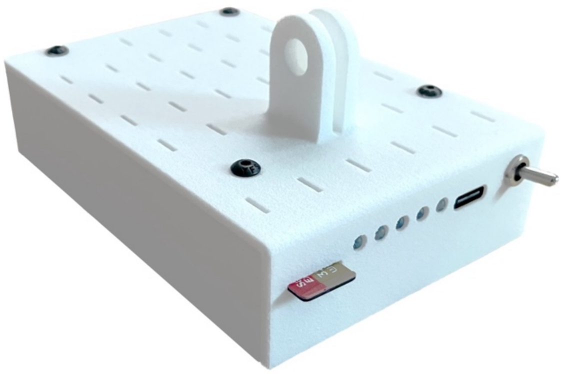
OnFlight Hub User Manual



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1 Support

If you have technical problems or cannot find the information you need in the provided documents, please contact our technical support team by email at: support@bolderflight.com. Our team is committed to providing the support necessary to ensure that you are successful using our products.

2 Introduction

The OnFlight Hub is a portable, high-performance, low-cost Inertial Navigation System (INS) and data logger for General Aviation (GA) aircraft. It is designed to be quickly mounted in a GA cockpit and log data to support pilot training, pilot proficiency, and reviewing previous flights. It is especially well-suited for student pilots, CFIs, and pilots conducting aerobatics, backcountry, glider, and ultra-light flights.

In addition to logging data, OnFlight Hub streams real-time data using the GDL 90 specification to *ForeFlight* and other GDL 90 compatible applications to provide position information and act as a backup Attitude and Heading Reference System (AHRS). A webpage is hosted by the OnFlight Hub to enable pilots to quickly view its operation and configure the device. A more complete set of data is also broadcast over UDP at a higher rate and enables developers to create applications using this real-time data. Finally, the OnFlight Hub can wirelessly receive real-time data from external air data and Above Ground Level (AGL) altimeter sensing modules. Starting with Firmware version 4, the Skeeter Enterprises Stadia portable AGL altimeter works natively with OnFlight Hub. Starting with Firmware version 6, analog input data and wireless heart rate sensors can be integrated with the OnFlight Hub as well.

OnFlight Hub fuses data from an integrated Inertial Measurement Unit (IMU), magnetometer, Global Navigation Satellite System (GNSS) receiver, and static pressure sensor at a rate of 50 samples per second while estimating and removing sensor biases in real-time.

An integrated battery provides over 13 hours of run-time and a USB-C port enables fully charging the OnFlight Hub in approximately 2.5 hours. GoPro and tripod mounts, along with a flat bottom to the case, enable a variety of mounting options. The size of the OnFlight Hub is 4 x 2.75 x 1 inches and it weighs just under 5 oz.

3 Operations

3.1 Overview

A functional block diagram of the OnFlight Hub software is in Figure 1.

An integrated IMU sensor provides 3-axis accelerometer and 3-axis gyro data. A magnetometer provides 3-axis magnetic field data, and a static pressure sensor provides static pressure data. Finally, an integrated GNSS receiver and antenna provides 3-axis inertial velocity (north, east, and down), position (latitude, longitude, and altitude), and time data.

Two processors are integrated with the OnFlight Hub; a Data Acquisition System (DAS) processor, which performs the real-time sensing, state estimation, and data logging and a WiFi processor, which acts as a wireless network server and provides a configuration website, broadcasts GDL 90 data for real-time viewing using applications such as *ForeFlight*, broadcasts real-time data over a UDP protocol, and can receive data from external sensing modules.

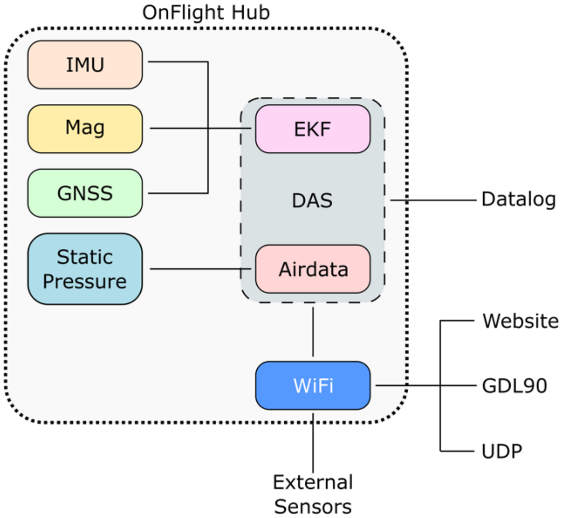

Figure 1: Functional block diagram.

At 50 Hz, a data ready interrupt generated by the IMU is used to trigger the start of a frame. In this frame, the DAS processor gathers data, if new data is available, from the IMU, magnetometer, static pressure sensor, and GNSS receiver. It also checks if data from external sensing modules is available from the WiFi processor. An Extended Kalman Filter (EKF) is used to fuse the IMU and GNSS data and air data estimation algorithms are used to estimate pressure altitude from the static pressure sensor.

The EKF is initialized with IMU and magnetometer data with a tilt compass to estimate initial pitch, roll, and heading. In subsequent frames, accelerometer and gyro sensor data is integrated in a time update to update pitch, roll, heading, inertial 3-axis velocities, and inertial 3-axis positions. When new GNSS data is available, a measurement update is performed to correct the data and estimate IMU biases to improve future time updates. Notice that magnetometer is only used to initialize the EKF and the following frames only rely on the IMU and GNSS data.

Both the raw sensor data and the processed data is available in the data log. IMU Bandwidth sets a low pass filter on the sensed accelerometer and gyro data from the sensor. During startup and initialization, gyro biases are estimated. Additionally, a scale factor and bias can be applied to the raw accelerometer sensor data. This approach is because gyros tend to have significant startup biases, which vary for each startup, so it is best to estimate these biases during initialization under the assumption that the unit is stationary. Accelerometer biases and scale factor tends to be stable and can be estimated once and removed. In the EKF, real-time biases are estimated and removed from the sensor data. These real-time biases pick up previously unaccounted for biases and errors as well as drift due to sensor temperature changes. An additional low pass filter can be applied following the EKF to remove further noise from the data. Figure 2 provides a functional diagram of the IMU data flow.

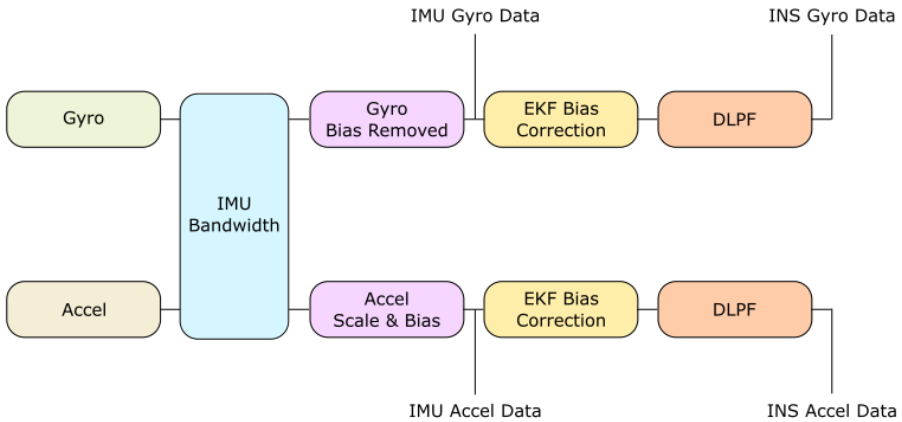

Figure 2: IMU data flow.

Similarly, the raw magnetometer data is recorded along with low pass filtered data. Note that no correction is applied from the EKF. A bias and scale factor can be applied to the raw sensor data to account for local magnetic fields.

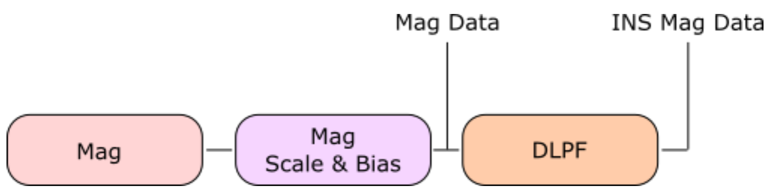

Figure 3: Magnetometer data flow.

Finally, the raw static pressure data is recorded along with low pass filtered data.

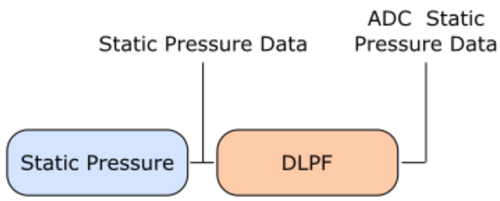

Figure 4: Static pressure data flow.

The accelerometer and magnetometer bias and scale factor are applied according to the following equation:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{corrected} = s\left(\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{meas} - \begin{bmatrix} x \\ y \\ z \end{bmatrix}_{bias}\right)$$

Where *s* is a 3x3 matrix to apply the scale factor. By default, *s* is the identity matrix.

3.2 Power and status

Figure 5 shows the power switch, USB-C charging port, LED status indicators, and micro-SD slot on the OnFlight Hub.

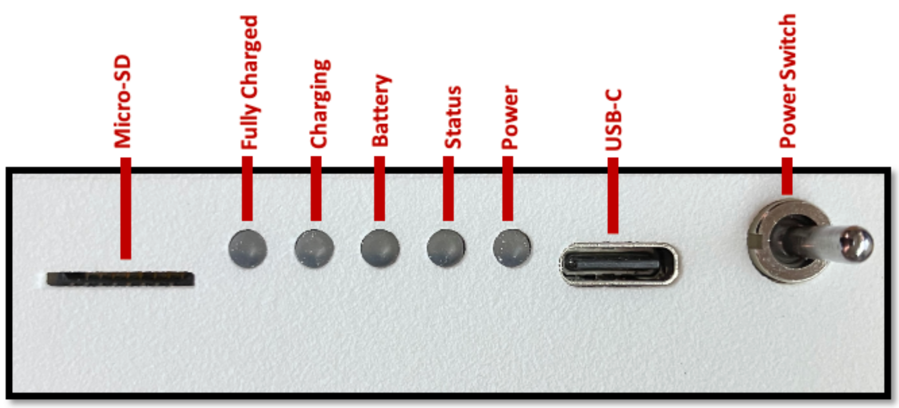

Figure 5: Switches and indicators.

Descriptions of the LED indicators are in Table 1. Note that a fast flashing mode of the status light was added in Firmware version 7 to indicate whether an SD card was present or not.

Table 1: LED indicator descriptions.

Name	Illumination Description			
	On	**Off**	**Flashing 2Hz**	**Flashing 1Hz**
Power	OnFlight Hub is on	OnFlight Hub is off	N/A	N/A
Status	INS is initialized and healthy	INS is either not initialized or has a poor GNSS fix	INS is initialized and healthy, but an SD card is **not** present	Fault occurred during initialization, contact Bolder Flight Systems
Battery	Battery is below 3.4V	Battery is above 3.6V	N/A	Battery is between 3.6V and 3.4V
Charging	Battery is charging	Battery is not charging	N/A	N/A
Fully Charged	Battery is fully charged	Battery is not fully charged	N/a	N/A

The *Power LED* indicates whether the OnFlight Hub is powered on or not. The power switch is a mechanical switch and power draw of OnFlight Hub should be minimal when it is powered off.

The *Status LED* is used to indicate the health and status of the OnFlight Hub. The OnFlight Hub performs self-tests during initialization – if the *Status LED* is flashing at 1 Hz, this indicates that a fault occurred during initialization, and you should contact Bolder Flight Systems. If the *Status LED* is off, this indicates that the INS has not yet initialized, probably due to not receiving a strong enough GNSS signal. If the *Status LED* was on and is now off, this indicates that the INS initialized, but now is no longer receiving a strong enough GNSS signal and the INS data may be unreliable. If the *Status LED* is illuminated, the INS is initialized, healthy, and the INS data can be trusted. Starting in Firmware version 7, a fast flashing indicates that the INS is healthy and initialized, but an SD card is not present.

The *Battery LED* is used to indicate the battery voltage level, which gives a rough estimation of run time remaining. The *Battery LED* will start flashing when the battery voltage is between the configured low and warning voltages, 3.4V and 3.6V by default. The *Battery LED* will fully illuminate when the battery voltage is below the configured low voltage level, 3.4V by default.

The *Charging LED* illuminates when the OnFlight Hub is charging and the *Fully Charged LED* will illuminate when the OnFlight Hub is fully charged.

3.3 Initialization

For the first 5 seconds after it is powered on, OnFlight Hub estimates initial biases for the IMU. It is recommended to not move the OnFlight Hub during this time.

OnFlight Hub requires a 3D GNSS fix with at least the configured minimum number of satellites to initialize the INS data fusion algorithms. Starting in Firmware version 8, the GNSS accuracy must be better than the configured minimums for INS initialization to occur as well. Once these are initialized, you will start to see good position, attitude, speed, and accuracy estimation data. Note that ground track and flight path angle will not be valid until you have some forward speed. Additionally, heading will likely be inaccurate at speeds of less than 10 knots.

3.4 Integration with Stadia AGL Altimeter (Firmware version 4 and newer)

Skeeter Enterprises LLC manufactures and sells a portable LIDAR altimeter for General Aviation called the Stadia. The Stadia can be easily mounted on a wing strut, wing tie down bolt, or tail tie down bolt and provides real-time measurement of the aircraft's height above the ground up to a range of 130 ft. Stadia has a battery life of 10 hours and transmits data over Bluetooth. Skeeter Enterprises is developing a RADAR altimeter for floatplane use as well.

OnFlight Hub with firmware v4.0 or higher supports the Stadia AGL altimeter out of the box and is capable of recording the altimeter data as well as displaying the data on our webpage and broadcasting real-time data over our UDP protocol.

To use Stadia with the OnFlight Hub, ensure that the Stadia is mounted to the aircraft, that the **Stadia is powered before OnFlight Hub is powered**, and that you don't have other devices connected to Stadia, such as a phone or tablet. During the first 10 seconds after boot, OnFlight Hub will search for Stadia and automatically connect to it. If the OnFlight Hub does not connect with Stadia on boot, it is assumed that a Stadia AGL altimeter is not present and no further connection attempts will be made. Once a connection with Stadia is established, the OnFlight Hub will collect 2 seconds of AGL altimeter data to estimate and remove bias due to the mounting location.

If the connection with Stadia is lost, the OnFlight Hub will attempt to re-acquire a connection over a period of 120 seconds.

Stadia reports its battery percentage remaining as well as the height above ground. OnFlight Hub records:

- The connection status with Stadia and whether a new message has been received.
- The Stadia battery status. The battery is reported as good above 30% life remaining, warning between 15% and 30% battery life remaining, and low below 15% battery life remaining.
- The AGL altitude data.

No information is available on the die temperature status of Stadia or whether the sensor is within range.

3.5 Integration with Bluetooth Heart Rate Sensors (Firmware version 6 and newer)

OnFlight Hub supports receiving Bluetooth heart rate data from straps and watches. This data is displayed on the OnFlight Hub configuration website, recorded in the data logs, and broadcast over UDP.

To use a heart rate sensor with the OnFlight Hub, ensure that the **heart rate sensor is powered and broadcasting data <u>before</u> OnFlight Hub is powered**. During the first 10 seconds after boot, OnFlight Hub will search for heart rate sensors and automatically connect if found. If the OnFlight Hub does not connect with a heart rate sensor on boot, it is assumed that one is not present and no further connection attempts will be made.

If the connection with the heart rate sensor is lost, the OnFlight Hub will attempt to re-acquire a connection over a period of 120 seconds.

3.6 Configuration

Connect to the wireless network called “OnFlight Hub”. Starting with Firmware version 6, the SSID is appended by the unit’s serial number to ensure that it is always unique. There is no password required to connect. If you would like to view the status of the OnFlight Hub or change its configuration, navigate to **192.168.23.1** in a web browser. The configuration webpage is shown in Figure 6.

Real-time data from OnFlight is shown on this page. The GDL 90 port is set to 4000 by default; however, if *ForeFlight* changes this in the future, or you would like to use an application that uses a different port, set the desired GDL 90 port, and press the *Update Config* button.

If you would like to reset the configuration back to defaults, you can accomplish this by pressing the *Restore Defaults* button.

The following sections describe the rest of the configuration in greater detail. Note that configuration updates, other than setting the GDL 90 port, will result in a reset of the DAS processor, which requires several seconds to take effect.

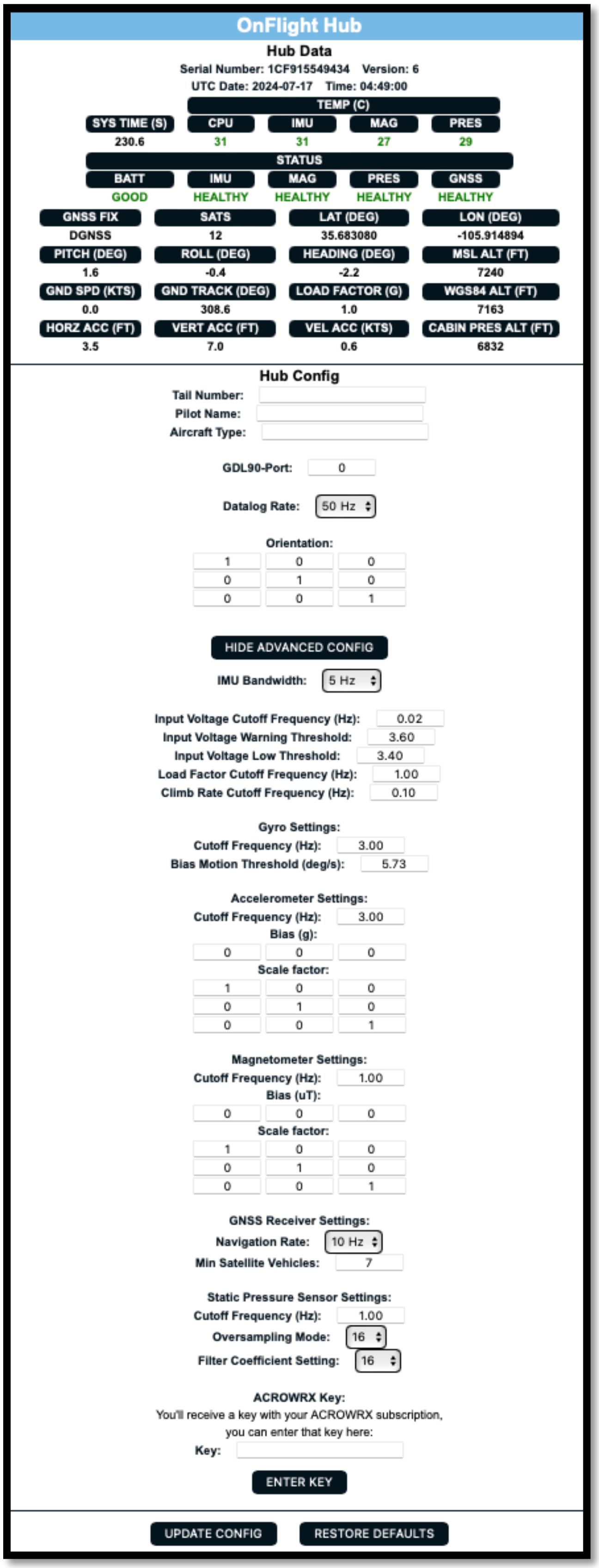

Figure 6: OnFlight Hub configuration webpage

3.6.1 Meta Data (Firmware version 6 and newer)

Meta data is collected and included in the OnFlight data logs, including the aircraft tail number, pilot name, and aircraft type. This data can be used by data log converters to automatically organize and analyze the flight data.

3.6.2 Data Log Rate (Firmware version 6 and newer)

The data log rate can be set, which enables the use of lower performance SD cards and reduces the resulting data log size. The configurable options include 50 Hz, 25 Hz, 10 Hz, and 5 Hz. Note that the OnFlight Hub will always run at 50 Hz, this option just changes the rate that data is stored to the SD card.

3.6.3 Orientation

OnFlight Hub uses a right-hand reference frame, as shown in Figure 7. This should be aligned with the aircraft reference frame, where the x-axis is out the nose, the y-axis is out the right wing, and the z-axis is down.

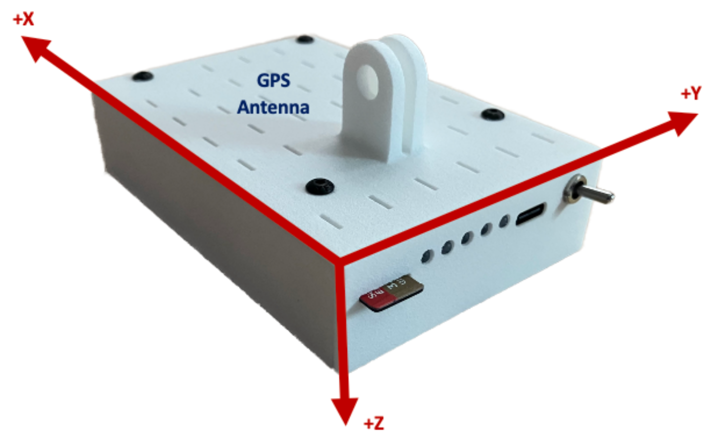

Figure 7: Reference frame.

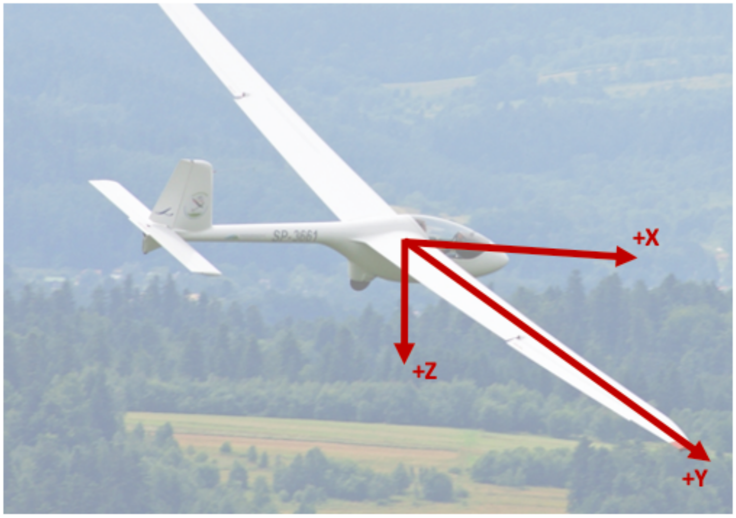

Figure 8: Aircraft reference frame.

This alignment can be done by physically mounting the OnFlight Hub aligned with the aircraft, Figure 9, or the OnFlight Hub can be rotated into the aircraft frame using a rotation matrix on the configuration website.

Figure 9: Example installation of OnFlight Hub aligned with aircraft reference frame.

The rotation matrix is defined as:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{aircraft} = c \begin{bmatrix} x \\ y \\ z \end{bmatrix}_{onflight}$$

Where *c* is a 3x3 matrix rotating the OnFlight Hub into the aircraft frame. By default, *c* is the identity matrix. Examples for several orientations are given below along with the corresponding rotation matrix.

Orientation	Rotation Matrix
+x forward out the nose, +y toward the right wing, +z down (default)	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$
+x aft out the tail, +y toward the left wing, +z down	$\begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$
+x forward out the nose, +y up, +z out the right wing	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$
+x forward out the nose, +y down, +z out the left wing	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & -1 & 0 \end{bmatrix}$
+x down, +y aft, +z out the left wing	$\begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & -1 \\ 1 & 0 & 0 \end{bmatrix}$

+x down, +y forward, +z out the right wing	$\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$

3.6.4 Mounting OnFlight Hub

The OnFlight Hub can be mounted with a suction cup via a GoPro style mount on top of the OnFlight Hub or via a tripod mount on the bottom of the device. The bottom of OnFlight Hub is flat to enable the use of Velcro for mounting as well. Note that the OnFlight Hub is designed to only be mounted inside of the cockpit.

The tripod mount on the bottom of the device, which is a 1/4-20 threaded insert, has 3/8" of thread available. **Do not insert a screw deeper than 3/8" or damage may occur.**

We recommend mounting via the tripod mount or the flat bottom of the device for use cases where accurate acceleration data is important, such as performing aerobatics.

Also note the location of the OnFlight Hub GNSS antenna, as shown in Figure 7, and try to ensure that it has a clear view of the sky.

3.6.5 IMU Bandwidth

The IMU bandwidth sets the internal low pass filter used by the IMU. Cutoff frequencies available are 5 Hz, 10 Hz, and 20 Hz.

3.6.6 Input Voltage

The input voltage measures the USB charging voltage, when a charger is connected, otherwise it measures the battery voltage and is used as an estimate of the run time remaining. The input voltage is a noisy signal and heavily filtered. The filter cutoff frequency can be set. Additionally, the voltage levels used for setting the warning and low battery voltage status can also be adjusted.

3.6.7 Load Factor and Climb Rate

Load factor is determined from low pass filtered z-axis acceleration, after the EKF, with the positive axis up. Climb rate is from the EKF vertical velocity, low pass filtered and converted to feet per minute. Both the load factor and climb rate low pass filter cutoff frequencies can be configured.

3.6.8 Gyro

During initialization, gyro biases are estimated assuming the OnFlight Hub is stationary. A threshold is used to identify when the OnFlight Hub is not stationary and to not include gyro measurements in the bias estimate when the measurement is above the threshold. The threshold value can be configured.

Additionally, the low pass filter cutoff frequency can be configured.

3.6.9 Accel

A scale factor and bias can be applied to correct the raw sensor values prior to the EKF. Additionally, the low pass filter cutoff frequency can be configured.

3.6.10 Magnetometer

A scale factor and bias can be applied to correct the raw sensor values prior to the EKF. Additionally, the low pass filter cutoff frequency can be configured.

3.6.11 GNSS

The GNSS navigation rate can be set. This is the rate at which new position and velocity data is available from the GNSS receiver. Available rates are 1 Hz, 5 Hz, and 10 Hz. Generally, higher rates provide better INS performance.

Additionally, the minimum number of satellites used in the GNSS solution when initializing the INS can be configured. Higher values force a better and more stable solution used in the INS; however, this requires longer to initialize. In general, this should likely be between 4 and 9 satellites.

Starting in Firmware version 8, the minimum horizontal and vertical accuracy can also be specified. This determines when the INS is initialized as well as when measurement updates from the GNSS occur. Firmware version 8 also changed the minimum number of satellites to 12 by default.

3.6.12 Static Pressure

The low pass filter cutoff frequency for the static pressure sensor can be configured.

3.6.13 ACROWRX Key

OnFlight Hub natively integrates with the ACROWRX aerobatics analysis software. When subscribing to the ACROWRX software a key is provided, which can be entered on the OnFlight Hub configuration page and enables selecting the ACROWRX data format output. The title of the configuration page will change to *"OnFlight + ACROWRX"* after the key has been correctly applied.

3.6.14 Stadia AGL Altimeter (Firmware version 4 and newer)

The real-time data from Stadia can be viewed on the OnFlight Hub webpage at 192.168.23.1. Additionally, a button is available to re-zero the Stadia AGL altitude at any time.

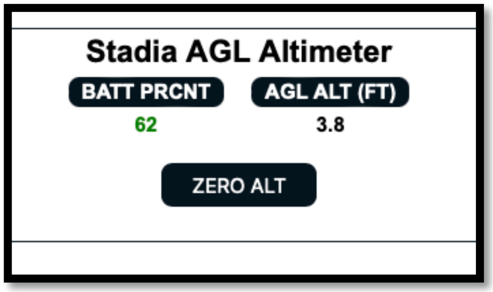

Figure 10: Stadia config.

3.7 GDL 90 Streaming

Data is broadcast using the GDL 90 specification over the configured port. Heartbeat and ForeFlight ID are sent 1 time per second. Position data (i.e. ownship), GNSS altitude, and attitude are sent 5 times per second.

Simply connect to the OnFlight Hub wireless network and launch *ForeFlight* or another GDL 90 application. *ForeFlight* will display the device name, serial number, estimated position accuracy, along with position and AHRS data.

3.8 Data Conversion

A data converter is available on Bolder Flight Systems, which can convert log files to CSV, MATLAB, and CloudAhoy formats. Several applications natively work with the OnFlight data format, including AviNet, FlySto, and ACROWRX.

Note that on MacOS, after installing the application from the DMG, you will need to navigate to your *Applications* folder, right click on the OnFlight Data Converter application and select open. A dialog box will inform you that Apple is not able to check the application for malicious code; selecting open again allows the OnFlight Data Converter application to run and it can now be run as normal from the dock or *Launchpad*.

4 Specifications

Size: 4 x 2.75 x 1 inches
Weight: 5 oz.
USB-C Input Voltage: 5V
Acceleration Range: +/- 16 G
Rotational Rate Range: +/- 2,000 deg/s
Velocity Range: 0 to 650 knots
Climb Rate Range: +/- 3,275 ft/min
Altitude Range: -10,000 ft to +55,000 ft
Temperature Range: -40 to +80 C chip die temperature