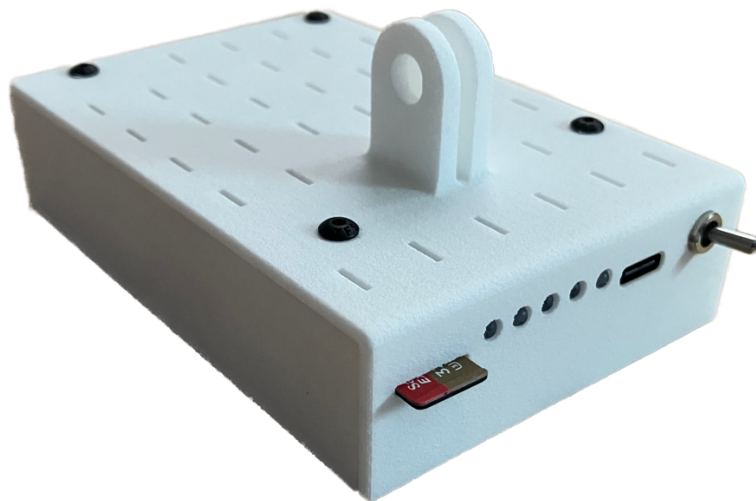# OnFlight Hub User Manual

Firmware v1.0, v2.0, and v3.0

Document Revision 1.1

Table of Contents

1   Technical Documentation

The following documentation and support software are included with OnFlight and available from our website:

- **User Manual (this document):** describes the OnFlight Hub, specifications, and operations.
- **CSV Data Log Description:** describes the fields available in the CSV formatted data logs.
- **Binary Data Log Description:** describes the binary data log format that OnFlight Hub uses to write data. This is useful for application developers who would like to natively read and use these data logs.
- **UDP Broadcast Description:** describes the real-time UDP broadcast packet format that is sent by OnFlight Hub.
- **External Air Data Interface:** describes the interface to send OnFlight Hub data from an external air data system.
- **External AGL Altimeter Interface:** describes the interface to send OnFlight Hub data from an external Above Ground Level (AGL) altimeter.
- **Data Converter:** application for Windows or MacOS, which converts the data from OnFlight to CSV format.

2   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.

3   Introduction

The OnFlight Hub is a portable, high-performance, low-cost Inertial Navigation System (INS) and data logger for General Aviation 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 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 to use this real-time data. Finally, the OnFlight Hub can wirelessly receive real-time data from external air data and Above Ground Level (AGL) altimeter data sources.

OnFlight Hub fuses data from an integrated IMU, magnetometer, 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 5 oz.

4   Operations

4.1   Overview

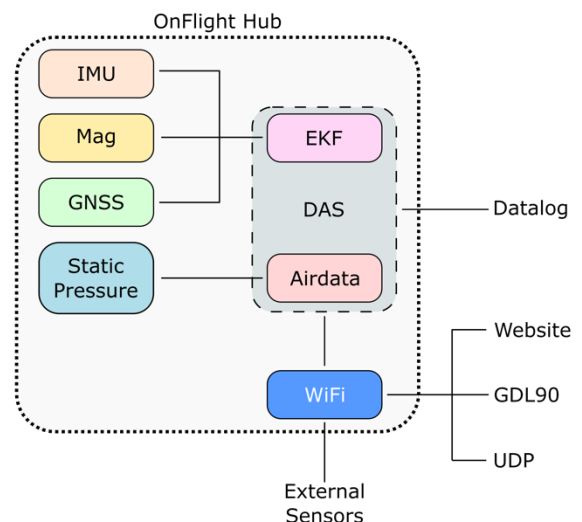A functional block diagram of the OnFlight Hub software is in Figure 1.

Figure 1: Functional block diagram.

An integrated Inertial Measurement Unit (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 datalogging and a WiFi processor, which acts as a wireless network server and provides a configuration website, broadcasts GDL90 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.

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 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. Additionally, 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.
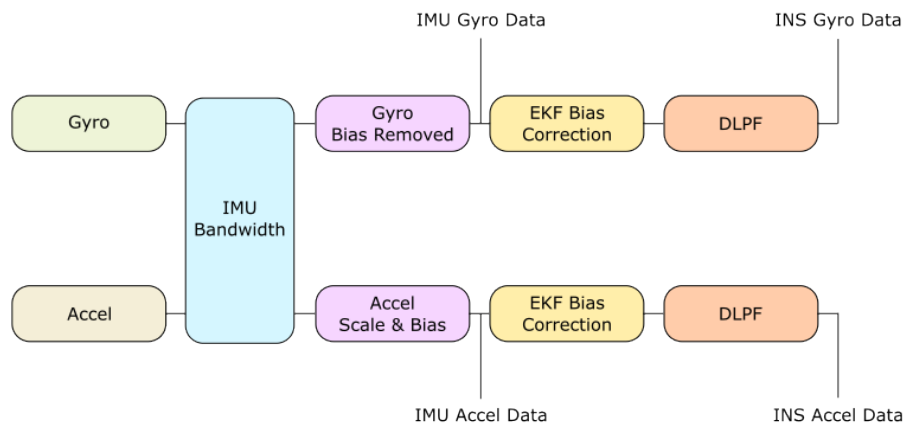

Figure 2: IMU data flow.

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.
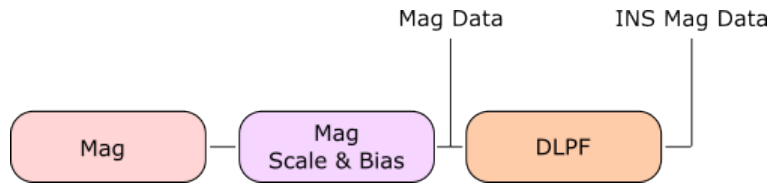
Figure 3: Magnetometer data flow.

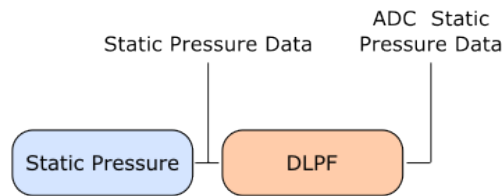Finally, the raw static pressure data is recorded along with low pass filtered data.

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.

4.2   Power and status

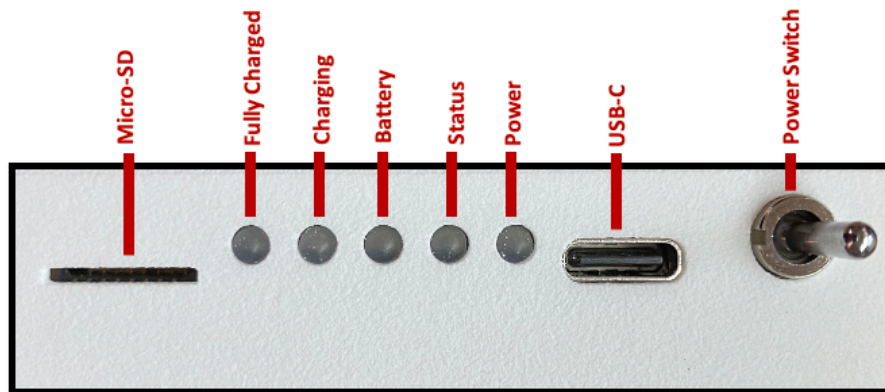Figure 5 shows the power switch, USB-C charging port, LED status indicators, and micro-SD slot on the OnFlight Hub.

Figure 5: Switches and indicators.

Descriptions of the LED indicators are in Table 1.

Table 1: LED indicator descriptions.

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

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.

4.3 Configuration

Connect to the wireless network called "OnFlight Hub". 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 GDL90 port, will result in a reset of the DAS processor, which requires several seconds to take effect.

Figure 6: OnFlight Hub configuration webpage

4.3.1   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.
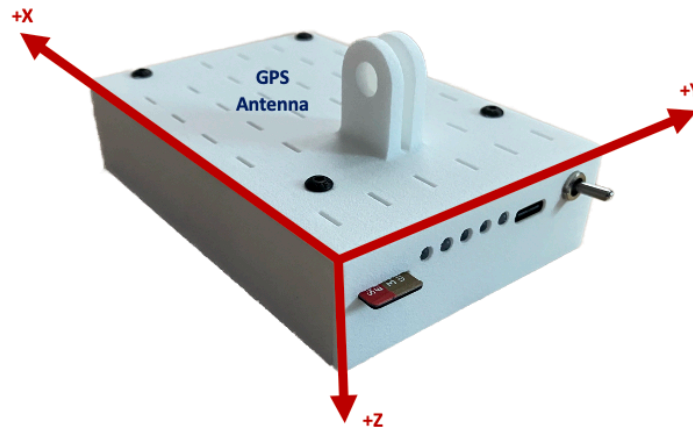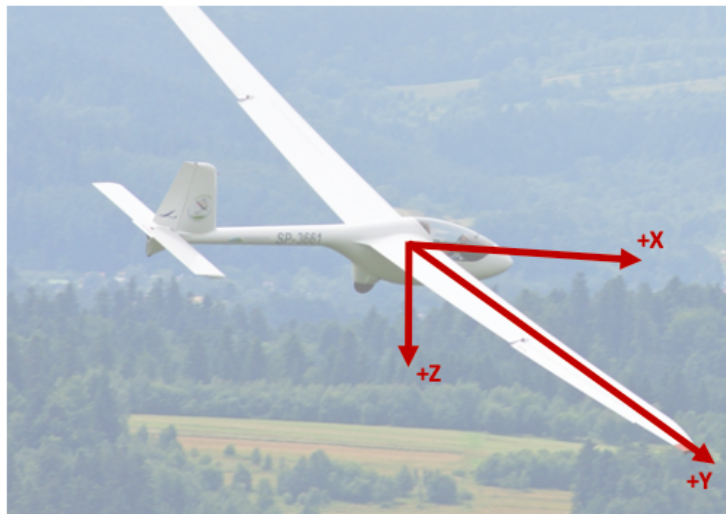

Figure 7: Reference frame.

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. For example, if the OnFlight Hub is installed in the aft windshield of the aircraft, the x-axis of OnFlight Hub would be in the opposite direction of the aircraft x-axis and the y-axis of OnFlight Hub would be aligned in the opposite direction of the aircraft y-axis. The rotation matrix in that case would be:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{aircraft} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}_{onflight}$$

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.

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.

4.3.2   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.

4.3.3   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.

4.3.4　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.

4.3.5　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.

4.3.6　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.

4.3.7　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.

4.3.8　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.

4.3.9　Static Pressure

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

4.4　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 GPS fix with at least the configured minimum number of satellites to initialize the INS data fusion algorithms. 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.

4.5　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), GPS 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.

4.6   Data Conversion

A micro-SD card must be inserted into the OnFlight Hub to record data. The card should be inserted prior to turning on the OnFlight Hub. It is recommended to format the micro-SD card as FAT32 or exFAT formats. We recommend using a high-speed card – a list of cards tested to work well with the OnFlight Hub is below:

- SanDisk Extreme 32 GB
- SanDisk Extreme Plus 32 GB
- SanDisk Ultra Plus 32 GB
- Delkin 64 GB

After the flight, the micro-SD card can be inserted into your computer to view the data files. Data files are named sequentially, based on the files present on the micro-SD card to avoid overwriting older files. These data files start with *data0.onflight*.

A data converter application is available for download for use with Windows and MacOS operating systems. A screenshot of the OnFlight Data Converter application is in Figure 10.
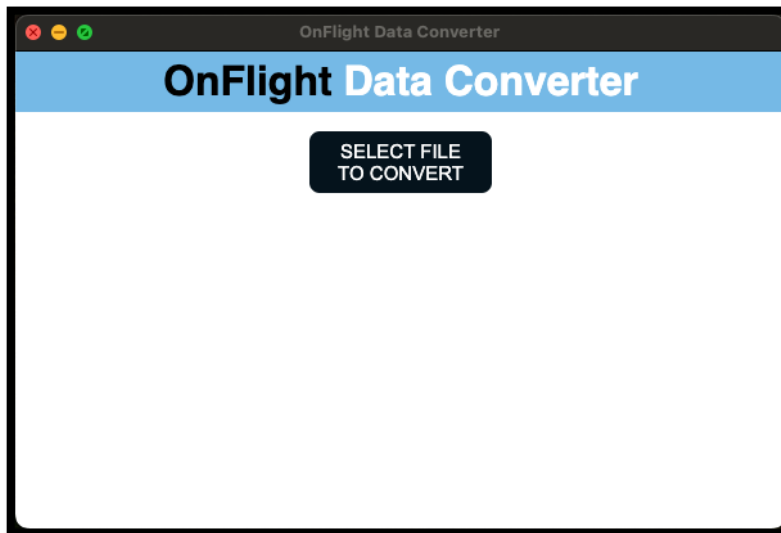
Figure 10: OnFlight Data Converter application.

Use the button to select the data file to convert, which will display a file selection dialog box to browse to the file's location. Once an OnFlight data log file is selected, this is confirmed on the application screen. You can select to output a CSV file, which will create a Comma Separated Variable log of all the available data from OnFlight at the full 50 Hz rate. This can then be loaded into many open-source and proprietary programs for analysis. The items included in the data log are described in more detail in the *CSV Data Log Description* document, Figure 11.
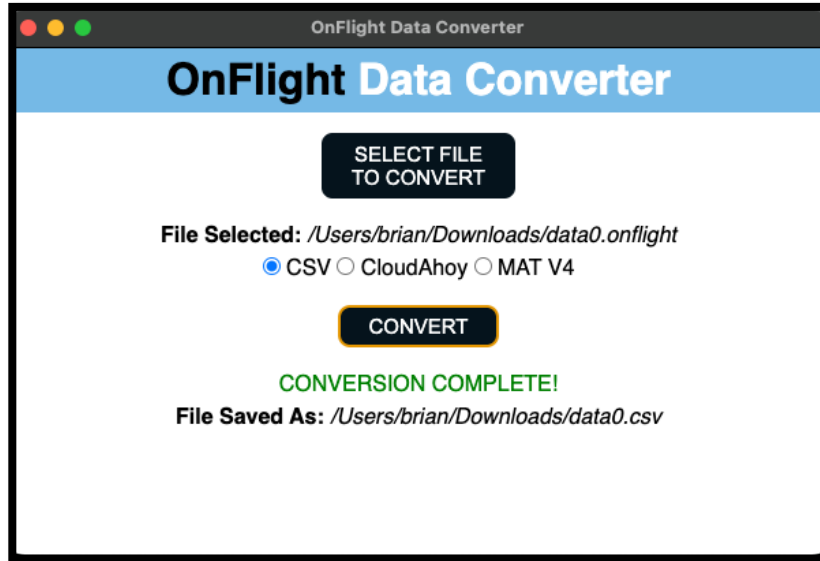
Figure 11: Converting to CSV format.

Alternatively, you can select to output a log compatible with *CloudAhoy*. This will require entering the aircraft's N-number and selecting whether an external airdata module was connected and whether angle-of-attack data is available in degrees, Figure 12.
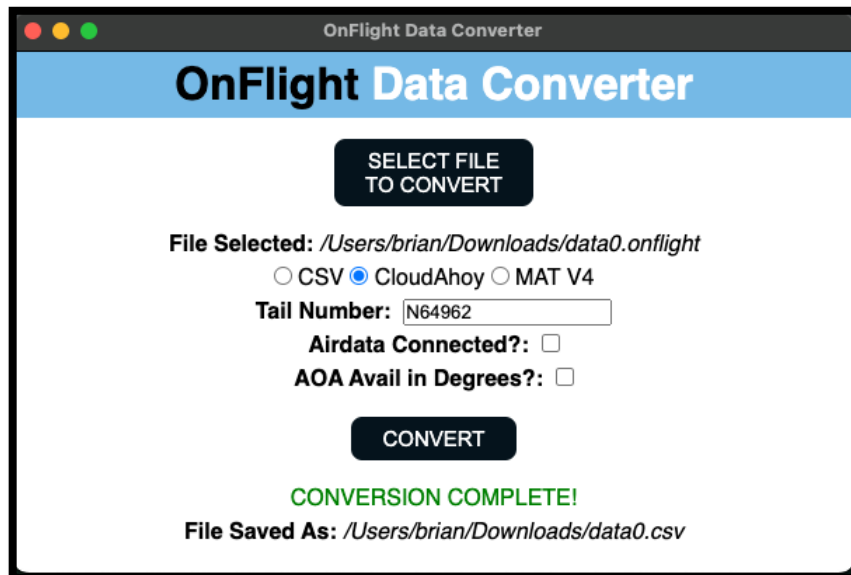

Figure 12: Converting to CloudAhoy format.

The data is down-sampled to 5 Hz and converted to a CSV log that can be uploaded to *CloudAhoy* for analysis, Figure 13.
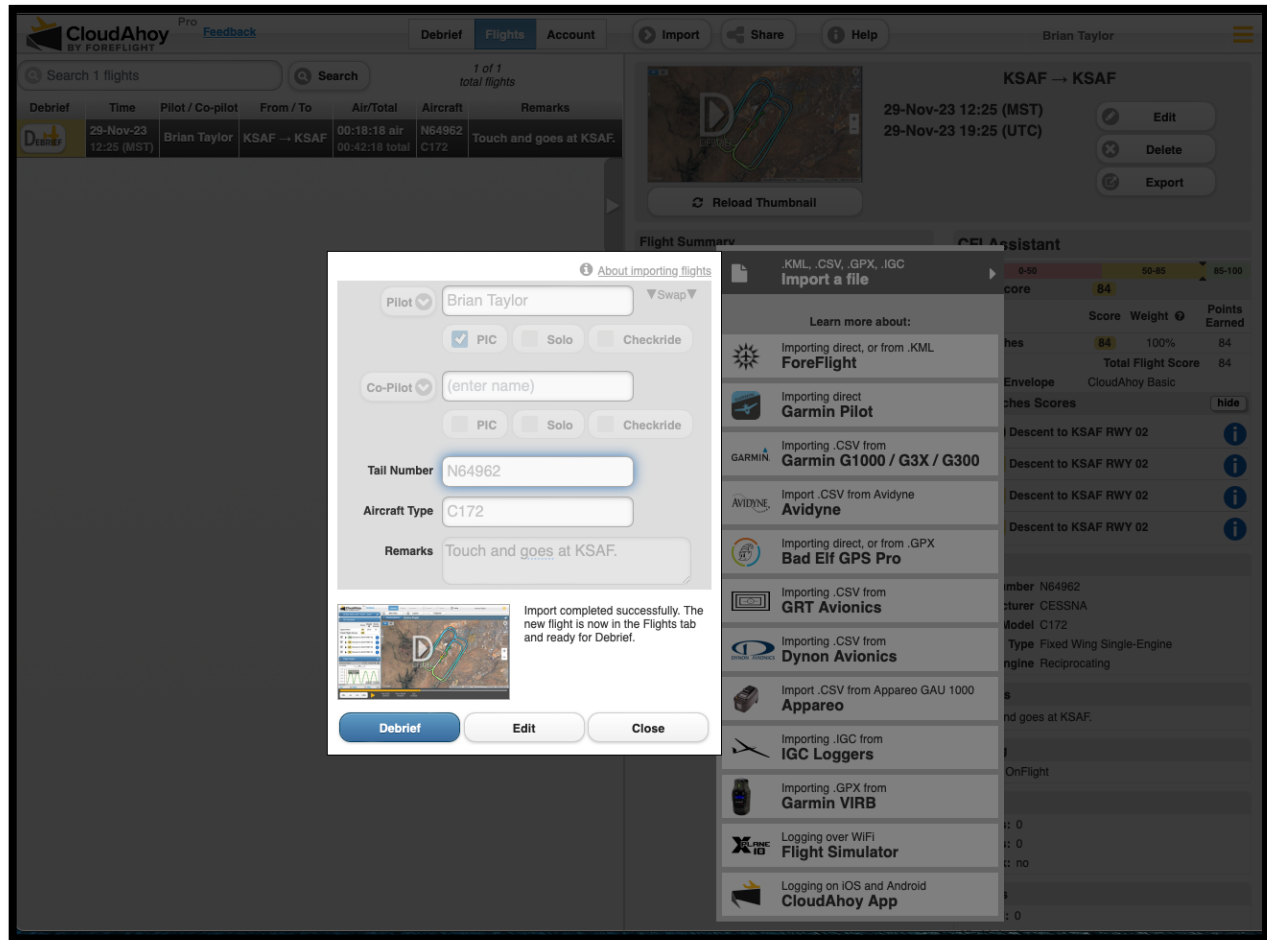
Figure 13: Importing data into CloudAhoy.

Finally, the data can be converted into a MATLAB MAT version 4 file, Figure 14. This is a binary format of all the data at the full rate and can be uploaded to MATLAB, Octave, python, and many other open-source programs for analysis. Note that, due to the nature of the MATLAB MAT file format, converting to a MATLAB file requires significantly more RAM than converting to the other formats. Additionally, the conversion process may take significantly longer to complete. The data fields follow the same naming convention as the CSV format.
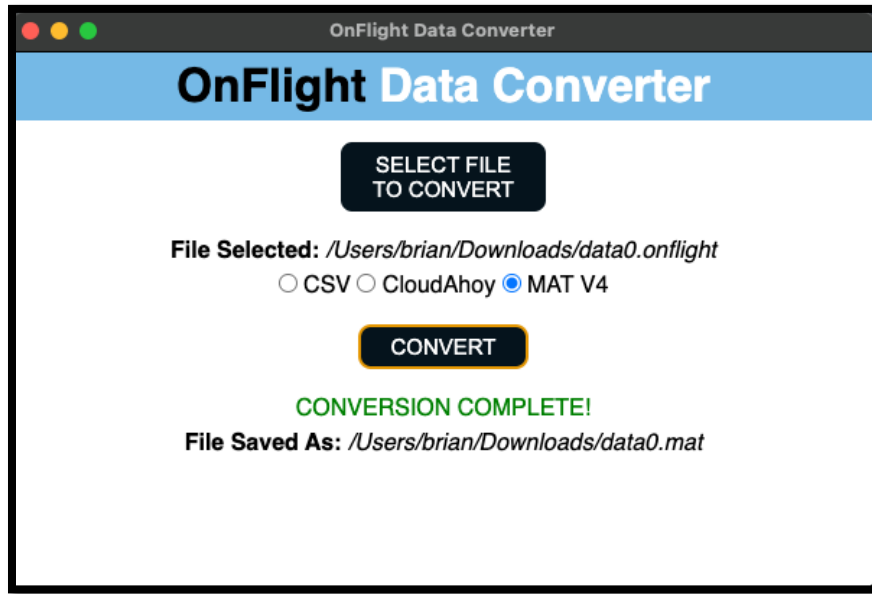
Figure 14: Converting to MATLAB MAT v4 format.

5   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