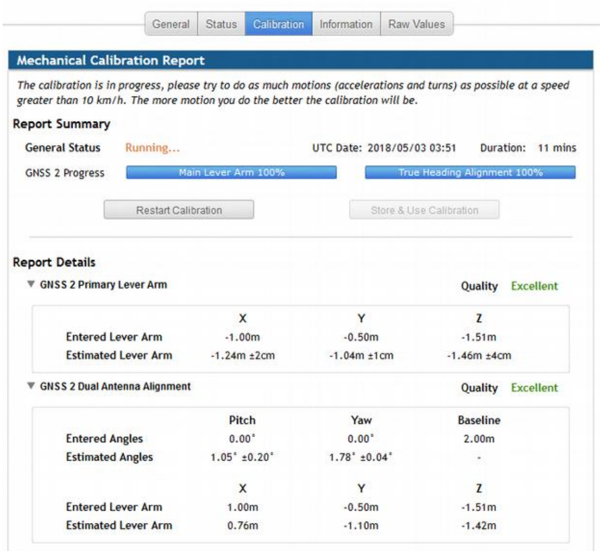


Figure 3: Running calibration in known lever arm mode

The typical recommendation is to perform high speed maneuvers, eight shape patterns, accelerations and deceleration phases.

To get more advanced feedback on the performance of estimated parameters, the calibration page also displays the estimated lever arms and angles, in comparison to what you entered initially, with associated standard deviations.

Depending on the GNSS environment and precision (RTK or not) and vehicle dynamics, the calibration can be performed within a few minutes, or can take more than half an hour. In case of low dynamics it may be impossible to reach a 100% finished calibration

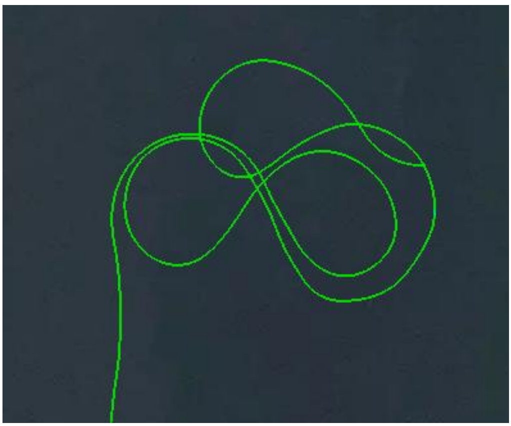


Figure 4: Typical maneuvers during a calibration

Step 4: Ending calibration

When active, the calibration continuously improves the lever arm and alignments. Even after reaching 100% completion, it is still possible to enhance the estimated values again by keeping maneuvering.

On the opposite side, in case of poor GNSS environment and/or low dynamics, it might be challenging/impossible to reach a 100% complete calibration.

That's why in the end, it belongs to the user to decide when the calibration should be stopped. User should also verify the consistency of the estimated parameters with respect to the entered values and actual setup. A minimum of 20% completion on each estimated parameter is required to unlock the calibration ending.

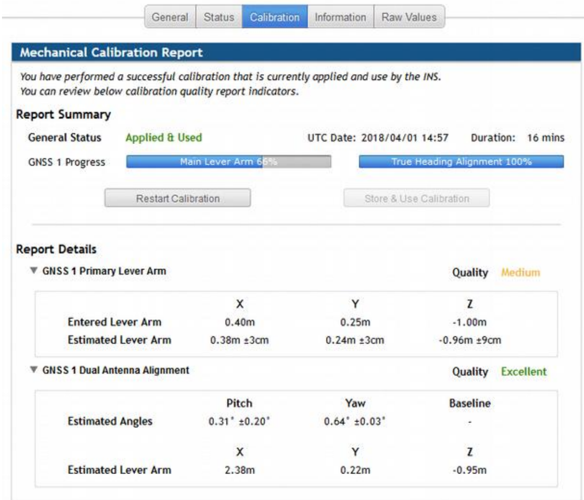


Figure 5: Applied calibration in auto lever arm mode

Once the calibration results are satisfactory, user can click on "Store & Use Calibration" button. This action will not restart the Kalman filter and he can move on to the actual mission directly. At next start, the unit will automatically load calibrated lever arms.

In case of inconsistency between actual setup and estimated parameters, user has the possibility to:

- Try a new calibration from scratch by pressing "Restart Calibration"
- Enter rough estimate of secondary GNSS lever arm to help the calibration procedure; then restart the calibration.

Checking what is actually applied, clearing calibration data

In any case, the parameters applied in the navigation filter are the one displayed in the configuration panel that can be freely edited. In case the setup is changed – compared to the previously applied calibration – it is always possible to modify the settings and start a new calibration, based on the newly entered values.

The calibration page always reflect the report from last calibration performed. In the same time, it checks whether this calibration is consistent with currently applied settings, using status "Applied and used" or "Not used".

Operation

Heading Alignment (initialization)

For applications with single antenna GNSS receivers, the unit will be able to provide full navigation data once the platform has been moved at higher speed than 10 km/h.

Applications that use a dual antenna GNSS system will start providing navigation data as soon as the GNSS true heading data is available. For such systems, the unit should be started up in a clear view of sky environment to prevent bad initialization of the GNSS true heading.

Warm-up

Full performance is reached after a warm-up time of 5 minutes. The system is operational before that time, but performance parameters cannot be guaranteed.

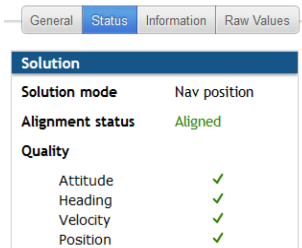
Ideally, the beginning of a mission should include some motion patterns with good GNSS availability that will be used to let the Kalman filter converge. This is the alignment phase.

There is no mandatory pattern to perform, the sensor will only need as much dynamics as possible (orientations and accelerations). A typical alignment pattern is shown in the next picture:

A few “eight” figures are sufficient most of the time, and the reported status flags will help you to validate that the alignment phase has ended.

Status check

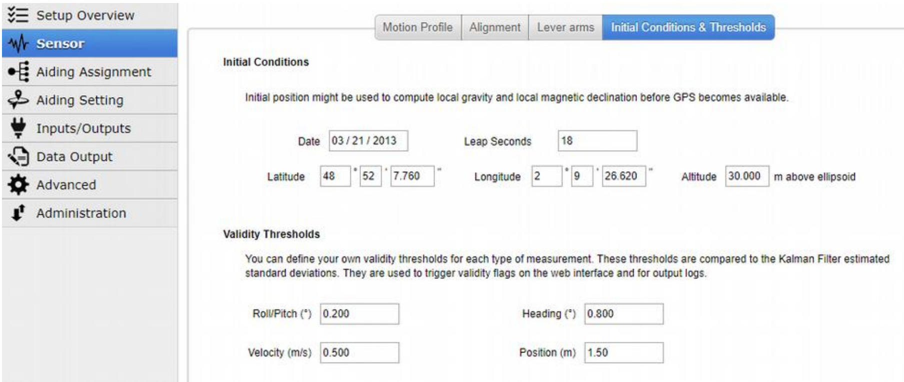
The web page provides advanced status feedback to make sure the system is working properly.



The Alignment Status is switched to green when internal filter parameters have converged and the system can achieve optimum accuracy. Other quality indicators focus on the accuracy of individual outputs (orientation, position, velocity).

Once these status flags are green, you can start your survey!

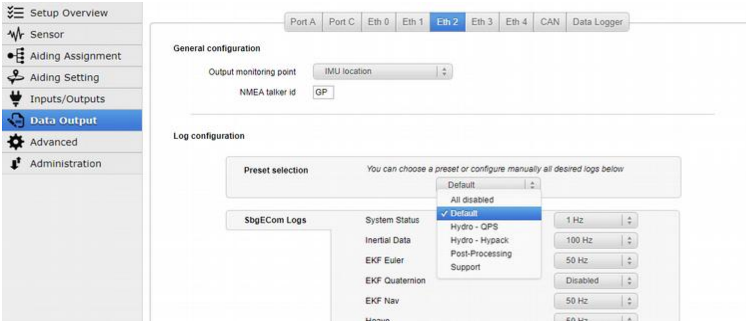
> **Note:** These status flags turn green when they reach a certain threshold. These thresholds can be configured in the section below:



Miscellaneous

Outputting data to third party software

It is possible to select a preset in order to configure the output protocols depending on what is expected by the third party software. For example, if using QPS, Hypack or PDS2000, the Hydro presets will correspond to the SBG Systems driver on the third party software side.

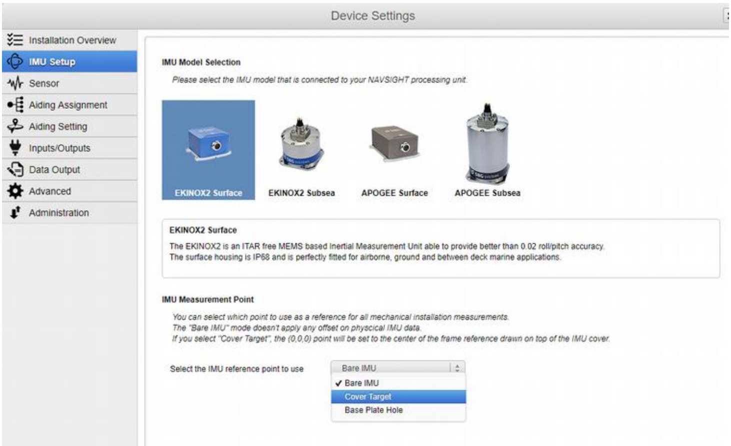


Note: If using a serial port to output data, it is important to make sure the baudrate is high enough for the amount of data being output to avoid saturating the port.

IMU Measurement Point

It is possible to choose what will be the reference point for the IMU for all lever arms measurements. This reference point can be the center of the IMU as described in the drawings in the Hardware Manual, or the target on the top of the housing, or the base plate hole.

Navsight/Quanta IMU measurement point:



Ekinox/Apogee IMU measurement point: