

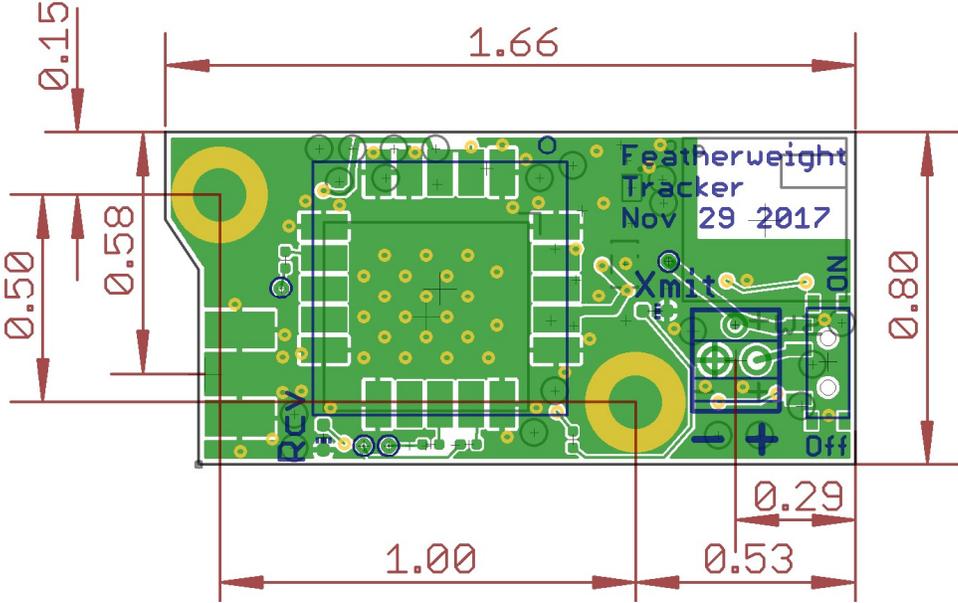
Featherweight GPS Tracker User's Manual

September 7, 2020

Hardware Configuration and Installation



The dimensions for the board are provided below, in inches. Note that with the antenna installed, the total length is approximately 4.1 inches. 4-40 screw size or the metric equivalent is recommended for mounting.



A step file is available from the [Featherweight GPS Tracker information page](#).

The GPS receiver is the large, square ceramic part shown in the first photo. To receive GPS signals properly, it needs to be clear of metallic obstructions between it and the sky. The Featherweight tracking app provides information about GPS signal strength that can be used for validating an installation.

The antenna connector is an SMA (not reversed polarity). The antenna provides the best signal strength in the direction radiating from the side of the antenna, and worst signal strength in the direction pointing down the long end of the antenna. For best results when tracking, keep your ground station antenna horizontal rather than pointed in the direction of the rocket.

Input Power

The Featherweight GPS Tracker is powered through the green screw terminal block. The recommended voltage range is from 3.4V to 4.5V. However, voltage from 3V to 9V can be used without damage. Carefully note the “+” and “-” polarity markings and follow them. The Featherweight Tracker can be damaged by reversing the power leads, though trackers built starting in April 2019 have protection against damage from brief connection of a small battery.

The recommended power source for flight is a lithium polymer, single-series battery (4.1V) with at least 150 mAh capacity. A 400 mAh battery is recommended. The Featherweight GPS Tracker consumes approximately 50 mA when not transmitting, and 90 mA when transmitting, for an average of approximately 75 mA. This current consumption is constant regardless of input voltage. If a 400 mAh battery is used, that will provide around 5 hours of continuous use. Battery voltage can be monitored from within the Featherweight tracking app.

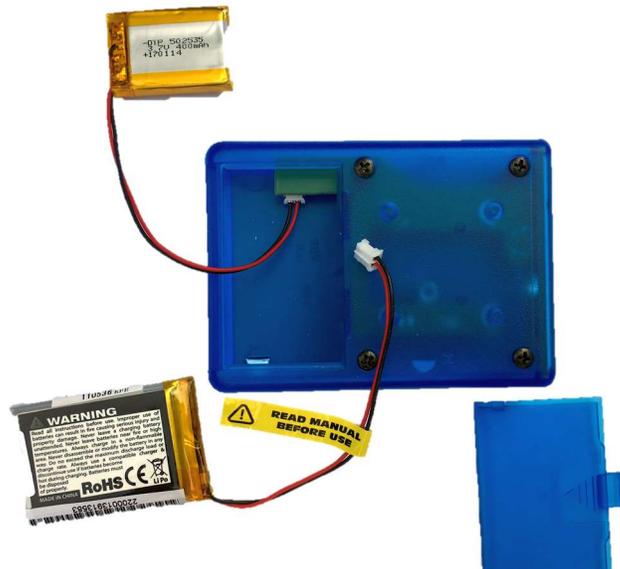
The slide switch located at the end of the board is used to turn the unit on and off. This switch is compatible with high-G flights and hard landings. However, if you would prefer to use an external switch, a wire can be soldered to a through hole via labeled “sw+” on the back side of the board as an alternative means of providing power that bypasses the slide switch and the input terminal block.

Enclosure



An optional enclosure can be purchased that provides protection for a tracker, a battery, and a battery charger. The input power for battery charging is a USB micro-B connector for a USB-compatible cable (not included) commonly used for charging cell phones or other devices.

When the battery door is removed, that provides access to the charger for other compatible batteries to be charged (see below). Compatible batteries have a JST connector with polarity shown below. Note that some batteries with JST plugs have the opposite polarity, so if you purchase a battery from a 3rd party, be sure to carefully compare the wire color to the wires on the battery that comes with the enclosure.



LEDs

The Tracker and the Ground station both have a red and a green LED, but they are used differently:

Tracker: The red LED has 2 functions: When it is quickly flashing when the unit is first turned on, that indicates that no GPS lock is available yet. After that, it turns on whenever it is transmitting, which is once per second.

The Tracker's green LED turns on when it is receiving an ack transmission from the Ground Station or from a lost rocket. Normally the Tracker and GS are in 2-way communication, but if the two units are not set to the same frequency and tracker ID, then no acks will be sent from the GS back to the tracker. If this green light is flashing, then that means that full 2-way communications are working.

Ground Station: The ground station red LED also flashes at power up until a GPS lock is acquired. After that, it flashes when it is transmitting data to other nearby ground stations for coordination. If there are no flashes except the green and red LEDs flash together once every 40 seconds, this indicates that no LoRa data has been received, and so the radio is resetting itself.

The GS's green LED turns on while data is being received from the tracker or another ground station. The length of the on-time indicates how long it is taking for the data to be received. When the GS is receiving each tracker packet, the green LED is on once per second.

For both units, the red and green LEDs will turn on briefly at power-up so you can know that power is applied and that the LEDs are working.

The Ground station has a white LED that shines blue through the enclosure to indicate when battery charging is in progress. The blue LED will turn off when the battery is nearly full and charging is complete. The charger provides approximately 300 mA to the ground station for charging and operation, so it can take approximately 7 hours to fully recharge a depleted 2000 mAh battery.

Featherweight Interface Program Phone App (iFIP)

Nov 23 2018 update: The iFIP can now be downloaded by visiting the following link, until it is available in the app store:

<https://testflight.apple.com/join/InpJx5lw>

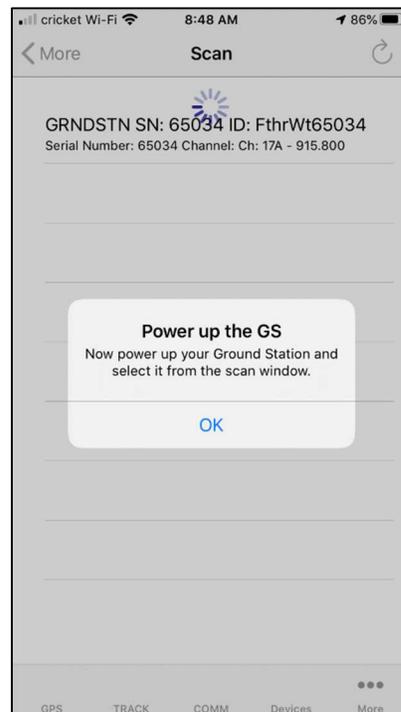
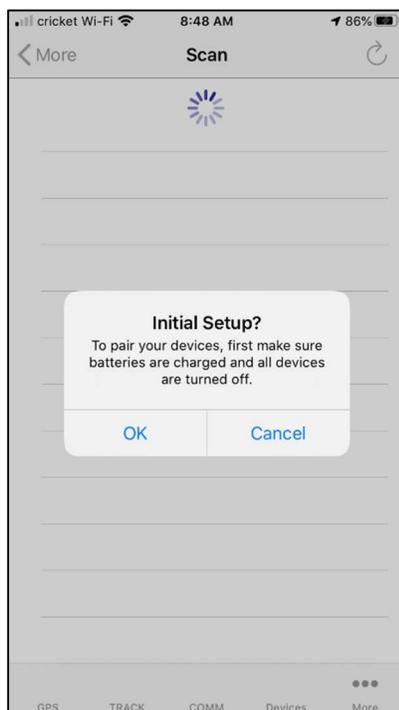
Instructions:

1. Install TestFlight app from the app store, on the iOS device you want to use
2. Click on the above link from the iOS device you want to use, to activate the TestFlight download and installation of the iFIP. The above link is also in the Featherweight Altimeters GPS website page, if you would like to navigate to it rather than typing in the above link in your iOS device.
3. Accept the conditions and continue the installation, then open the app.

The iFIP application on your phone displays data that it receives from the tracker and the ground station (GS) over Bluetooth. The first time you connect your phone to your Tracker and GS, you do this using the Scan page and the Devices page. After the setup is complete, the phone and the devices will remember each other so that they will automatically start working together once you turn them on and start the FIP.

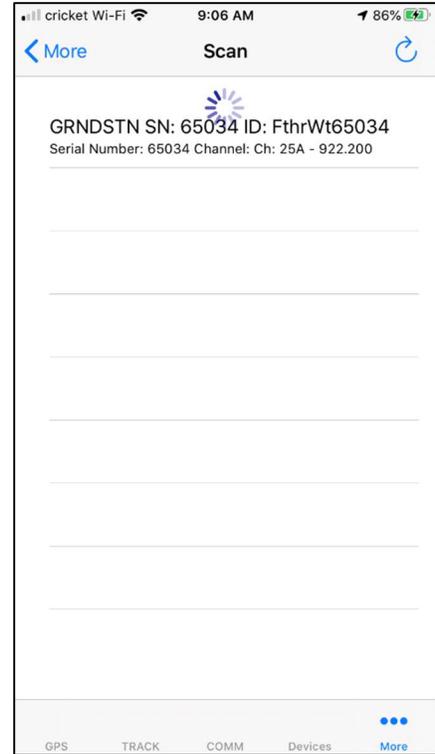
Initial Setup:

1. Make sure that Bluetooth is turned on in your phone, and start with both units off. Open the FIP and go to the Scan page. It will look like this at first:

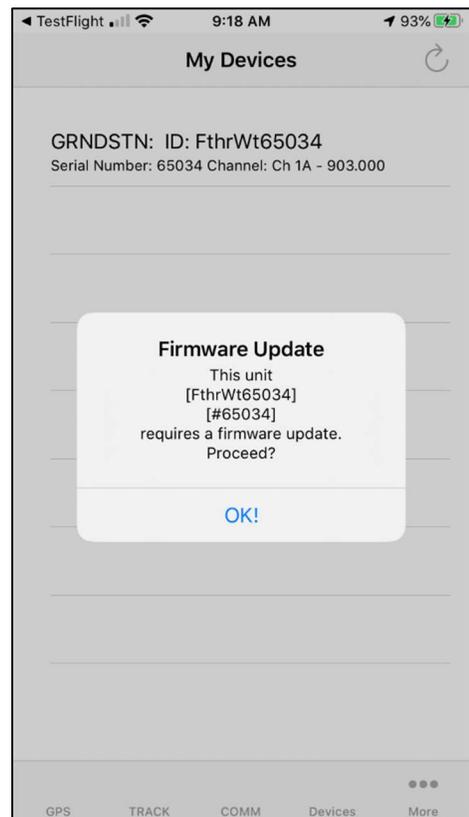


2. Press "OK" in this dialog box, and the next one.

3. Turn on the ground station, and after a few seconds it will show up in the scan list as shown on the right:

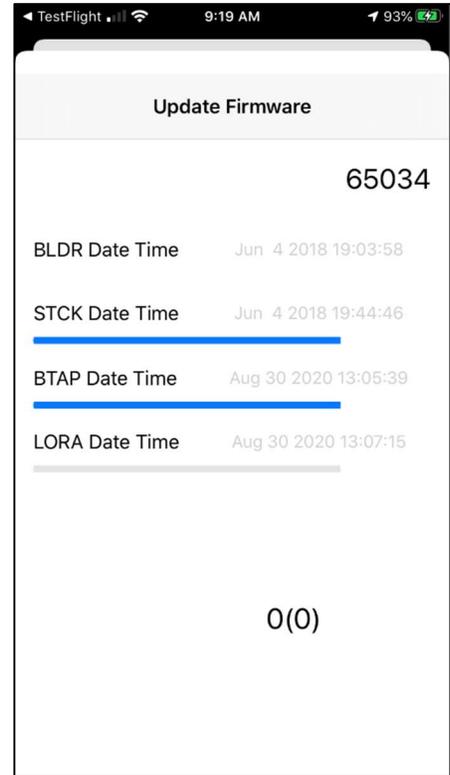


4. Select the ground station. If there is a new version of firmware that needs to be installed on the unit, the following dialog box will appear. Press OK

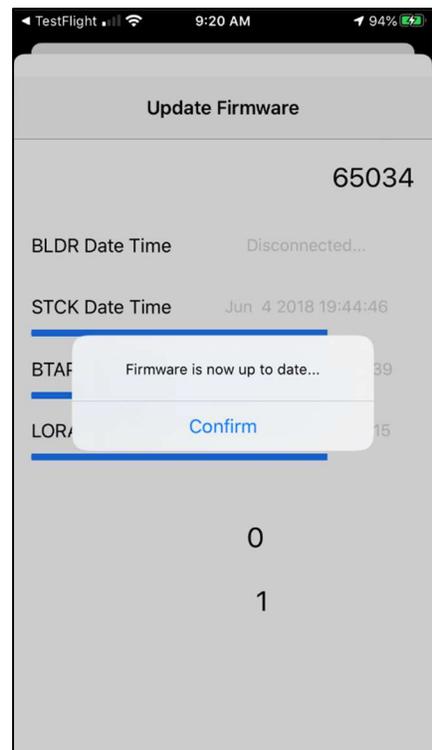


5. The phone will start uploading new firmware to the ground station or tracker, first the Bluetooth application software (BTAP), and then the firmware that controls the LoRa radio and GPS (LORA).

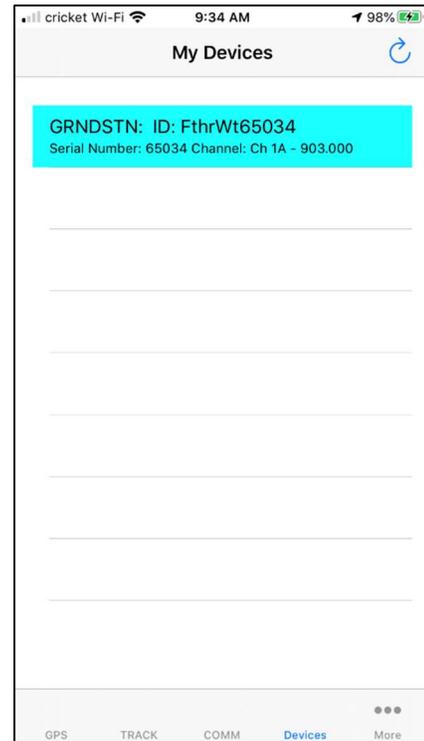
6. When it gets done uploading the LORA firmware, it will take about 20 seconds for it to verify and move the new firmware where it needs to go in memory.



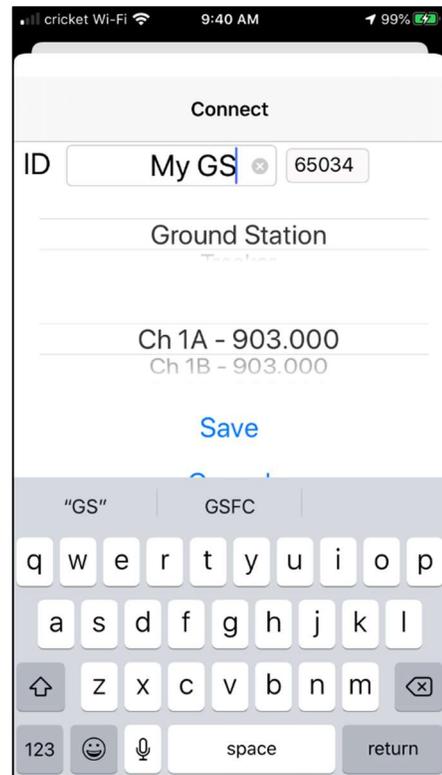
7. When that is complete, the dialog box will pop up and press "Confirm."



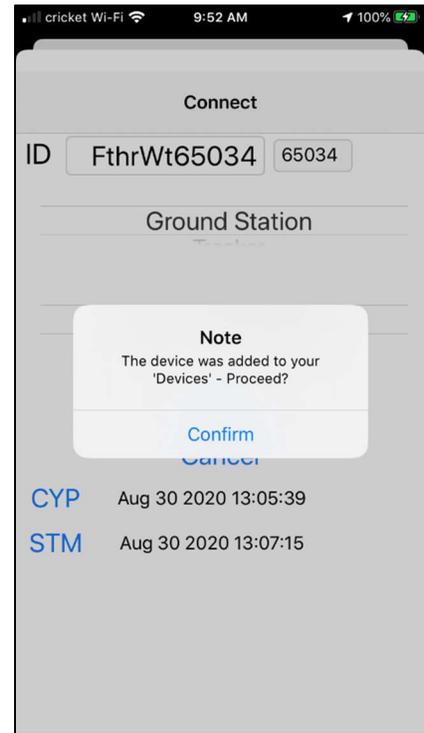
- The ground station is now in the “My Devices” list, which is always available at the bottom of the screen. The blue highlighting indicates that this unit is currently connected via Bluetooth. Click on the unit to bring up its device configuration screen:



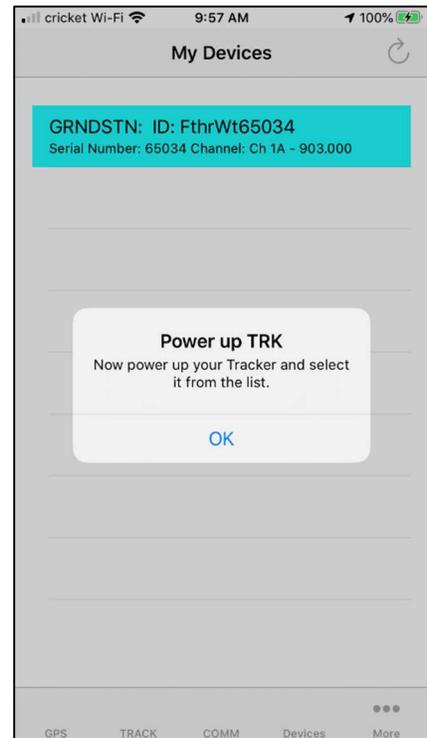
- Touch the text box to start entering your own name for the ground station, if desired. The ground station name will only be used by your phone, and it's a way to help you to identify different ground stations if you have more than one. Next to it is the device serial number, which is set in production to match the label on your unit, and cannot be changed.
- Select a channel from the rolling list. There are two channels, A and B, for each of the available frequencies. The A and the B channels work the same; they are just available to allow more Featherweight trackers to operate at the same time without interference at larger launches.
- Press “Save” to store the settings. Because of the battery-saving nature of Bluetooth Low Energy protocol, it sometimes takes a few seconds to up to a minute for the new settings to get transferred over Bluetooth.



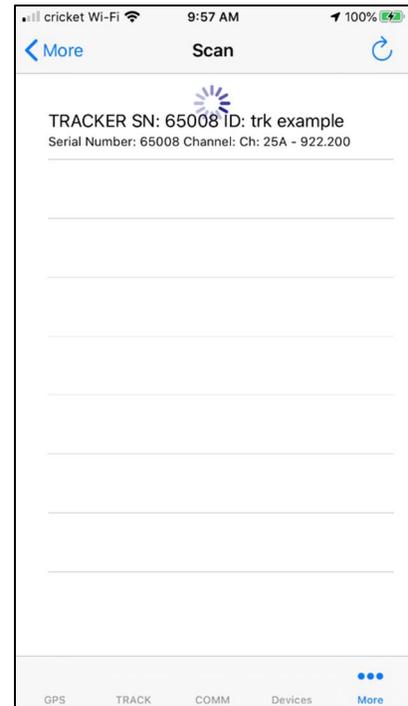
12. When the new settings have been completed, press the “Confirm” button in this dialog box, and the phone continues the setup.



13. The app goes back to the “My Devices” page and asks to continue the initial setup with the tracker. Click “OK.”



14. Turn on the tracker and it will show up in the Scan page. Select the tracker and the phone proceeds to the device setup page, updating the firmware along the way, if necessary.

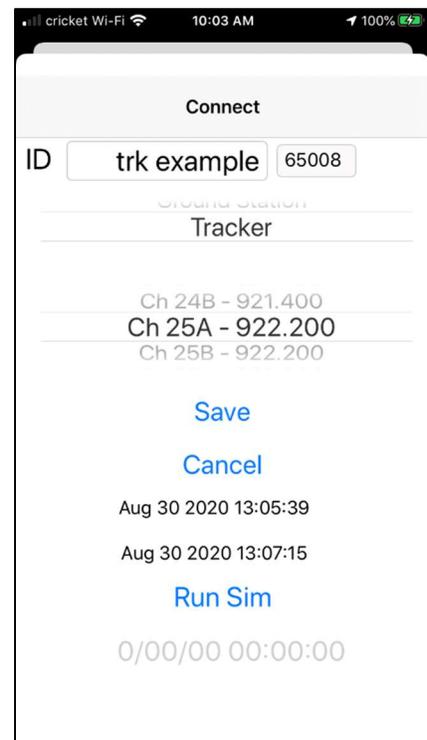


15. In the tracker setup page, the ID you enter for the tracker is important. This ID is a publicly-visible text string that uniquely identifies your tracker. You can use it to switch between different trackers installed in different rockets (or different rocket stages), and it is also what other people can use to know which frequency channels are occupied, and to tune in to track your rocket's flight on their phones. This ID can be up to 11 characters long.

16. Below the Tracker ID is an option to change your tracker to be used as a ground station. Tracker units can be used in either role, using this selection option.

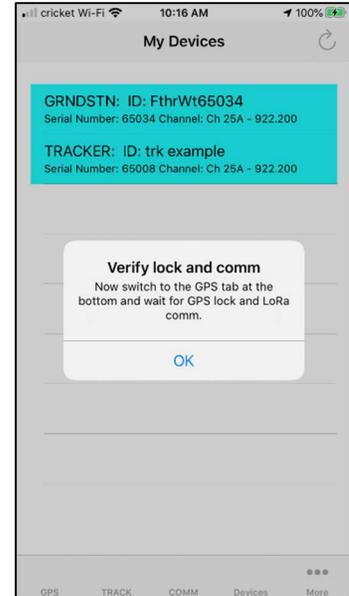
17. The frequency is set to match the ground station's frequency during the initial setup. If you would like to change to a different frequency, also change the ground station's frequency to match so that the units can communicate.

18. Press Save to continue.



19. After a few moments of saving and confirming the configuration, the initial setup shows the following screen:

Press o.k. The initial setup is now complete.



20. Click on the GPS tab at the bottom left of the screen go to the GPS screen, shown below:

Next is where you can switch your unit between the operating modes tracker and ground station. Featherweight GPS units can be changed when needed, using this selection. Start with the first unit as your tracker to follow along with these instructions.

Tracking pages:

The FIP currently has 3 pages that can be used to monitor and find your rocket:

GPS page

The GPS page is used to make sure that both units have a good GPS signal and fully charged battery before the flight. The left side shows the ground station and the right side shows the tracker.

The GS is connected to the Phone over Bluetooth. Changes to time since last contact if comm is lost.

Ground Station Altitude above sea level, in feet

Ground Station GPS Quality

Selection wheel for ground station

LoRa is connected from the GS to the Tracker. Changes to time since last contact if comm is lost.

Tracker GPS Satellites and Signal Strength

Total number of satellites tracked. Green shows that the GPS has a position fix.

Selection wheel for tracker

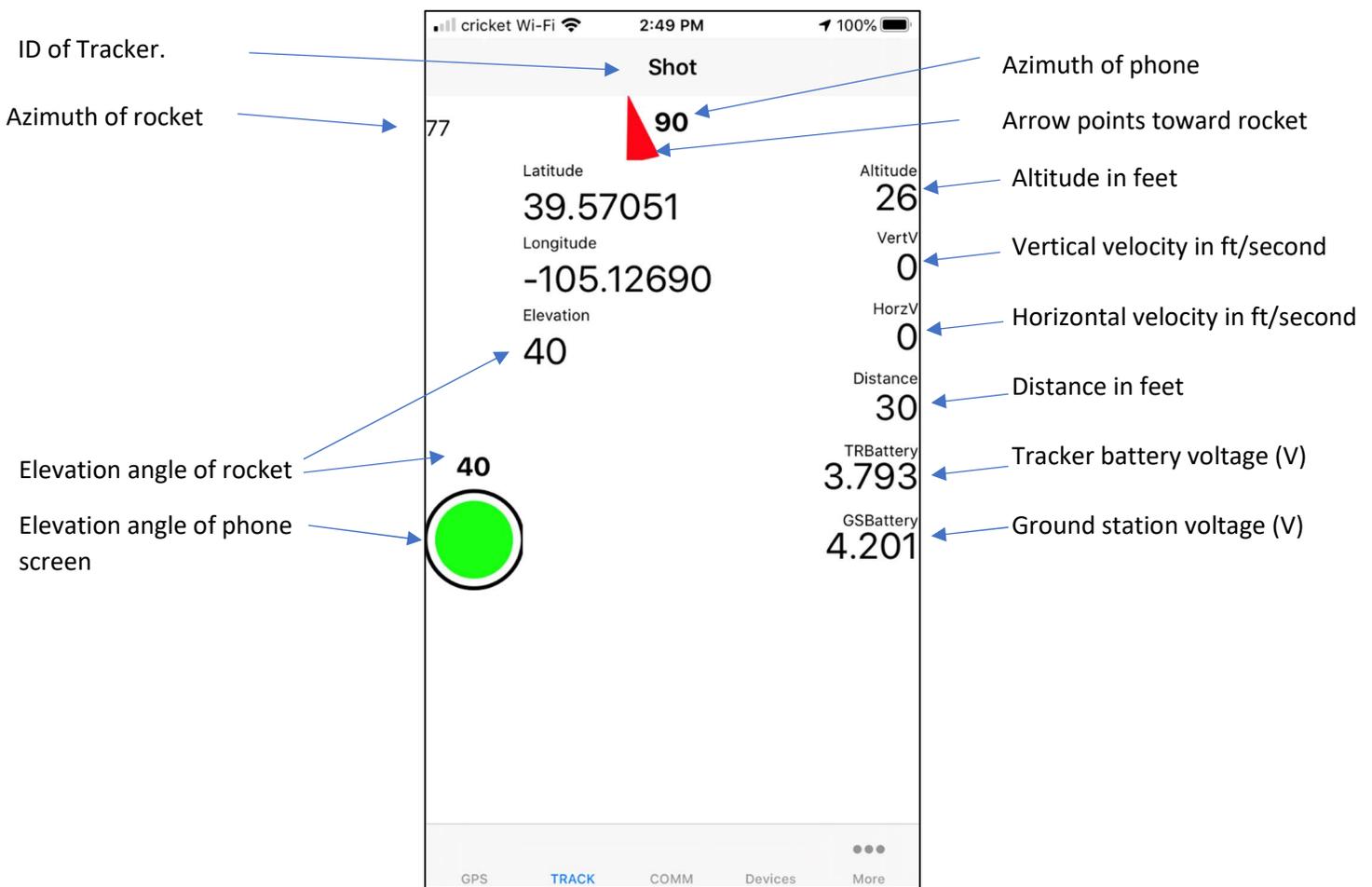
The colored bars show how many satellites are being tracked (The whole outlined box represents 24 satellites), and how strong the signal is to each satellite. The table below explains the color code.

Color bar	Signal Strength (dB-Hz)	Signal Quality
Orange	Less than 24	Weak, can result in 10s of meters horiz. error
Yellow	24 to 32	O.k. Can add small amount of inaccuracy
Green	32 to 40	Good Full accuracy available.
Blue	40 and Over	Very good. Full accuracy with margin

Both the number of satellites and how strong they are can affect how accurate the GPS solution is, and how robust it is to sudden accelerations like launch. Good GPS performance will have 10 or more satellites, with about half or more of those as green or blue signal strength. Don't worry if the weakest satellites are yellow or orange; the receiver will prioritize its stronger satellites in its solution. This graph is useful for evaluating whether your rocket materials and/or paint might be reducing your available GPS performance, for example a carbon fiber airframe. If your GPS page is showing only orange and yellow signal strengths, or no lock at all, your setup is likely to lose GPS fix at launch, and may have trouble getting a fix again after launch. This can be corrected by moving your tracker in your rocket to a location that has an RF-transparent portion of the airframe, such as cardboard or fiberglass.

Track Page

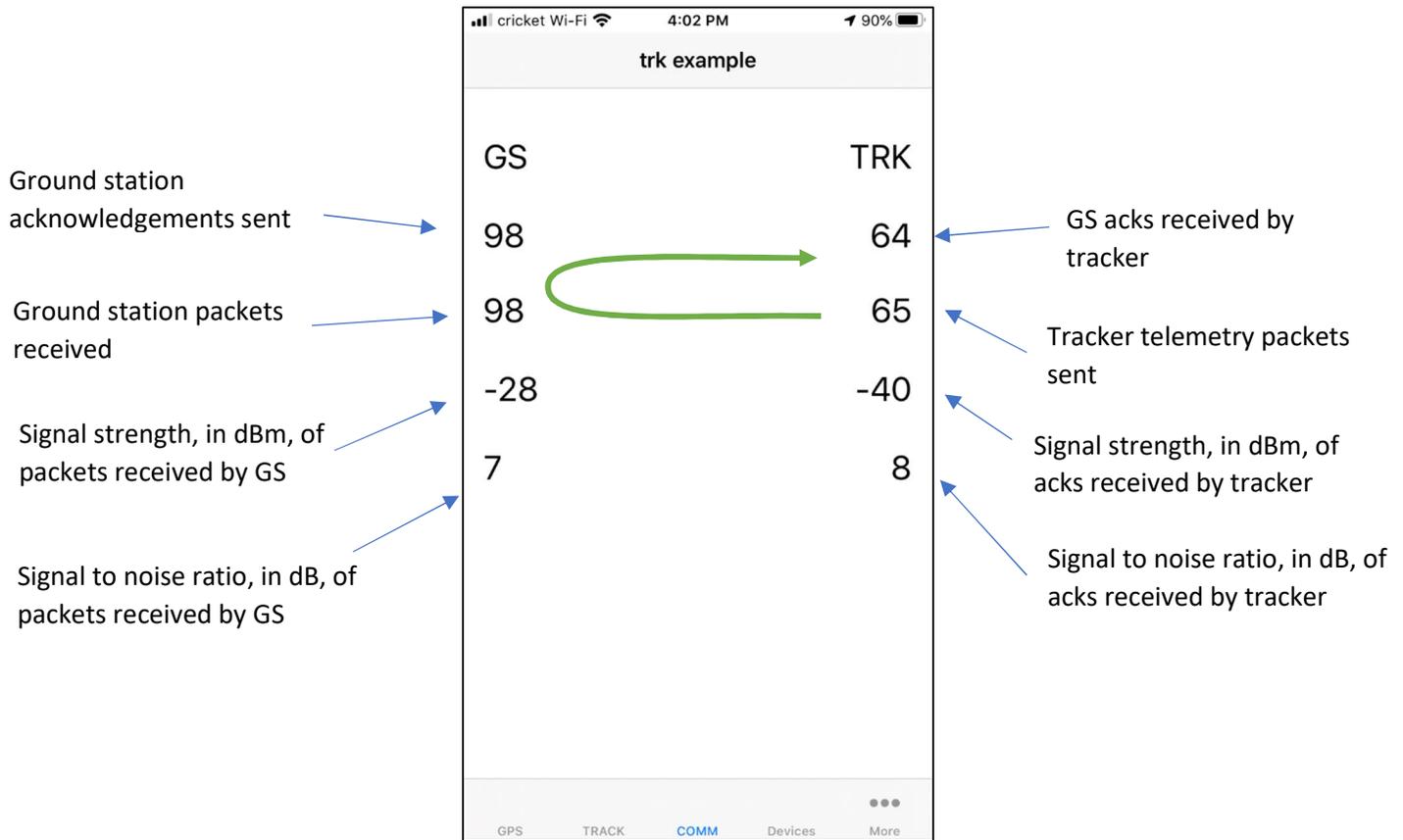
The Track page is designed to be used for tracking rockets real-time in flight.



The phone uses its built-in magnetic compass and gyroscopes to calculate how the phone is oriented, and it uses that information to generate the red pointing arrow and circle outline that are used point to the rocket real-time. For best pointing accuracy, make sure the phone is away from permanent magnets. Sometimes the iron of a vehicle can also disturb the compass function, so if spurious pointing results are seen, try again from outside the vehicle.

Comm Page

The Comm page shows information about the LoRa radio performance:



The top two lines are counters of data packets sent between the tracker and the ground station. The green arrow represents the flow in time. First the tracker sends a telemetry packet to the ground station and the GS receives it. Then the GS transmits an acknowledgement that the tracker receives. When 2-way communication is working properly, all 4 counters should increment by one count per second. If the upper right counter of tracker acknowledgements is not incrementing, that usually indicates that the GS and tracker are not configured properly for 2-way communication. In that situation, go to the devices page and ensure that both the GS and the tracker are on the same channel, and re-save each unit. Also go to the GPS page and select the desired tracker from the tracker selection wheel, if it is not selected already.

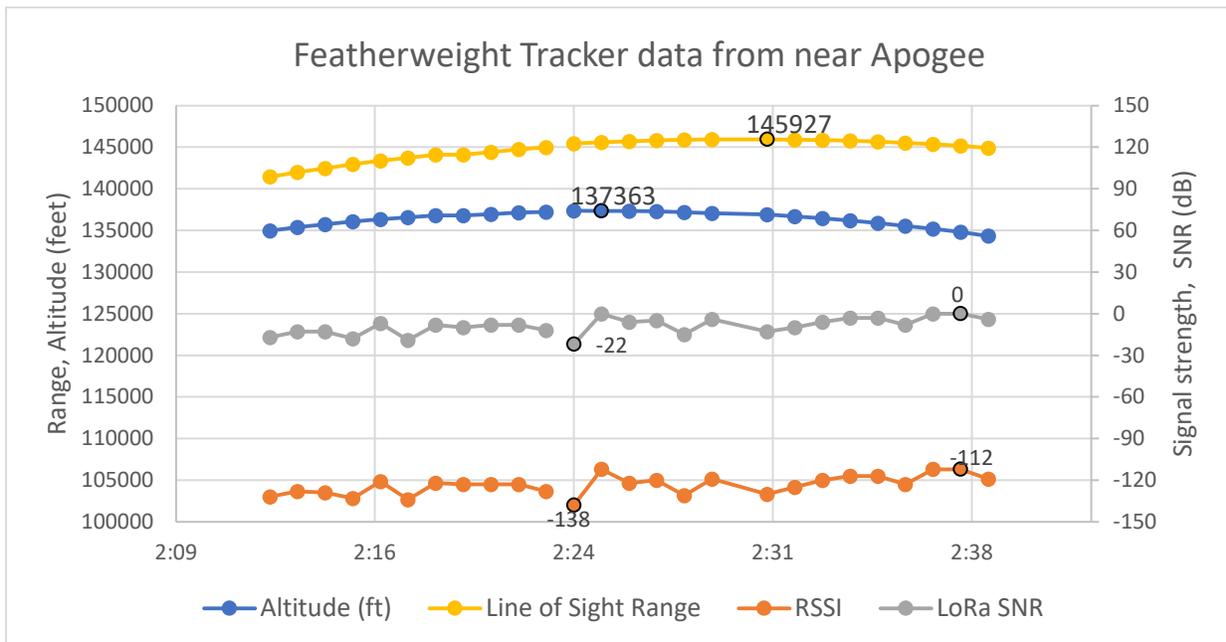
The third line is the LoRa signal strength, in dBm (decibels compared to 1 milli-Watt) so that you can compare very different values without having to deal with very different numbers. 0 dBm means your receiver is getting 1 milliWatt of received RF power. Every 10 dB corresponds to a factor of 10 in received power and square root of 10 in range. Every 20 dB corresponds to a factor of 10 in available range.

Some useful approximations:

dB	Power Factor	Range Factor
3 dB	2	1.4
6 dB	4	2
10 dB	10	3.1
20 dB	100	10
30 dB	1000	31
40 dB	10000	100
60 dB	1000000	1000

The faintest signal that the Ground station can receive is around -133 dBm, and you can use this to estimate how much range you can expect to get based on a ground test of your own rocket setup. For example, if you do a ground test with your rocket 100 feet away, you should measure a received signal strength of around -73 dBm. Since this is 63 dB stronger than the minimum signal strength of 133 dBm, you should expect a factor of 60 dB + 3 dB in received power, or 1000x range x 1.4x range to get a maximum available range of 100 x 1000 x 1.4, or 140,000 feet. If your measured signal strength at 100 feet is -67 dBm, that 6 dB improvement is a factor of 4 in power and a factor of 2 in range, for a total of 250,000 feet.

A small hand-held yagi antenna can add around 6-8 dB to this budget, which translates to a factor of 2-3 in available range. However, for the vast majority of flights, the included stub antennas are sufficient. A Featherweight GPS tracker was used to track a rocket to over 137,000 feet altitude and 145,900 feet total range in September 2017 above the Black Rock Desert using just the standard stub antennas that are included with the standard products.



Standard output power and standard stub antennas were used at both ends of the link, and the rocket installation configuration was far from ideal. Even so, the signal strength information indicated that there was still substantial margin available for even longer range, even out to the edge of space (100

Km). As long as there is a clear line of sight between you and tracker, your Featherweight GPS Tracker will have enough range to communicate. After landing, however, it is common for the signal to be lost because of terrain interrupting the line of sight. In these cases, just track to the last location and the signal can be automatically re-acquired. The Featherweight GPS system is unique in providing another way to receive your rocket's landed location, even over the horizon: The lost rocket feature which is described in the next section.

Launch Event Features

While the Featherweight GPS tracker system works great on its own, it also offers unique benefits at launch events when it automatically coordinates with other Featherweight users. This coordination takes place after each communication from your tracker to your ground station has been confirmed. The tracker transmits a packet of data to its paired ground station once each second. Then the ground station responds with an acknowledgement packet of its own back to the tracker to let the tracker know that its communication was successful. This all takes place in a fraction of a second. For the remainder of the second, the tracker and ground station both switch their LoRa radios to special dedicated frequencies used by all Featherweight users to exchange information. The tracker listens for lost rockets on a "lost and found" channel, and the ground station listens and transmits on a ground station coordination channel. Then at the start of the next second, the Tracker and Ground Station switch back to their paired communication channel.

Lost Rocket Mode

The lost and found channel is used by trackers that have detected that they are lost by the following conditions:

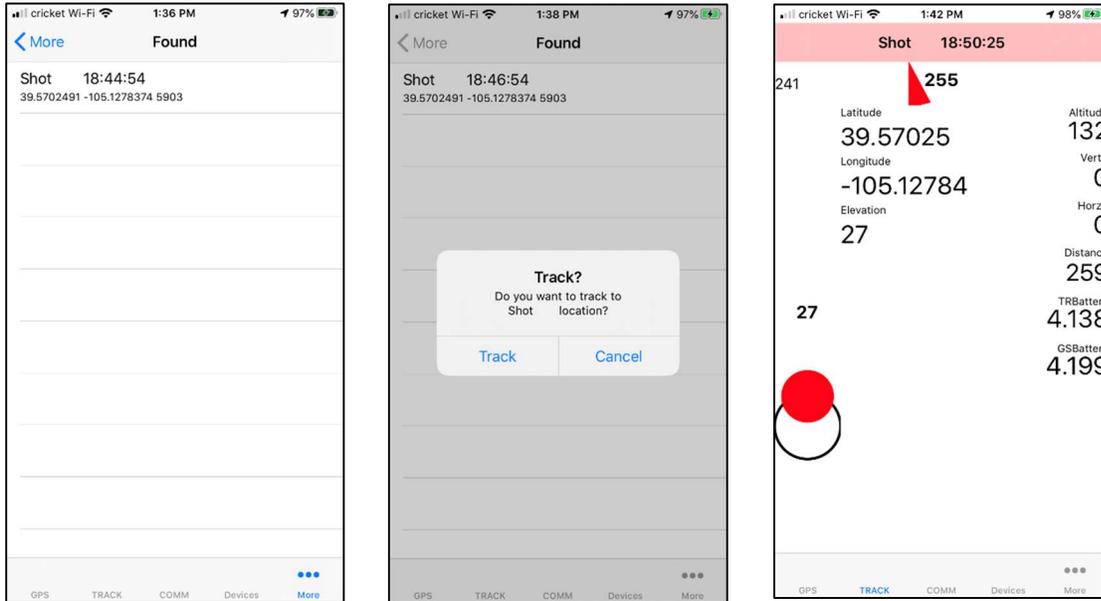
- Launch and landing are detected (see onboard data logging section)
- No ground station acks received by the tracker for 5 minutes
- No Bluetooth communication for 5 minutes

Lost trackers extend their battery life by using a special wakeup sequence. A lost tracker will wake up, wait a few seconds for GPS lock, transmit once on its paired channel, listen for a response, then transmit once on the lost rocket channel before going back to sleep. The sleep mode duration starts out at 8 seconds, and gets progressively longer as time goes on, up to about 1 minute after a day.

As an example, let's say you launch your rocket and it lands over a ridge, where no direct communication back to your ground station is possible. 5 minutes after landing, it will start transmitting on the lost and found channels. When another Featherweight user launches their rocket, it will quickly get high enough to have a direct line of sight to your rocket, and it will easily be able to receive your lost rocket's location. Then it sends all of its normal data together with the lost rocket location and other information back to its ground station. The ground station transmits this information back to the other Featherweight ground stations, at the launch site, including yours!

You can access this relayed data by going to the More/Found page, where each found tracker's LoRa ID is listed, along with the Lat/Lon, elevation, and how long ago the last data was received from that tracker. If you select your found rocket, you will get a dialog box asking if you want to track to that location. If you click "Track", then the found rocket will show up in the devices list and in the selection

wheel of trackers on the GPS page. Below left: A found rocket shows up in the More/Found list. Below middle: After selecting the found rocket. Below left: tracking to the found rocket.



Monitoring Other Rockets (future feature)

The ground stations also send ground station coordination packets to other ground stations periodically to let all ground stations in the area know which channels are being used. In future phone releases, this information will be used to show a list of other rockets at the launch so that you can follow along and monitor your friend's flights or that big high altitude project on your own phone.

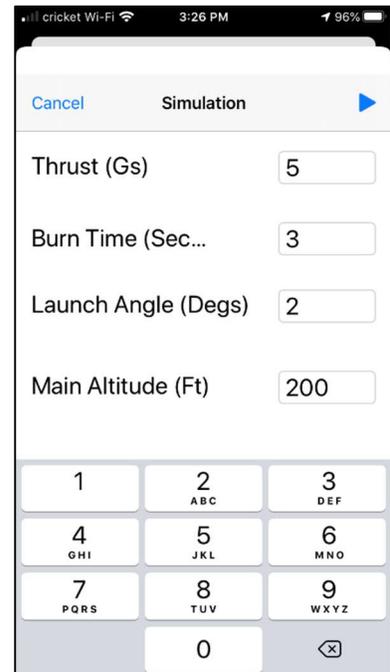
Spoken Telemetry

The Featherweight GPS Tracker phone application provides live spoken updates for the telemetry throughout the flight. During ascent, the altitude is spoken as the rocket passes through round-number altitudes. The apogee altitude is also spoken. During descent, the altitude and velocity are both spoken, so that you can tell without looking at the phone whether deployments were successful. A variety of voices and accents are available to choose from under More/Settings. Be sure to take your phone out of silent mode in order to use this feature. You can try out this feature before launch day using the simulated Flight capability

Simulated flight

A sophisticated simulated flight feature allows you to try out almost all of the Featherweight GPS system features before launch day, including real-time telemetry, spoken telemetry, and data logging. To simulate a flight, select a tracker from the devices page and click the “Run Sim” button. In the example on the right, a simulation of a flight with 5 Gs of thrust, a burn time of 3 seconds, and a launch angle of 2 degrees was selected. Press the play arrow in the upper right corner to start the simulation.

The simulation runs within the tracker, and the tracker and the rest of the system respond as if the flight were real. Flight telemetry is spoken, real-time data is updated in the pages, and flight data is recorded onboard the tracker and within the ground station. The simulation incorporates a 2-dimensional dynamics model, with aerodynamic drag, that assumes one ballistic coefficient for launch to apogee, a lower ballistic coefficient consistent with drogueless descent, and then a final, lower coefficient that transitions at the main altitude and is consistent with a parachute descent. As a special case, a ballistic flight can be simulated by leaving 0 for the main altitude. This disables the simulated apogee and main chute deployments. The launch angle has positive angles toward North, and negative angles toward South, to simulate horizontal velocity.



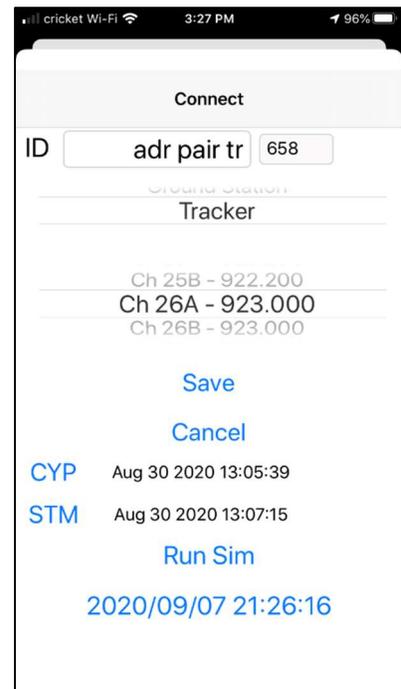
Data Logging

The Featherweight GPS Tracker detects launch automatically, and logs data internally from the ascent at 10 samples per second, and then after apogee, switches to 1 sample per second during the descent. This internal data records up to 6144 samples from the flight.

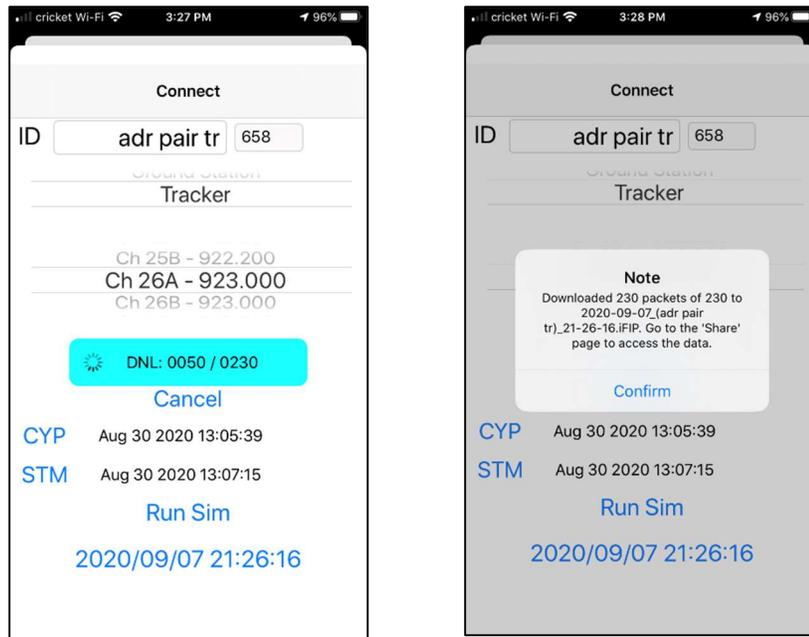
Due to storage limitations within the tracker, only the most recent flight is recorded. After landing, no new flights are recorded until either the data download is complete, or the tracker has its power cycled. The storage space used for the flight data is also used for the firmware update process, so be sure to download flight data before a new firmware update may need to be installed.

The tracker uses a sophisticated algorithm to detect both launch and landing from the GPS data, which is tolerant to potential dropouts in the GPS fix during high performance flights. Only data with a valid GPS fix is recorded in the internal data storage.

To download the internal recorded data after the flight, go back to the tracker device page, and at the bottom, the date and time of liftoff of the recorded flight is shown. Click on that date/time, and the download of the data will begin.



The following screen shots show the download in progress and then when it completes:



The flight data logging is approved by Tripoli records committee for use in Tripoli altitude records. It includes the following data:

- UTC Time
- UNIX Time
- Altitude (ASL, Feet)
- Latitude
- Longitude
- Total number of satellites
- GPS location fix flag
- Horizontal velocity (feet/second)
- Vertical velocity (feet/second)
- Heading (degrees from North)
- GPS quality flags
- Number of GPS satellites with > 40 signal strength
- Number of GPS satellites with > 32 signal strength
- Number of GPS satellites with > 24 signal strength
- LoRa radio signal strength of ground station ack packets
- Tracker battery voltage

Note: If the download seems fails to progress to completion, force-quit the Featherweight phone application, power-cycle the tracker, and then re-start the app.

Troubleshooting

Units not seen in device list or scan page

1. Make sure that both units are powered (verify by watching for LEDs)
2. Verify that the phone's Bluetooth is on (look for the black Bluetooth icon in the upper right of the screen)
3. Look for a device in both the device list and the scan page

Units show up on device list but there's no tracker data

1. Make sure that both units are on the same frequency, and have the same TrackerID
2. Make sure both units have antennas connected
3. Make sure that one unit is set to be a ground station and the other is a tracker
4. If the ground station is showing green flashes approx. once per second, the LoRa data link is working, so verify the BlueTooth (see above)

Units are communicating (packet counts increasing in comm window) but the GPS information is grayed out

1. The GPS receiver is not getting an adequate signal. Move objects away from the antenna and move to an open location with a clear view of the sky.
2. GPS acquisition can take up to a minute in good signal conditions, or several minutes in a location without a good view of the sky.