Ellipse AHRS & INS

Use in airborne applications

Operating handbook

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Support

EMEA +33 1 80 88 43 70
support@sbg-systems.com

Americas: *+1 (657) 549-5807*
support@sbg-systems.com

SBG SYSTEMS

This operating handbook explains how to install and setup an Ellipse in airborne applications such as aircraft, helicopter, or UAV. Mechanical installation is explained as well as software configuration and magnetic calibration.

- *Mechanical installation with alignment, vibration and magnetic field considerations*
- *Software configuration with motion profile, GPS antenna lever arm*
- *Magnetic calibration in case of magnetometers use*

Mechanical installation

Inertial Systems are very sensitive to their environment and the location of the inertial system into the aircraft is a key point to get accurate and reliable measurements.

Sensor accuracy can be greatly compromised if following instructions are not followed.

Vibrations

The Ellipse is designed to handle vibrations. Nevertheless in case of highly vibrating environment, an efficient mechanical vibration isolation is required for proper operation. Silicon dampers can be used for that purpose.

Ellipse placement in the aircraft

The vehicle coordinate frame is defined as follows:

- X axis points to the front of the aircraft
- Y axis points rightward.
- Z axis points downward.

The Ellipse MUST be mechanically aligned with the vehicle coordinate frame, as explained in the following diagram. **Alignment accuracy should be better than 0.5°.**

Note: If a correct mechanical alignment is not possible, then a software alignment can be used. Please refer to the Ellipse User Manual for such operation.

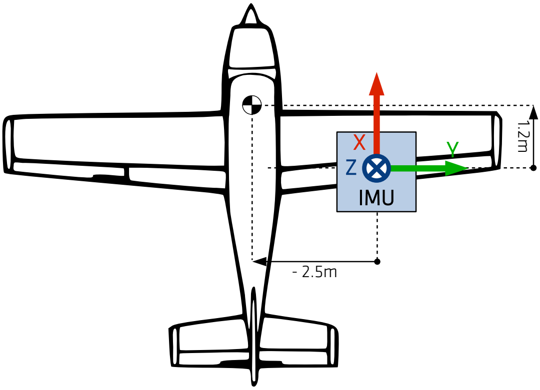
The main lever arm is the signed distance, expressed in the vehicle coordinate frame, **FROM** the Ellipse center of measurements **TO** the vehicle desired measurement point. It can be used to deport the velocity and position outputs to this specified location.

Only velocity and position outputs are affected by this main lever arm measurement.

Magnetic environment

If magnetometers are used for heading observation, user should also consider the magnetic environment.

The Ellipse **magnetometers require** for good operation a **clean magnetic field**. The sensor should be placed away from any magnetic interference such as: DC motors, radios, strobe lights, power supplies etc.

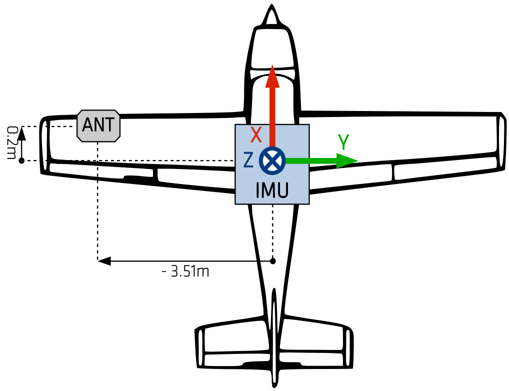


GNSS Antenna placement

GNSS antenna must be fixed with respect to the Ellipse. It should have a clear view of sky.

The GPS lever arm is the signed distance, expressed in the vehicle coordinate frame, **from** the Ellipse center of measurements, **to** the GNSS antenna. It must be measured within 5cm accuracy.

In addition, this lever arm should be lower than 10m for best performance.



> **Note:** If the Ellipse is not aligned with the aircraft, lever arms are still taken to the reference frame of the aircraft, with X pointing forward, Y to the right, and Z down. This is also the reference frame of the Ellipse considering the re-alignment has already been applied.

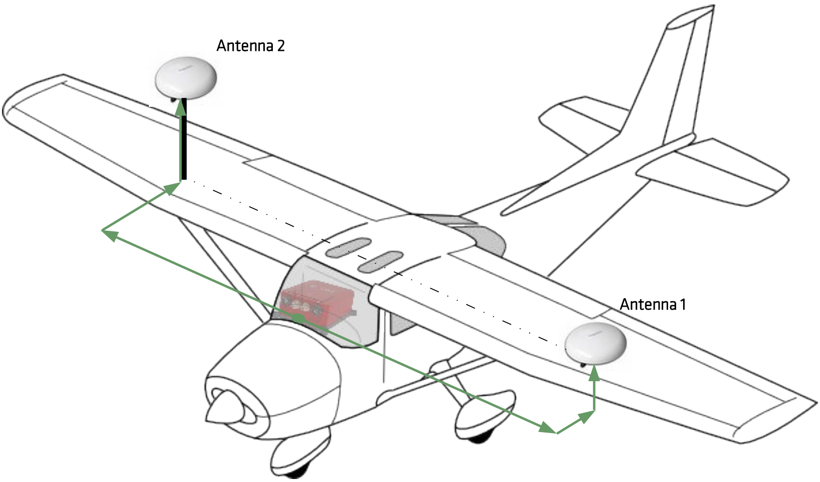
Dual GPS Antenna Placement

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

- Same antenna type, same cables with identical lengths must be used for both antennas.
- Both antennas must be turned the same way (connectors oriented in same direction)
- Both antennas must have the same view of sky when mounted on the vehicle.
- Both antennas must be placed on a ground plane (typically the aircraft's roof or wings, horizontal bars), more than 10cm away from the ground plane's edges.

Once installed, the main GPS antenna lever arm must be measured. It is the signed distance, expressed in the vehicle coordinate frame, from the Ellipse center of measurements, to the main GPS antenna. It must be measured within 5cm accuracy. Then, the same should be done for the second antenna.

Precise lever arms can also be estimated in Post processing using Qinertia.



Software configuration

All Ellipse configuration is done through the sbgCenter interface, or using low level communication protocol.

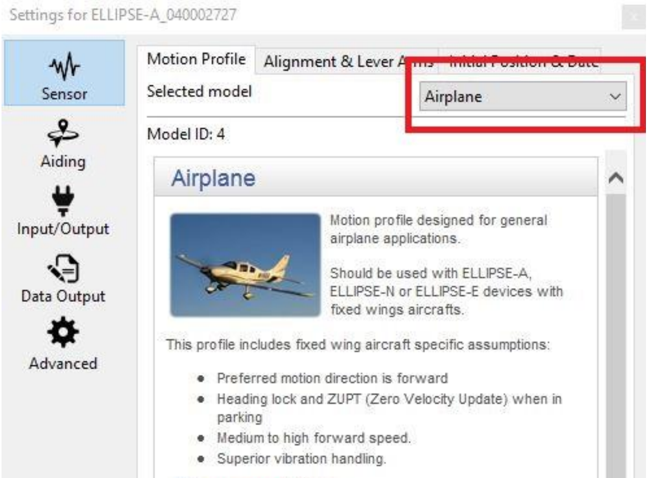
> **Note:** At the first access, the Ellipse will have its default configuration. This data output configuration should be used it you want to send logs to Support. Don't hesitate to contact the Support Team for help.

Sensor

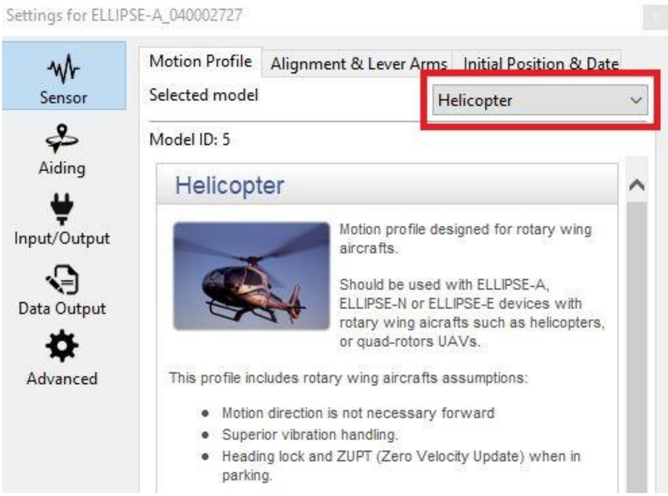
Motion Profile

For airborne application, several motion profiles are available:

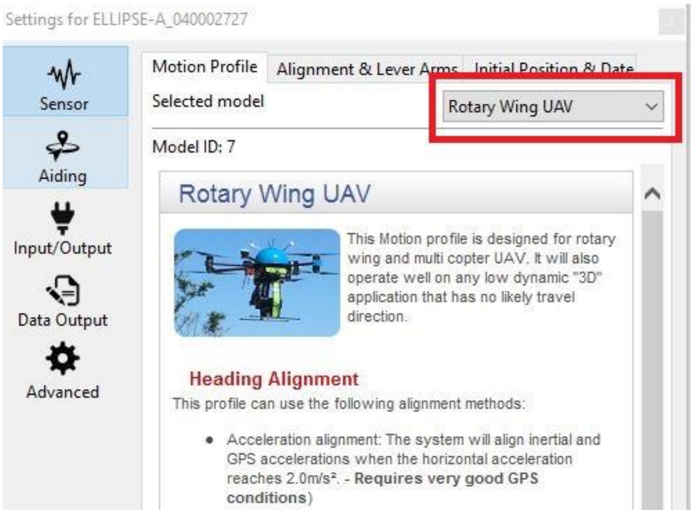
- Airplane



- Helicopter



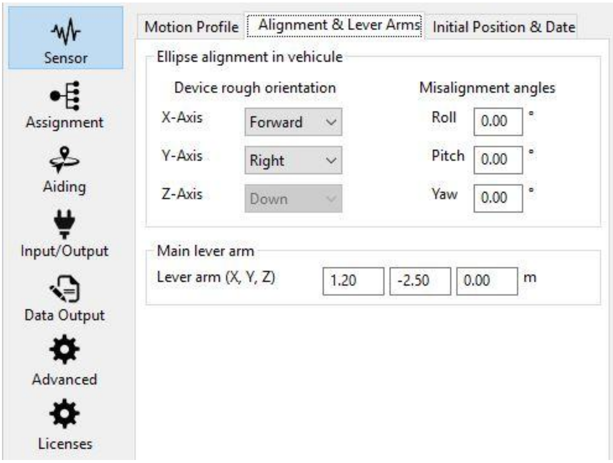
- Rotary Wing UAV



Alignment and lever arms

Here you can configure the alignment of the device and its lever arm in regard to the center of rotation of the aircraft.

On the alignment settings you only need to set up the first two axis, then the third one will be automatically computed.



Initial Position and Date

This parameter will matter if you are using magnetometers: the initial position and date will be used to compute the magnetic declination.

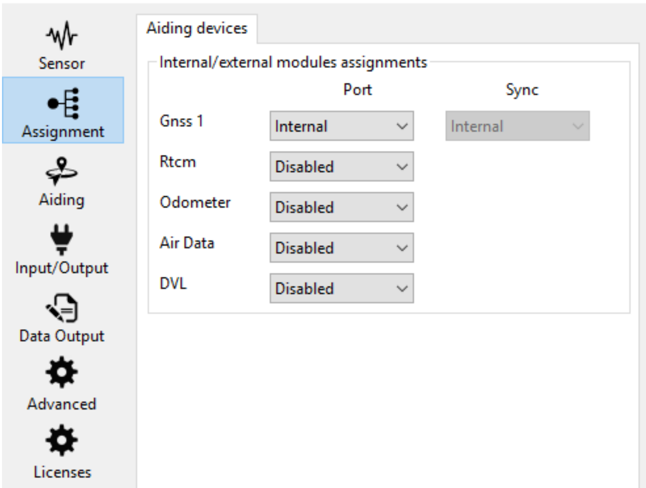
In case you use magnetometers as a heading source, then a magnetic calibration is mandatory. A 3D calibration should be preferred over a 2D one if possible. If a 2D magnetic calibration is performed, it will be only valid locally, and should be re-done if the aircraft is in a different geographic area.

Assignment

GNSS Receiver assignment

Here it is possible to select the serial port to receive the GNSS Receiver data, and select the input Synchronization as well.

The Ellipse N and D GNSS are automatically set to “Internal” by default to select the on-board GNSS Receiver. In addition, they accept In case the Internal GNSS Receiver is selected, the user can also set an RTCM corrections input on any available serial port.

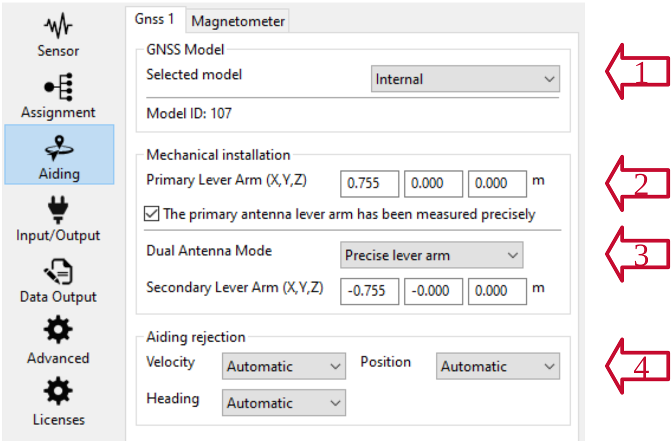


Other Aiding Inputs

You can enable Air Data aiding input for airborne application, in case you have such external sensor available. Please note that Odometer is for Automotive applications, and DVL for Marine applications.

Aiding

GNSS Configuration



Please check following point at the GPS configuration level:

1. Choose this parameter depending on the GPS you are using (NMEA, Ublox or Novatel, Septentrio)
2. Set up the lever arm of the GPS depending on its position on the aircraft (GNSS Antenna placement). f your lever arm has been precisely measured within 1-2 cm, or estimated by Qinertia, you can check the "Primary antenna Lever arm has been measured precisely" box. This will optimize Kalman filter warmup-time and overal performance.
3. Select Rough lever arm if you measured it within 5cm accuracy. If precisely measured or estimated by Qinertia, you can select "precise lever arm" to optimize filter warm-up time and performance.
4. Automatic rejection mode is advised for each parameter. Automatic mode automatically detects the confidence so the Kalman filter knows it can rely more on a parameter or less on an other.

Magnetic calibration in airborne applications

When magnetometers are used as heading reference, a **magnetic calibration is mandatory for normal sensor operation.** Different calibration methods are provided, depending on accuracy or ease of use requirement.

Light UAV calibration

As long as a UAV (fixed or rotary wings) is light enough to be held by a few persons, a 3D calibration, made on the ground is to be preferred. The basic procedure is the following:

1. Install the sensor as described in previous sections, and place the whole system **away from external magnetic disturbances** (buildings, other vehicles, etc)
2. Press "Start acquisition" button on sbgCenter calibration window
3. **Rotate the system as much as possible**. The main point is to cover the whole flight profile, but a larger amount of points, beyond the flight profile will provide even better results.
4. Press "**Calibrate**" and check calibration results. Press "**OK**" to finalize the calibration procedure.
5. Power cycle the sensor if you need immediate operation after calibration.

Airplanes, helicopter and large UAV applications

In flight 3D calibration

This calibration will give the best results as it allows to map the magnetic field in real 3D so that magnetometers readings are kept consistent even during turns and pitching.

In order to perform the calibration procedure, user can use the integrated sbgCenter calibration tool, or a data-logger to store the "magnetic calibration data" outputted by the Ellipse during calibration procedure.

Procedure

Once the aircraft is in steady flight at a reasonable altitude, the goal is to cover different orientations which are representative of the flight domain of the aircraft.

The calibration accuracy does not depend on any precise orientation (facing true North for example) and rather depends on how many significantly different orientations have been covered. The calibration algorithms are able to map the 3D magnetic field in orientation that have not really been covered during calibration; however, it is good to cover the full flight domain to get the best results.

For example an Extra 300 aerobatic airplane should get the best results by performing several representative aerobatic maneuvers in different directions in order to get a good 3D coverage of the magnetic field. In the other hand, a Cessna 172 private airplane could only perform high inclination eights to get optimal results.

Procedure tested on a private airplane

The following procedure has been tested with success on a piston private airplane.

The calibration starts in a steady flight. Two 360° turns will be performed decomposed in the following steps:

Step 1: Calibration Start. Press **“start acquisition**” button.

1. High bank right rolling – without turning.
2. High bank 120° left turn

Step 2:

1. High bank right rolling – without turning.
2. High bank 120° left turn

Step 3:

1. High Pitching: +20° then -20° then return to level flight
2. High bank right rolling – without turning.
3. High bank 120° left turn

Step 4:

1. High bank 120° right turn

Step 5:

1. High bank left rolling – without turning.
2. High bank 120° right turn

Step 6:

1. High Pitching: +20° then -20° then return to level flight
2. High bank left rolling – without turning.
3. High bank 120° right turn

Step 7: Calibration end. Press “**Calibrate**” button, then “**OK**” button write the calibration data to your sensor.

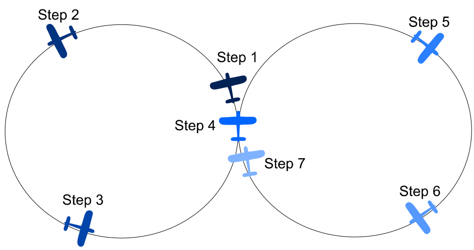


Figure 1: Trajectory performed during calibration

Once these tests are done the calibration can end. It is not crucial to perform exact 120° turns, but the procedure should perform rolling points at significantly different headings. In addition the pitching in the first turn should not be performed at the same heading as the one done in the second turn.

Note: This procedure can be easily transposed to rotor-craft. The procedure can be performed in a stationary flight, by making several pitching and rolling maneuvers at different heading values. The goal is to expose the sensor to as much orientations as possible.

Ground calibration (2D)

Although this method is not the most accurate, it's possible to calibrate the magnetometer on the ground, using the "2D" calibration method.

The procedure is really simple and only requires a few steps on the ground to be performed:

1. Install the sensor as described in previous sections, and place the whole system away from external magnetic disturbances (buildings, other vehicles, etc).
2. Place the aircraft on a horizontal platform. The aircraft must be kept horizontal (in its line of flight level). This is the case with most tricycle landing gears airplanes, but this should be a concern with conventional landing gears.
3. **Calibration Start.** Start the sbgCenter calibration tool and press "**start acquisition**" button.
4. Perform a 360° circle with the aircraft. The calibration mode has to be set on "2D". The aircraft should be at least 10m away from any metal building or other aircraft.
5. **Calibration end.** Press "**Calibrate**" and check calibration results. Press "**OK**" to finalize the calibration procedure.

Note: For highest performance, please consider the 3D calibration.

Calibration result examples

On the following screen-shots, it is possible to see that the calibration coverage is not a full 3D sphere but covers significantly different orientations. The first screen shows an example of the calibration procedure explained above. The second one shows a calibration only performed with a simple “8” performed.