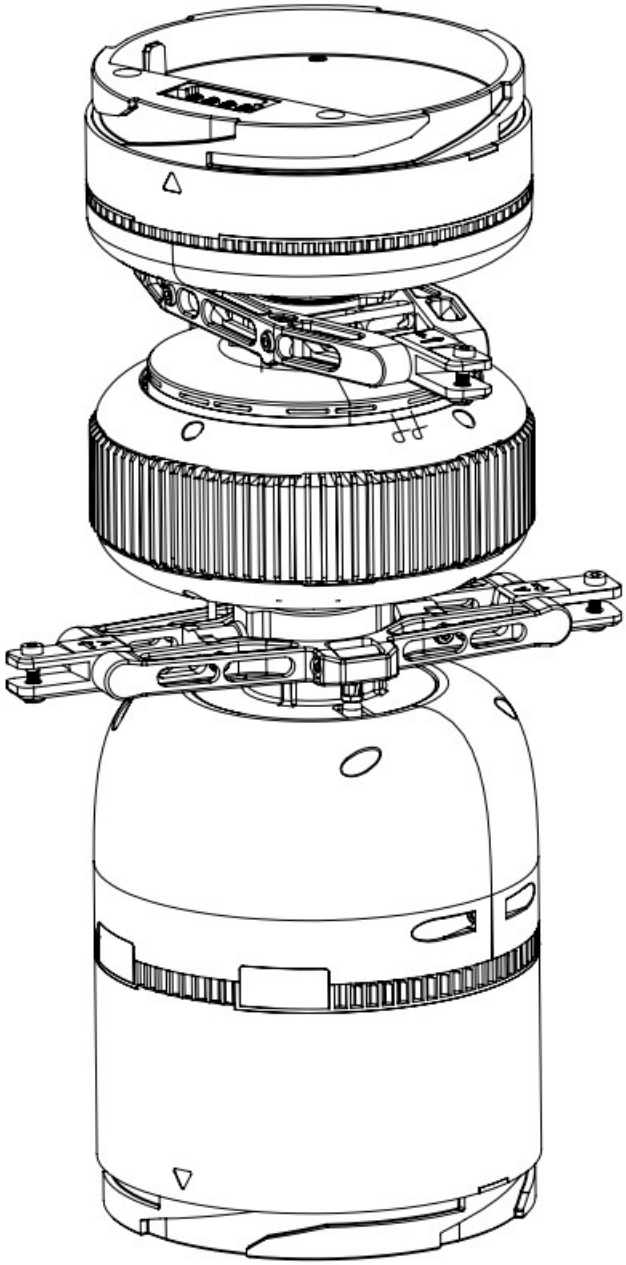
ASCENT AEROSYSTEMS



# AIRCRAFT FLIGHT MANUAL

## SPIRIT (MODEL K257)

UNMANNED AERIAL VEHICLE

REVISION 2.1.0

This document may contain technical data that is subject to the U.S. Export Regulations (15 C.F.R. Sec. 730)

## WARNINGS AND CAUTIONS

**OPERATOR EXPERIENCE AND TRAINING**. This product is a high performance unmanned aerial vehicle intended for use by experienced operators only. Read and understand this flight manual before operating. Seek help from a qualified instructor. Training services for this system are available upon request.

**FLIGHT MANUAL CONTENT.** This Aircraft Flight Manual describes the product as it was manufactured. It is a highly configurable system, and Ascent AeroSystems has no way of knowing the status of the aircraft after it has entered service with the Operator. For this reason, the operating procedures and information provided in this manual may no longer be accurate for the modified aircraft. Note that the procedures provided in this section do not apply to accessories or products manufactured by other parties. Refer to the information provided by the OEM for each product, and contact Ascent AeroSystems at support@ascentaerosystems.com.

**CARE AND MAINTENANCE**. The Operator is advised that this product, like all unmanned aerial vehicles (UAVs), is a mechanical device and requires routine care and maintenance during normal operation. Operator, not Ascent AeroSystems, is responsible for maintaining the product and all related components and accessories, and for ensuring that it is in airworthy condition before each flight. At a minimum, Operator must care for the product in accordance with Ascent AeroSystems' instructions. This product may become inoperative from time to time in normal use. If it is malfunctioning in any way, Operator must not use the malfunctioning device and contact Ascent AeroSystems prior to further operation.

**ASSUMPTION OF RISK**. THE NORMAL AND ROUTINE OPERATION OF UAVS INVOLVES RISKS OF BODILY INJURY, PROPERTY DAMAGE, AND ECONOMIC DAMAGE TO CUSTOMER AND TO OTHERS, EVEN IF THE OPERATOR EXERCISES DUE CARE AND FOLLOWS OEM INSTRUCTIONS. OPERATOR KNOWINGLY AND VOLUNTARILY ASSUMES THESE RISKS AND CONSEQUENCES AND THE CONSEQUENCES THEREOF.

The following conventions are used in this document:

| WARNING |
| --- |
| MEANS THAT IF THE WARNING IS NOT HEEDED, DEATH OR SERIOUS INJURY MAY RESULT. |

| CAUTION |
| --- |
| Means if the precaution is not taken, property damage or injury may result. |

Spirit UAV export control classification number (ECCN): 9A012

# SECTION 1: SYSTEM INTRODUCTION

## APPLICABILITY

This Aircraft Flight Manual is applicable to Ascent AeroSystems Spirit Model K257.

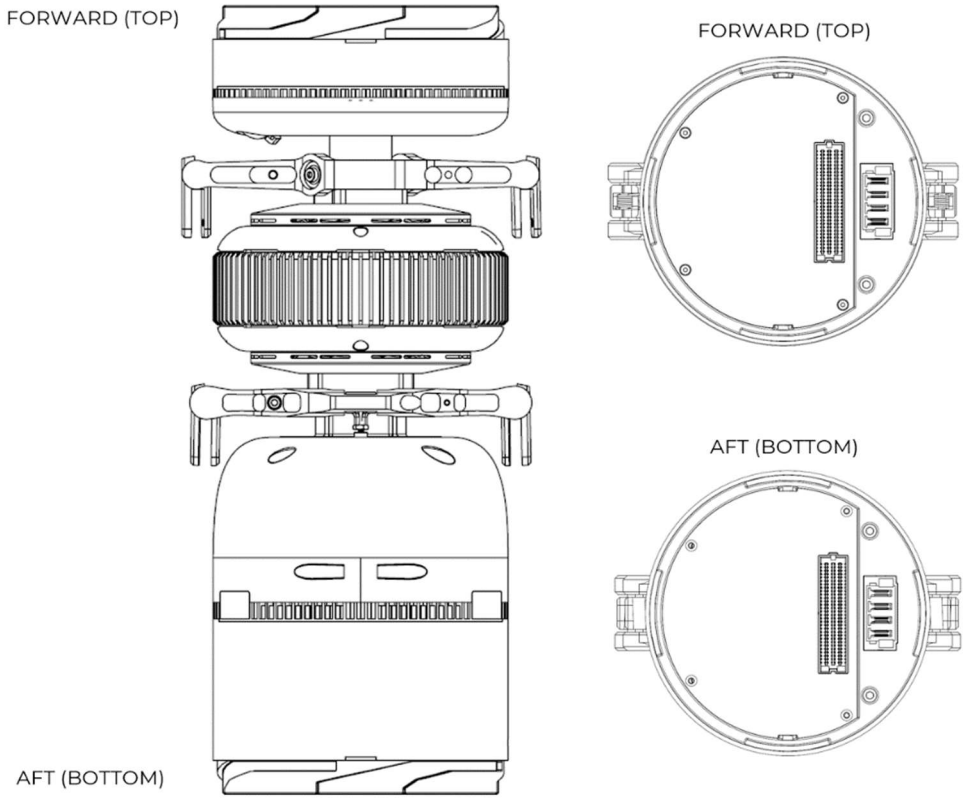



*Figure 1: Spirit Aircraft Core*

## INTRODUCTION

Spirit is the world's first commercial grade coaxial small unmanned aerial vehicle (sUAS). It is designed to be portable and rugged, with features that make it ideal for operation in remote areas where a conventional multirotor is impractical. It is also an open and flexible platform ideal for system developers.

### Summary of Components

At the heart of Spirit is the Core, pictured in Figure 1. It contains all the components needed for controlled propulsive flight. Batteries and other accessory modules are then attached to the Core to build the complete flight system. In most flight configurations one or two battery modules are attached as well as a GPS lid and a payload module with integrated landing legs. Some flight configurations may also include an external radio module or a module that houses additional navigation sensors.

The Spirit also requires a ground control station (GCS) used by the pilot to direct the Spirit's flight and monitor the Spirit's telemetry data. The GCS has both a hardware and software component and the Spirit is generally agnostic to either.

This modularity creates a large variety of configurations which can affect the details of how Spirit is operated. Therefore, this manual focuses on principles of operation that are common across Spirit configurations. Details on accessory modules, GCS hardware and software, and other configuration specific components, are provided in the Supplements to this manual. A Supplement will detail that component's integration into Spirit, but complete information for many of these systems is available only through their respective OEMs.

| CAUTION |
| --- |
| The information provided in this document related to third-party products is not comprehensive and is not sufficient to ensure safe operation. Operators should refer to the OEM's documentation before operating aircraft integrated with 3rd party equipment. |

## SPIRIT CORE

The Core is the heart of the Spirit sUAS. It houses all the essential components for flight such as rotors, motors, speed controllers, servos, and flight computer. In some configurations the Core may also contain a radio for communication with the GCS.

### Core Orientation

While it appears symmetric, the Core does have a front and back and a top and bottom. Knowing its orientation is important during setup, flight, and maintenance. There are several features visible on the Core that indicate its orientation while it is powered down.

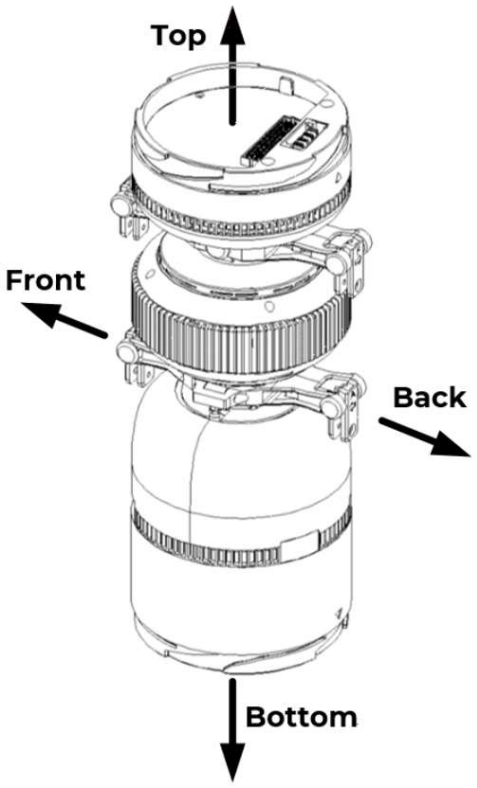



*Figure 2: Core Orientation*

Front-Back

- Data and power connectors are biased towards the Core's back.
- The Core's power button and USB port are on the back of the Core.

Top-Bottom

- The top section of the Core is shorter than the bottom section.
- The Core's power button and USB port are on the top section of the Core.
- Only Spirit's bottom rotors have links connecting to the swashplate.

## Power and Data Connectors

On the top and bottom interfaces of the Core is a 50-pin data connector and a 4-position battery power connector. The power connectors allows a flight battery to be installed on either side of the Core. The data connectors allow payloads and accessories to communicate with each other and the Core's flight computer.

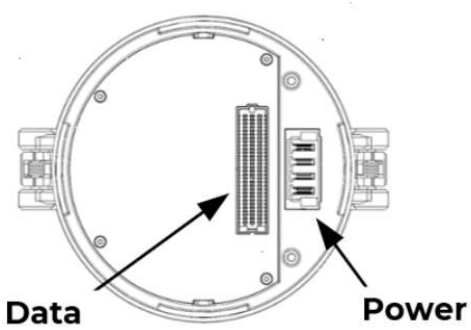



*Figure 3: Data and Power Connectors*

## Power Button and USB

Spirit's primary power button is located just above the Spirit's top rotor on the back and underside of the top section of the Core. Pressing and holding this button for approximately 3 seconds will power on Spirit if a flight battery is mated to the Core. To power off the Core, press and hold the button for another 3 seconds.

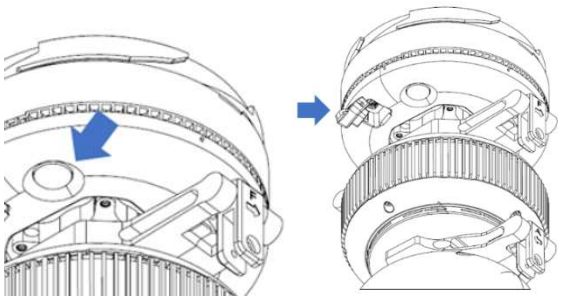


*Figure 4: Location of Power Button and USB Plug*

Next to the Core's power button and behind a rubber water-proof plug is the USB port. The USB port is connected directly to the flight computer and is used to flash updated firmware to Spirit, to access stored logs and to connect to various GCS software packages used to configure and troubleshoot the aircraft. Connecting to the USB port will power the aircraft's flight computer and LEDs, but accessories located outside the Core will not be powered. If a radio has been integrated into the Core, it will also not power.

LEDs

The Core has four high intensity LEDs that are intended to provide help with orientation during setup and flight. Additionally, these LEDs will flash patterns to indicate events such as flight mode changes and failsafe states. The table below provides a summary of Spirit's flash patterns meanings.

| **LED COLOR** | | **FLASH** | **MEANING** |
|---|---|---|---|
| **FORWARD** | **REAR** | | |
| **DISARMED (ON GROUND)** | | | |
| YELLOW | YELLOW | Flashing | Spirit Powered, no GCS connected |
| -- | BLUE | Flashing | Spirit Powered, GCS connected, no GPS lock |
| -- | GREEN | Flashing | Spirit Powered, GCS connected, GPS lock |
| YELLOW & BLUE | YELLOW & BLUE | Rapid flash | Arming sequence initiated, no GPS lock |
| YELLOW & GREEN | YELLOW & GREEN | Rapid flash | Arming sequence initiated, GPS lock |
| - | GREEN | Rapid flash | Enhanced GPS lock (SBAS) |
| **ARMED (IN FLIGHT)** | | | |
| WHITE | BLUE | Steady | Armed, no GPS lock |
| WHITE | GREEN | Steady | Armed, GPS lock |
| **TRANSIENT MESSAGE: ARMED (IN FLIGHT)<br>Message will appear then disappear** | | | |
| RED | RED | Double flash | Arming failed |
| GREEN | GREEN | Double flash | Flight Mode change successful |
| YELLOW | YELLOW | Double flash | Flight Mode change failed |
| BLUE & YELLOW | BLUE & YELLOW | Flashing | GPS Glitch Alert |
| **FAILSAFE MESSAGE: ARMED (IN FLIGHT)<br>All 4 LEDs rapid flashing** | | | |
| YELLOW | YELLOW | Flashing | Low or Critical Battery failsafes active |
| YELLOW | WHITE & YELLOW | Flashing | Loss of GCS Link failsafe active |
| YELLOW | RED & YELLOW | Flashing | Navigation Failure failsafe active |

## Rotor Blades

The Spirit Core spins a pair of coaxial rotors for propulsion. When viewed from above, Spirit's top rotor spins counterclockwise (CCW) and its bottom rotor spins clockwise (CW). While all of Spirit's rotor blades look identical, they are not. The top and bottom blade sets are mirrors of themselves and must not be installed on the wrong rotor.


*Figure 5: Spirit Rotor Blades*

To aid in blade installation, a small arrow is cut just above each blade's attachment point to the Core. These arrows show the direction the rotor will rotate. When installing blades, the blade's leading edge must be pointed in the direction of the arrow.

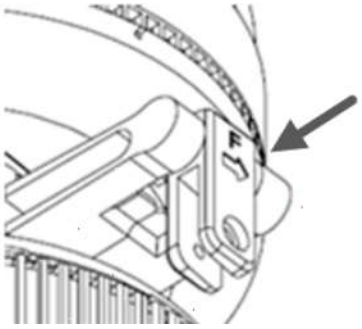


*Figure 6: Rotor Direction of Spin Marking*

| CAUTION |
| --- |
| Rotor blades are provided as pairs which are balanced to each other. Only a balanced pair should be installed on Spirit's rotors. If a propeller blade is damaged both blades in the pair must be replaced.<br><br>Pairs should not be split up and mixed with other blades. Operators should mark pairs to prevent mix-ups. |

## CLICK-RING INTERFACE

The Spirit Core and its modules attach using a common interface designed to ensure positive mating with minimal opportunity for misalignment. On one side of this interface is a rotating **locking ring**. The locking ring has an OPEN position and a LOCKED position. In the OPEN position, the locking ring can mate with other modules. On the other side of the interface is a **threaded ring** with no moving parts. The Core has threaded rings at both ends to accept payloads. These interfaces are shown in Figure 7.

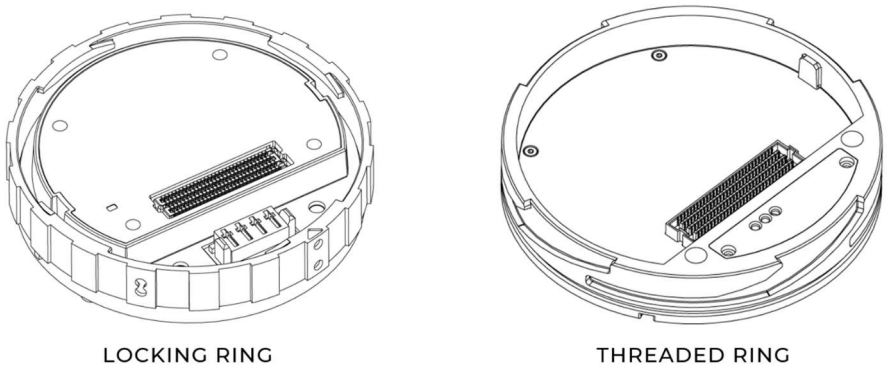



*Figure 7: Locking and Threaded Rings*

To connect modules:

1. Inspect mating connectors for debris or bent pins prior to connecting. Avoid placing unconnected mating ends of the Core, batteries, and payloads on dirty surfaces where debris can get into the connectors.

2. Inspect the locking ring for cracks, breaks or damage. Ensure the gasket is properly seated within the locking ring.

3. Ensure the locking-ring is open by turning it until the two separated (OPEN) indicator dots are centered on the alignment arrows (▲▼ symbols). See Figure 8 below.


*Figure 8: Locking Ring in the Open and Locked Positions*

4. Align the connectors and mate the modules. They should settle into each other.

5. **Twist just the locking ring** so that the two joined (CLOSED) dots are centered on the alignment arrows (▲▼symbols). Note the positive detent “click” in the locked position.

6. Verify that the connection is secure by visually checking that the gap between modules is uniform around the entire circumference and that there is no play between modules when flexed.

| CAUTION |
| --- |
| Only turn the locking ring when mating modules. Do not twist modules relative to each other. |

| WARNING |
| --- |
| THE THREADED RING AND LOCKING RING THAT FORM THE QUICK-CONNECT ATTACHMENT POINTS BETWEEN THE CORE, BATTERIES AND MODULES ARE STRUCTURAL COMPONENTS AND ARE THEREFORE CRITICAL FOR VEHICLE INTEGRITY. DAMAGED COMPONENTS OR IMPROPER CONNECTION MAY RESULT IN AN IN-FLIGHT SEPARATION OF MAJOR VEHICLE COMPONENTS THAT WILL RESULT IN A LOSS OF CONTROL AND CRASH. CAREFULLY ENSURE THE INTEGRITY AND PROPER FUNCTIONING OF EACH CONNECTION BEFORE FLIGHT. |

## SYSTEM ASSEMBLY

A Spirit system can be assembled for flight in many ways but all setups share some commonality. The image below shows a typical setup for a Spirit. A single flight battery is installed on its top interface. A payload module with integrated landing legs is attached to the Core's bottom interface and at the very top of the vehicle is a GPS lid. If a second flight battery were used, it would be installed on the Core's bottom interface between the Core and the Payload module.

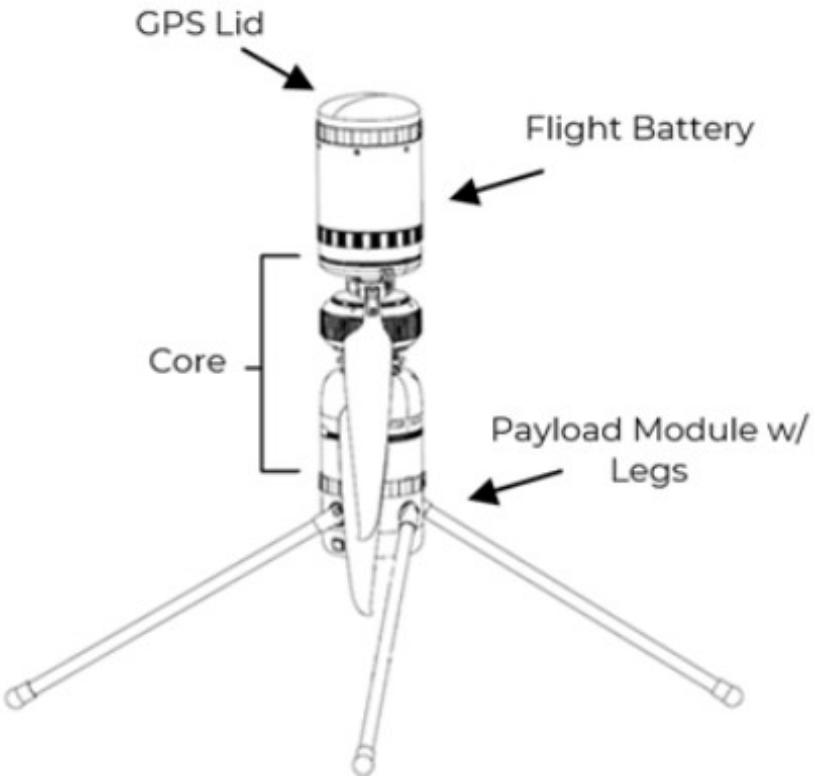



*Figure 9: Assembled Spirit*

## Attaching Batteries

All configurations will have at least one battery module. If using a single battery, it will typically be attached to the Core's top interface.

If two batteries are used, they should be attached with one mated to the top interface of the Core and the other to the bottom. Batteries cannot be stacked or daisy-chained together and batteries cannot have other modules between them and the Core.

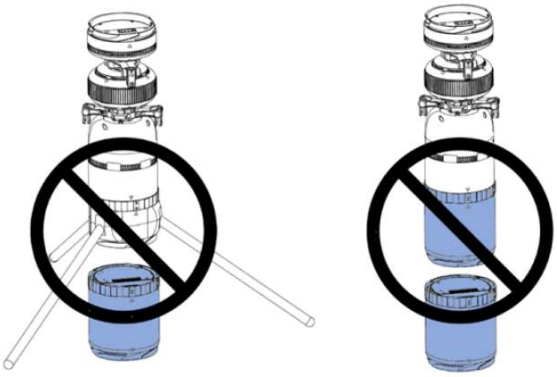


*Figure 10: Incorrect Battery Placement*

If two batteries are used, they should be of similar charge levels. Never connect a charged battery onto a Core if a depleted battery is still attached.

| CAUTION |
| --- |
| If flying with a single battery, it must be installed on the Core's top interface unless a top mounted payload requires the battery to be installed on the bottom interface to meet the Spirit Center of Gravity requirements (see SECTION 8: ). |

## Payload Modules

There are two types of payload modules: terminal and intermediate. Terminal modules only have a single click-ring interface and as the name implies, they are only installed at the ends of the Spirit system. Intermediate modules have interfaces on both their top and bottom sides allowing additional modules to be installed above or below them. Examples of terminal and intermediate modules are shown in Figure 11 below.

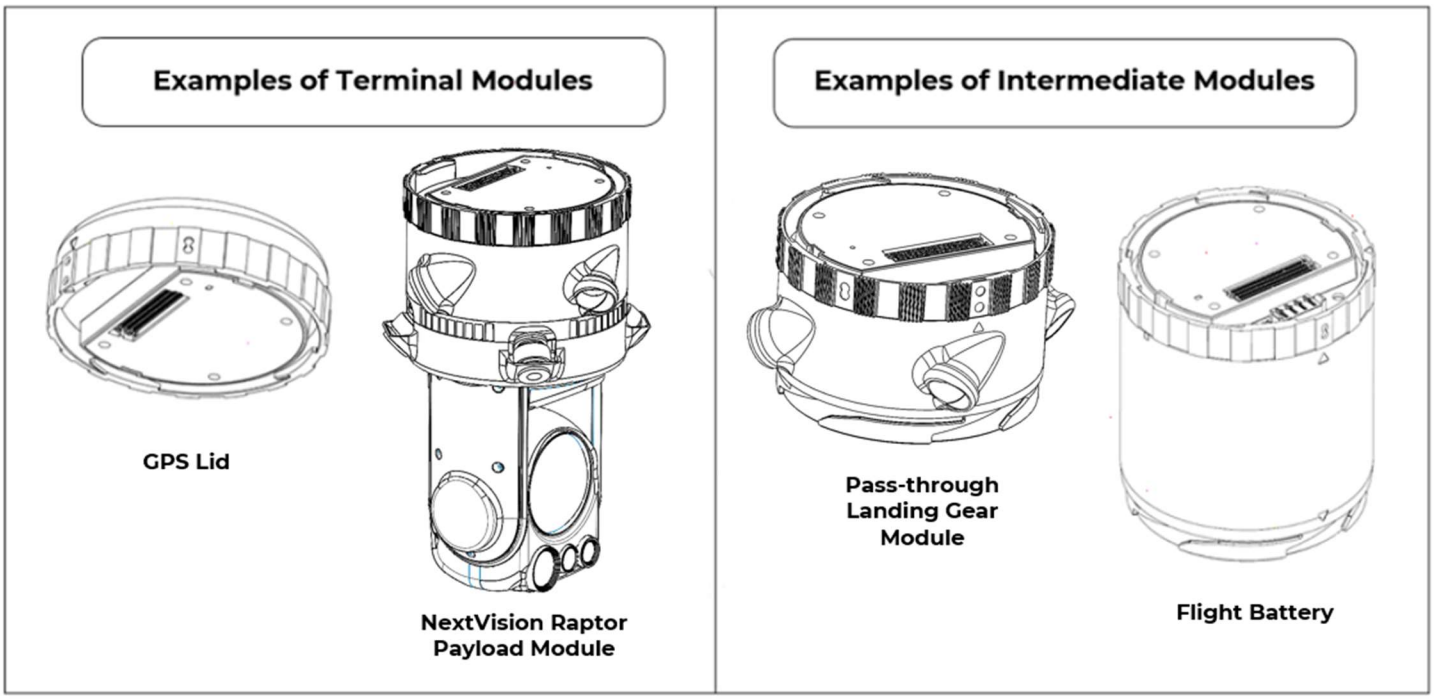



*Figure 11: Terminal and Intermediate Modules*

### Assembling for Flight

When assembling a Spirit for flight it is often convenient to start with the module containing the landing legs and then work upwards. This will keep the user's hands free as the assembled system will be supported on the landing legs.

Typically, the bottom-most module will be a terminal payload module with integrated landing legs and the top-most module will be a terminal module with an integrated GPS.

If unsure how to assemble Spirit, contact support@ascentaerosystems.com.

| CAUTION |
| --- |
| Do not install or remove modules when the vehicle is powered. Power off the Spirit before attaching modules. |

## SOFTWARE

### Vehicle Side

**Firmware**: This is the base-level software logic that controls the Spirit in flight. It is compiled code that is loaded into the Spirit flight computer during a firmware update and is not editable by the Operator. The latest firmware is available by contacting support@ascentaerosystems.com. Spirit uses the Pixhawk Cube autopilot, powered by the ArduCopter open-source firmware.

ArduCopter: http://ardupilot.org/copter/docs/introduction.html

ArduCopter communicates with the Ground Control Station (GCS) software and flight planning software via a messaging protocol called MAVlink.

**Parameter Settings File**: The parameter file contains all the values for the settings which configure the autopilot. Examples include: maximum climb rate, geofencing constraints or what data to log during flight. Each parameter can be adjusted by the Operator using a Ground Control Station (GCS). Most settings never need to be changed, but some must be modified regularly.

| WARNING |
| --- |
| SPIRIT IS AN ENTERPRISE-GRADE UNMANNED AERIAL SYSTEM INTENDED FOR USE BY EXPERIENCED PROFESSIONAL OPERATORS. WHILE EACH SPIRIT IS CONFIGURED WITH OEM-RECOMMENDED PARAMETER SETTINGS BEFORE SHIPMENT, ACCESS TO THESE SETTINGS IS UNRESTRICED AND OPERATORS ARE ABLE TO CHANGE ANY PARAMETER. MOST GCS APPLICATIONS DO NOT PROVIDE ANY GUIDANCE OR WARNING ABOUT THE EFFECT OF A PARAMETER CHANGE. ONCE A PARAMETER HAS BEEN CHANGED, THE VEHICLE MAY NOT PERFORM AS IT DID PRIOR TO THAT CHANGE. IT IS POSSIBLE TO CHANGE PARAMETERS THAT MAKE THE VEHICLE UNCONTROLLABLE AND TO DISABLE SAFETY FEATURES THAT MAY BE REQUIRED BY LAW IN SOME JURISDICTIONS. FOR THIS REASON, OPERATORS MUST KNOW EXACTLY WHAT THE EFFECT OF A SETTING IS BEFORE CHANGING THE VALUE. |

## Ground Side

**Ground Control Station (GCS) Software**: This is the software the pilot uses to interface with Spirit. The primary function of GCS software is for vehicle control, flight monitoring and autonomous mission planning. Among the most popular open source GCS is MissionPlanner (Windows) and QGroundControl (Windows, Android), which also provide access to ArduCopter settings.

Mission Planner: http://ardupilot.org/planner/

QGroundControl: https://docs.qgroundcontrol.com/en/

Ascent AeroSystems does not control, review, or maintain these software applications, but a vast amount of information about these applications is available online, including user guides, videos, blogs, and user forums.

While any GCS which communicates in MAVlink could be used to control Spirit, Ascent maintains a version of QGroundControl that is tailored for Spirit operation called AscentQ. This software is installed on most Spirit ground controllers.  AscentQ is discussed later in this manual.

| CAUTION |
| --- |
| All Spirits are equipped with a customer-selected GCS and test flown with an accompanying set of autopilot parameters before shipping. Where possible, automatic updating has been disabled on the GCS. DO NOT update GCS software without an instruction guide provided by Ascent AeroSystems. To confirm you have the latest versions, contact support@ascentaerosystems.com |

# SECTION 2: SPECIFICATIONS AND LIMITATIONS

The data below is for the Spirit Core. See Supplements for details on accessories.

## DESCRIPTIVE DATA

| | |
|---|---|
| Type | Coaxial Unmanned Aerial Vehicle |
| Drive system | Direct drive with 2x brushless motors<br>Active electromagnetic rotor braking |
| Control system | Cyclic pitch control on bottom rotor |
| Rotor blades | 21.5 x 7.3” carbon fiber |
| Flight battery nominal voltage | 44.4v (12S) |

## DIMENSIONS & WEIGHTS

| | |
|---|---|
| Average system diameter | 4.2 in. (106mm) |
| Max diameter with retracted rotors | 5.1 in. (128 mm) |
| Rotor diameter (tip to tip) | 25 in. (635mm) |
| Height of Core | 12.0 in. (257mm) |
| Empty weight (core only) | 4.0 lbs. (1,820g) |

## LIMITATIONS

| | |
|---|---|
| Temperature (operation) | -5°F to 120°F (-20°C to 49°C) |
| Temperature (storage) | -40°F to 130°F (-40°C to 54°C) |
| Ingress Protection | IP56 |
| Precipitation[1] | No operational limitations restricting flights in rain, sleet, snow, or mixed precipitation. |

[1] Icing conditions should be avoided. Regulatory restrictions may apply if precipitation reduces operators’ line-of-sight.

| | |
|---|---|
| Wind[2] | 35 mph continuous<br>50 mph gust |
| Altitude | >10,000ft |
| Maximum takeoff weight | 13.5 lb (6.12 kg) |
| Minimum takeoff weight | 7.5 lb (3.40 kg) |
| Max payload power draw | > 100 W |

## PERFORMANCE

Flight Performance is heavily influenced by the aircraft's weight, aerodynamic drag, and available power. The data below should be considered approximate and does not necessarily reflect the minimums and maximums of all configurations.

| | Default Software Limit[3] | Routinely Demonstrated | |
|---|---|---|---|
| | | 1 Battery | 2 Batteries |
| Climb rate | 16 ft/s (5 m/s) | 33 ft/s (10 m/s) | 26 ft/s (8 m/s) |
| Decent rate | 10 ft/s (3 m/s) | 26 ft/s (8 m/s) | 20 ft/s (6 m/s) |
| Forward velocity (airspeed) | 33 mph (15 m/s) | 65 mph (29 m/s) | 56 mph (25 m/s) |
| Maximum lean angle | 30° | N/A | N/A |
| | | | |
| Maximum Range Speed | | 33 mph (15 m/s) | 45 mph (20 m/s) |
| Maximum Endurance Speed | | 22 mph (10 m/s) | 45 mph (15 m/s) |

[2] Maximum demonstrated wind: 35 - 40 mph. Maximum wind is at Operator's discretion after considering all relevant factors including sustained wind speed, gust factor, terrain, obstacles, pilot experience, visibility, battery state and vehicle configuration. Other factors impacting performance may need to be considered.

[3] Can be changed by operator.

# SECTION 3: SPIRIT OPERATION

This section is intended to give an overview of Spirit operation so detailed sections later in this manual have context. This section should not be considered comprehensive. Pilots must read and understand all sections of this document and relevant supplements before operating Spirit.

## PRE-FLIGHT

Common in aviation are pre-flight checklists. Some checks should be made well in advance of flight to give the operator time to address issues. These are covered in the "Hours Before Operation" section below. Other checks are made at the flight location in the minutes before takeoff. These are covered in the "Minutes Before Operation" section below. Spirit operators should adopt the use of checklists. The lists below walk the reader through pre-flight activities and should be used as the starting point for an operational checklist. Operators are encouraged to expand and tailor their pre-flight checklists to their operations.

### Hours Before Operation

Equipment should be gathered, and all components needed for the operation accounted for. Predicted weather should be checked and safety mitigations such as geo-fences and failsafe settings considered.

Aircraft Power Off Checks

- Perform a pre-flight inspection of all hardware. See pre-flight inspections in the Field Inspection Manual for details about inspecting the Core. See the appropriate supplement for the pre-flight inspection of batteries and accessories.
- Ensure flight batteries are charged.
- Ensure ground controller battery is charged.
- Pre-download maps of the operation area onto the GCS
- Ensure the vehicle has proper regulatory markings.

### Aircraft Power On Checks

These checks are performed using AscentQ on Spirits' GCS:

- Check Spirit settings are configured for the planned flight configuration.
- Check failsafes and geofences are set as desired for the operation.
- Verify that no warnings or errors display and that the vehicle's heading is correct.
- Cycle through the physical buttons on the ground controller and confirm they are properly set.
- Exercise payload controls (ie camera pan & tilt, record start & stop).
- Test any other equipment that will interface with the Spirit during the operation.

| WARNING |
| --- |
| ALWAYS REMOVE ROTOR BLADES BEFORE POWERING ON SPIRIT WHILE INDOORS. DO NOT ARM THE AIRCRAFT WITHOUT BLADES INSTALLED |

## Minutes Before Operation

### Setup

At the flight location, a takeoff spot should be selected and the pilot should assemble Spirit and position it for takeoff.

- The takeoff location should be level, free of overhead obstructions and away from sources of magnetism and RF interference. This is also the location where the Spirit will likely land, so select a spot away from fences, rocks or other obstacles that could make landing risky.
- The back of the Spirit should face the operator at takeoff.
- Check rotor blades are clocked to prevent hangups or strikes during spoolup.
- Pilot and crew should leave at least 15 meters between themselves and Spirit at takeoff.
- Spirit should have a clear view of the sky if operations are dependent on GPS.

| CAUTION |
| --- |
| Spirit's rotor blades should be properly set before takeoff to prevent strikes during spoolup. All four blades must be parallel with Spirit's body with the top blades laying clear of the bottom blades. |

### Power On

Power on Spirit's Core by pressing and holding the Core's power button until tones are heard (approximately 3 seconds). Spirit will then require approximately 10 seconds to bootup. Bootup is complete once the two LEDs on the back of the Core blink steadily (either blue, green or yellow).

- Yellow blinking: Ground controller not connected
- Blue blinking: Ground controller connected; 3D-fix not yet achieved.
- Green blinking: Ground controller connected, 3D-fix achieved.

Pilots should become familiar with the startup tones and LED flashes when powering Spirit so they can identify an abnormal startup.

The pilot can power the ground controller and launch their Ground Control Station (GCS) software at any point. Unless stated otherwise, this manual will assume an operator is using AscentQ as their GCS software.

Once launched, AscentQ will connect to Spirit. The pilot should wait for the GCS to download vehicle parameters and then perform the pre-flight checklist contained within AscentQ.

In addition to the Pre-Flight Checklist in AscentQ (See Section 4: AscentQ), the pilot should check:

- No errors or warnings displayed on the GCS.
- Payload controls function as expected.
- Run any final pre-flight checks unique to their operation.
- Desired flight mode selected.

## TAKEOFF

### Arming

Once all pre-flight checks are completed, the pilot should command the Spirit to arm. Arming is the first step to takeoff and if successful will spool up the vehicle's rotors. Arming and disarming are discussed in greater detail in the Arming and Disarming section of this manual.

Once commanded to arm, Spirit's flight computer runs a series of 'pre-arm' checks to help ensure a safe takeoff. If Spirit fails any of these pre-arm checks, arming will abort, and the pilot will be notified on the GCS. Examples of failed checks would include trying to arm with a geofence set but with inadequate GPS fix, or trying to arm with two flight sensors providing contradictory values.

### Takeoff

Once the vehicle is armed, the exact method used to command takeoff will depend on the vehicle's current flight mode. Flight modes are discussed in greater detail in the Flight Mode section of this manual. Typically, takeoff is commanded by raising the throttle (left joystick) above mid-stick. Pilots should smoothly raise the throttle until the vehicle is clear of the ground. The higher and longer the throttle is raised, the more aggressive and higher the takeoff will be.

It is recommended that pilots become familiar with taking off in a manual flight mode before using an automated takeoff.

After takeoff, the pilot should ascend to 15 meters and briefly enter a hover to check for any anomalous sounds or behaviors. These include:

- excessive vibration
- unusual noises
- inability to hold position (depending on flight mode)
- on-screen warnings

Once confident, the pilot can switch into their preferred flight mode and begin their mission.

| CAUTION |
| --- |
| Takeoff is a high risk portion of flight as the vehicle is close to the ground and electrical and mechanical systems are being stressed for the first time of that flight. Pilots should always monitor takeoff closely and be prepared to take manual control of the vehicle with a non-gps dependent flight mode such as alt-hold. |

## FLIGHT

How the pilot operates Spirit is largely dictated by the flight mode the pilot is using. Flight modes such as ALT-HOLD and LOITER require manual inputs from the pilot via joysticks while modes such as AUTO or GUIDED only require entering waypoints on-screen. Flight modes are fundamental to operating Spirit, therefore, a pilot should be very familiar with the modes they may use.

When switching flight modes using physical buttons or on-screen controls, a pilot should always confirm on their GCS that they have entered the new flight mode.

If ever confused by the response of the aircraft to pilot's inputs, the GCS should be checked to confirm the vehicle's current flight mode.

Prior to flight, pilots should also be familiar with failsafes they might encounter as well as vehicle recovery techniques. Failsafes and vehicle recovery techniques are discussed later in this manual.

### Manual Flight Modes

These flight modes maneuver the vehicle in real time via joystick inputs from the pilot. Spirit joysticks are typically configured as 'mode 2', meaning climb/yaw are controlled with the left stick and pitch/roll on the right stick.

While in a manual mode:

- pilot input should be smooth and continuous
- the pilot should avoid rapid changes in direction while at high speeds
- the pilot should be aware of wind strength and direction

### Autonomous Flight Modes

These flight modes fly the vehicle without direct pilot input according to a pre-planned route loaded to the vehicle before or during a flight.

Pilots should closely monitor autonomous flights and be prepared to recover into a manual flight mode if the vehicle's flight path becomes blocked or abnormal behavior is noticed.

## LANDING

Landing can be performed either manually or with automated flight modes such as LAND or Return-to-Launch (RTL). When landing with an automated flight mode, pilots should carefully monitor progress and be prepared to takeover control with a manual flight mode.

### Altitude

Spirit's altitude is relative to its takeoff location and can regularly be inaccurate by 2 or 3 meters, therefore, altitude should not be used as an aid for landing. Altitude accuracy is further affected by large changes in barometric pressure brought on by evolving weather during the flight.

Most automated landing modes will descend at maximum decent speed until a few meters above the ground. Then, anticipating contact with the ground the vehicle will slow considerably. If the error in the vehicle's altitude estimate is large enough, the vehicle may never slow and will make contact with the

ground at its maximum descent speed. For this reason, pilots should monitor the aircraft when they autonomously land and be prepared to take manual control if decent speed is not reduced before touchdown. Pilots should also take manual control of the aircraft if it is unable to hold its ground speed near zero prior to touchdown. Too much horizontal velocity at touchdown risks toppling the vehicle.

## Getting on the Ground

| CAUTION |
| --- |
| Landing is a high risk portion of flight as the vehicle is close to the ground and susceptible to incident, so landing techniques should be well understood and the spirit should be closely monitored until it is landed and disarmed. |

Landing with Manual Flight Modes

- The pilot should be close enough to the landing site to clearly see the vehicle touchdown.
- Descend to approximately 2 meters (shoulder height) and hold a hover.
- Verify zero ground speed. If not in a GPS aided flight mode the pilot will need to compensate for wind.
- Smoothly lower the throttle and slowly descend (~0.75 m/s) until touchdown.

At touchdown, hold the throttle completely downand disarm the aircraft.

| CAUTION |
| --- |
| Failing to hold the throttle completely down after landing but before disarming does not minimize the vehicles thrust and can risk toppling or takeoff. |

When landing, it is important to avoid toppling the Spirit. The Spirit risks tipping over if the following landing techniques are not used:

- Land straight down with zero horizontal velocity.
- Touchdown assertively. Once touchdown is imminent pull the throttle all the way down. Avoid 'light feet' at ground level.
- Do not return the throttle to its middle position at the moment of touchdown. This can be interpreted by many flight modes as the pilot's desire to hover at ground level, which is a dangerous condition. Hold the throttle stick completely down for several seconds after touchdown.

Being close to the ground is hazardous to any aircraft and pilots should avoid maneuvering or hovering at very low altitudes. If too much ground speed develops during landing pilots should raise the throttle and climb away from the ground before another land attempt. High wind speeds can exacerbate these situations.

| WARNING |
| --- |
| RAISING THE THROTTLE PAST MID-STICK AFTER TOUCHDOWN WILL TRIGGER A TAKEOFF IN SEVERAL FLIGHT MODES. |

## Landing with Automated Flight Modes

A pilot should monitor the progress of any automated mode and be prepared to take manual control if Spirit has too much horizontal or vertical velocity prior to touchdown.

Most automated landing modes will allow pilot input via the joysticks to move the aircraft's landing point as it descends. Avoid joystick inputs when under 2 meters from touchdown as they will increase ground speed and can cause the aircraft to topple. If repositioning is needed in the moments before touchdown, the pilot should take manual control and climb away from the ground.

Once landed the pilot should disarm the Spirit either by waiting for the aircraft to timeout or by manually disarming via the ground controller. Disarming will stop the rotors from spinning.

## Powering Down

Once Spirit is disarmed the pilot can approach the aircraft to power it down. This is done by pressing and holding the Core's power button until Spirit's LEDs turn off.

Spirit is not waterproof when disassembled as the interfaces between modules are exposed. If Spirit is particularly wet or dirty it may be advisable to keep the system assembled until it can be cleaned and dried.

| CAUTION |
| --- |
| Do not leave Spirit flight batteries attached to the Core for extended periods of time. |

# SECTION 4: ASCENTQ

AscentQ is Ascent Aerosystems' custom version of QGroundControl, an open-source Ground Control Station (GCS) software commonly used for command and control of UAV. It is typical for UAV manufacturers to modify QGC to offer an experience tailored for their vehicle.

The following will detail Ascent's version of this software; however, operators must be familiar with how the baseline version of QGC works as this document assumes users are familiar with the basic layout and features of the software. Details about QGC can be found here:
https://docs.qgroundcontrol.com/master/en/index.html

There may be differences between versions of AscentQ depending on the physical controller and operating system the software is loaded on (ie the Windows based SkyNav versus the Android based Herelink). Unique differences will be noted in the supplement section of this manual specific to the controller.

## FLIGHT INTERFACE

The organization of the user interface should be recognizable to anyone familiar with QGroundControl. The primary screen is known as the 'Fly View' which is the primary interface a pilot would use during operation. The Fly View is pictured below in Figure 12.

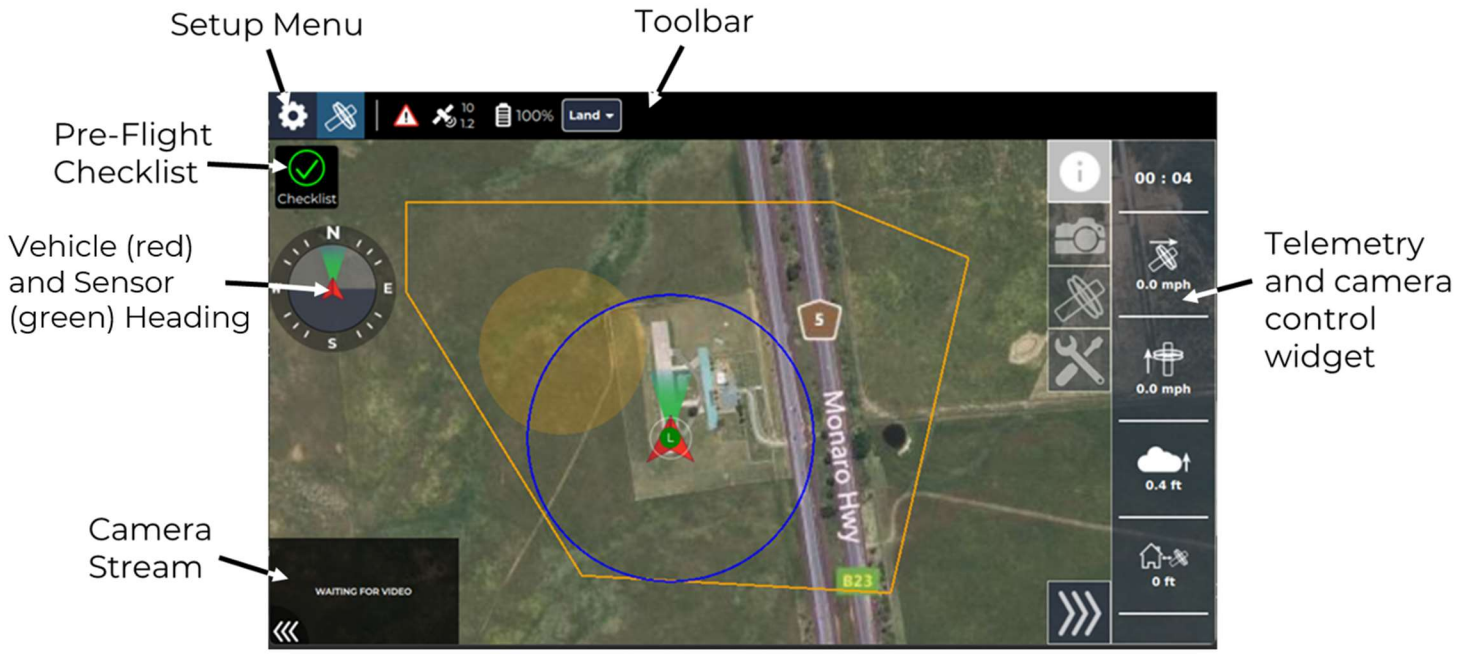



*Figure 12: Fly View Interface*

## Toolbar

Below the key items on the Fly View Toolbar are identified. Each item can be selected to access additional information or vehicle commands.

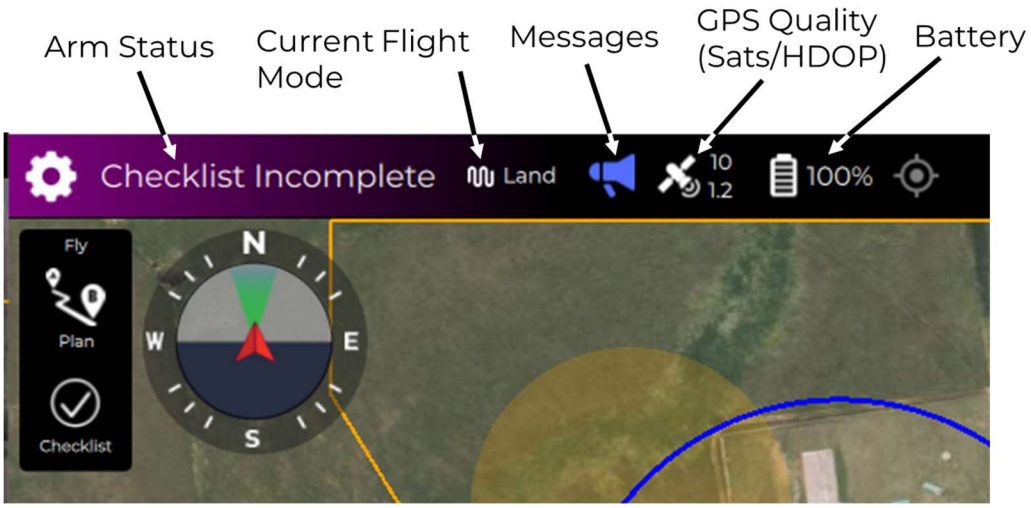



*Figure 13: Toolbar Icons*

## Telemetry and Control Widget

This widget on the right-hand side of the screen has four tabs: telemetry, camera control, Spirit control and maintenance. Below is a description of each.

### Telemetry

Figure 14 below identifies the displayed telemetry data. The units can be changed from metric to imperial by tapping on the icons.

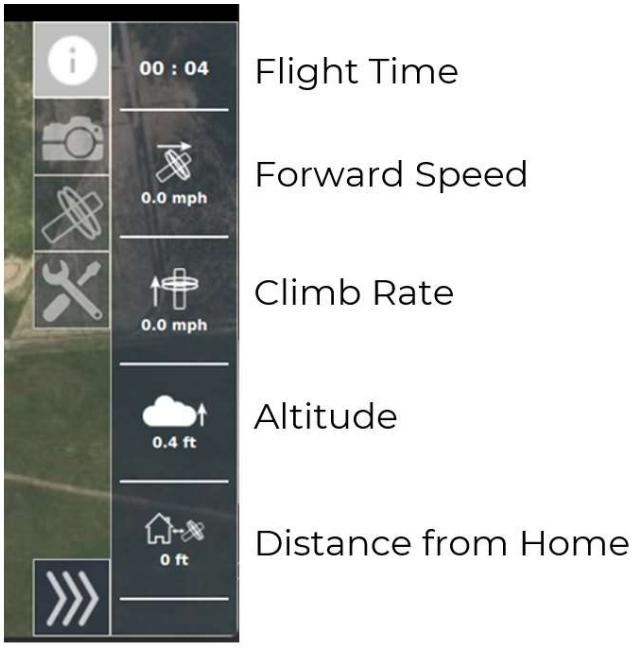



*Figure 14: Telemetry Tab*

Camera Control

This tab will populate with controls specific to a camera payload attached to Spirit. Operators should reference the appropriate supplement for details on this tab. Figure 15 below shows the tab of a common camera. The arrows at the top of the tab cycle between camera control pages.

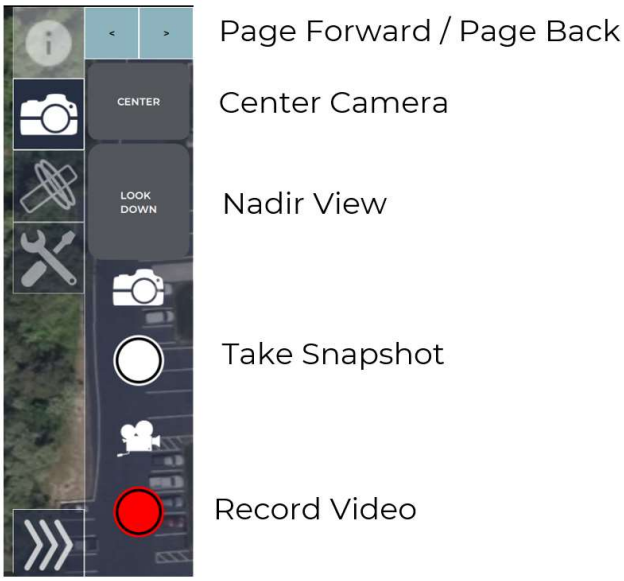



*Figure 15: Camera Control Tab*

Spirit Controls

This tab contains buttons for miscellaneous Spirit controls. Figure 16 below identifies the buttons. The LED toggle can be used to turn the vehicle's LEDs on or off. The arm and kill buttons are discussed in the Arming and Disarming section of this manual.

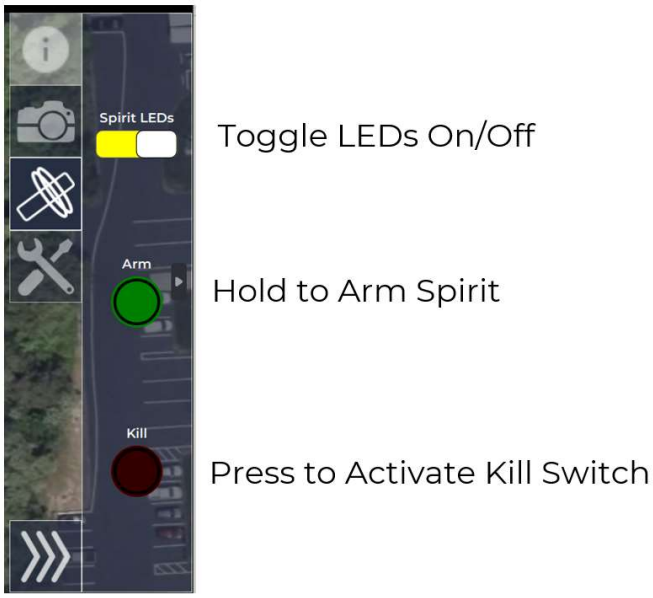



*Figure 16: Spirit Controls*

Maintenance Tab

This tab contains information about the operational life of the aircraft. The 25-Hour countdown timer keeps track of when the vehicle is due for a 25-hour inspection. See the Field Inspection Manual for additional details. Once the inspection is performed the operator can reset the counter in this tab.

The service countdown keeps track of the time until the vehicle needs to be serviced by an Ascent trained technician. Once this countdown has expired, contact support@ascentaerosystems.com for guidance.

The battery health estimate monitors the attached battery's performance during the flight and estimates its health once the vehicle lands and disarms. If two batteries are installed on the aircraft, the health estimate cannot distinguish between the two and the reported health will be an average of the two batteries.


Total Vehicle Flight Time

25 Hour Countdown Timer

Countdown to Servicing

Battery Health Estimate

*Figure 17: Maintenance Tab*

## CONNECTING TO ASCENTQ

Once Spirit is powered on and its radio has boot up, AscentQ should automatically connect to the aircraft. The user will recognize the connection from an audio alert stating the vehicle is connected as well as telemetry beginning to populate the interface.

### Downloading Parameters

If this is the first time AscentQ has connected to the aircraft since the software was launched, AscentQ will download all the current parameters (settings) that are loaded on Spirit. This downloading can be recognized by the horizontally growing green status bar across the top of the screen (see in Figure 18). It is recommended to allow parameter downloading to complete before starting any preflight procedures. Several menus and screens will not be accessible until after the parameters have been downloaded.

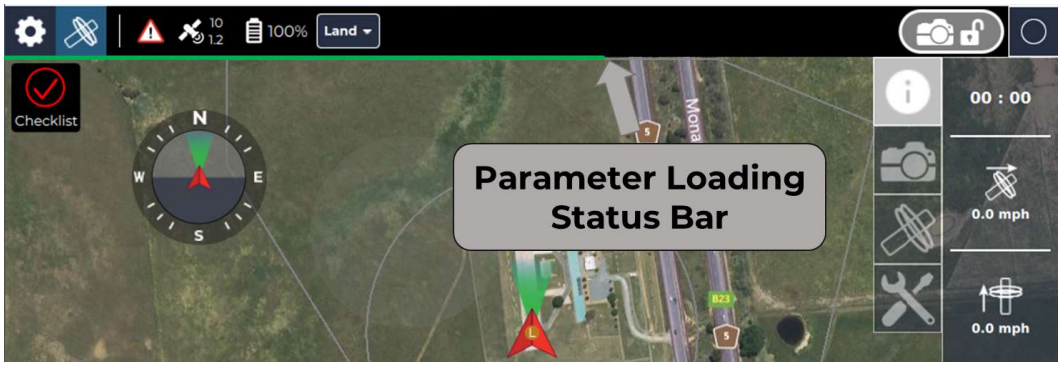



*Figure 18: Parameter Loading Indicator*

### Troubleshooting

If Spirit does not connect to AscentQ when launched:

- Check that Spirit is powered on and its internal radio has had time to fully boot up (typically 1 minute).
- Some Spirit configurations require a separate radio module. If necessary, ensure this module is attached to Spirit and powered.
- Confirm that the radios installed in the ground controller and in Spirit are from the same manufacturer and known to be compatible.
- Some GCS may not connect or lose connection if their WIFI is turned on. See the appropriate ground controller supplement.
- See the appropriate ground controller supplement in this document for methods to check the status of the controller radio.
- See the appropriate radio supplement in this document for details on how to check the radio connection between the controller and Spirit.

## PRE-FLIGHT CHECKLIST

Once the parameters are downloaded, a Pre-Flight checklist will pop up on screen. The operator should complete the checklist, clicking on each item once complete, which will collapse the item and turn it green. Once all items are complete, the checklist will disappear.

If the pre-flight checklist does not pop up once connection is established with the Spirit, the user should manually open the checklist by clicking on its icon on the left of the screen. At any time, the checklist can be closed and then reopened using this icon. A refresh icon located in the top right corner of the checklist can be used to revert all completed checklist items.

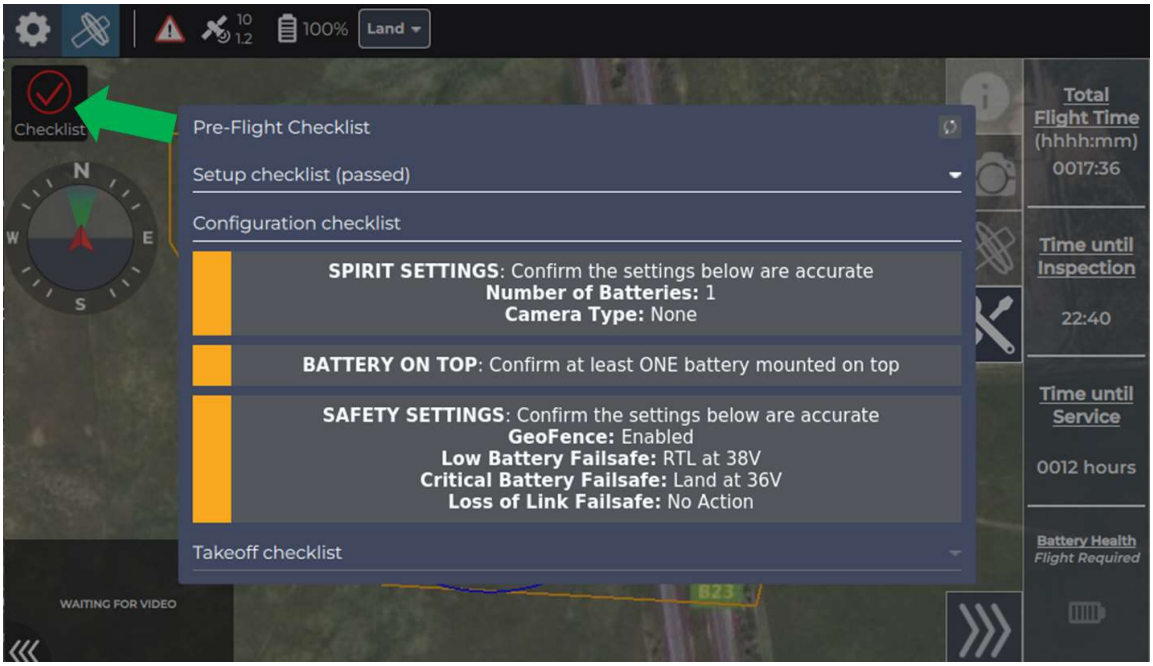



*Figure 19: Preflight Checklist*

Some of the checklist items will display the current settings of the vehicle. For example, the status of geofences and other failsafes. These settings cannot be modified in the checklist but are displayed for the convenience of the operator. Note, these values will not display if AscentQ is still downloading parameters from the vehicle.

If the checklist is not completed, the user will not be able to arm Spirit using the on-screen interface. However, Spirit can always be armed by holding the left joystick down and to the right for 3 seconds. See the Arming and Disarming section of this manual for more details.

The on-screen checklist does not include several important inspection steps which are detailed in the Aircraft Field Inspection Manual. All operators should read and be familiar with the Field Inspection Manual before operating Spirit.

| CAUTION |
| --- |
| The pre-flight checklist in AscentQ should not be considered comprehensive and complete for all possible flight operations, environments, or payloads. Users should create additional preflight checklists tailored for their operations. |

## SPIRIT CONFIGURATION

Before takeoff, the Spirit configuration settings must be checked.

Spirit's modularity means it must accommodate a variety of takeoff weights. ***It is critical*** **that the operator correctly configures the vehicle software prior to takeoff. This is done by selecting the number of batteries installed on the aircraft and the type of payload equipped**. Spirit uses this information to determine its takeoff weight and set critical tuning and flight control parameters. Incorrectly setting these values prior to flight can lead to system instability, poor flight performance or a loss of the vehicle. Checking the values of these configuration settings is an item on the pre-flight checklist (see Figure 20).

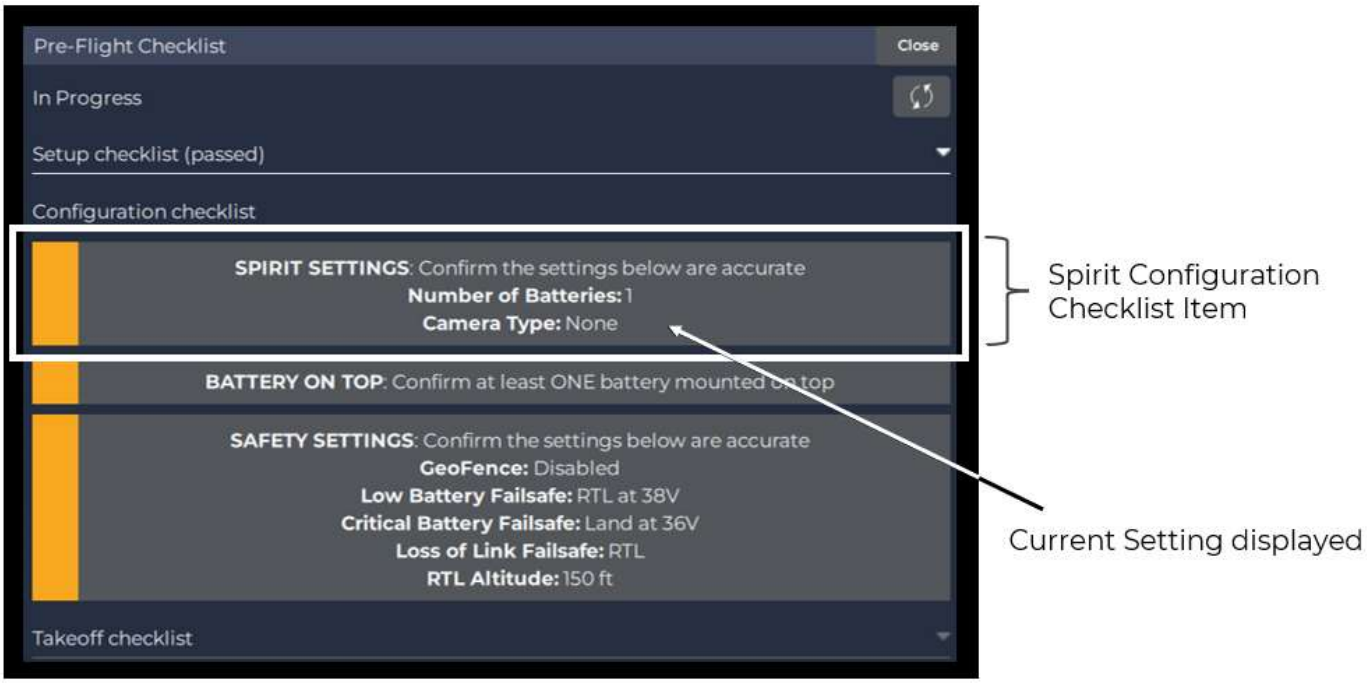



*Figure 20: Spirit Configuration Checklist Step*

Spirit's configuration settings are modified through the Spirit tab on the Vehicle Setup Screen.

| WARNING |
| --- |
| THE NUMBER OF ATTACHED BATTERIES AND THE PAYLOAD TYPE MUST BE SET BEFORE FLIGHT. FAILURE TO PROPERLY SET THESE VALUES CAN LEAD TO UNSTABLE FLIGHT. |

## VEHICLE SETUP SCREEN

To enter the Vehicle Setup Screen, click on the gear icon at the top left corner of the Fly screen. Then, select Vehicle Setup from the popup menu.

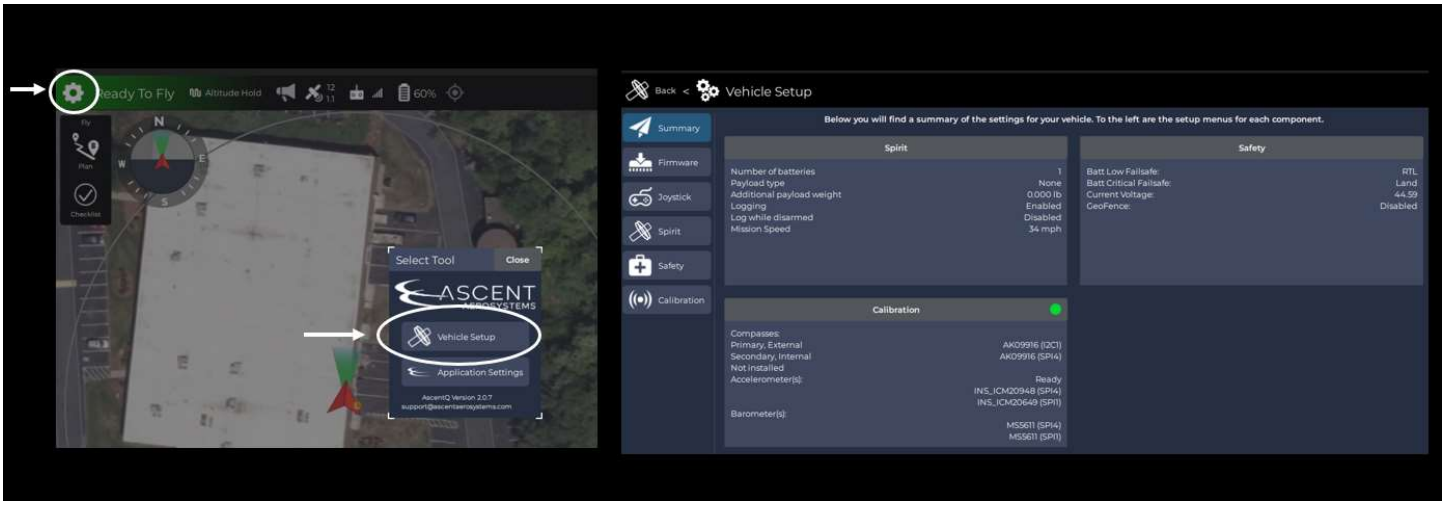



*Figure 21: Vehicle Setup Screen*

The Vehicle Setup screen is divided into 6 tabs located on the left of the screen. The first time the Vehicle Setup screen opens it defaults to the Summary tab. This tab provides a dashboard of the vehicle's current settings and health.

### Spirit Tab

This tab contains the critical Spirit Configuration settings.

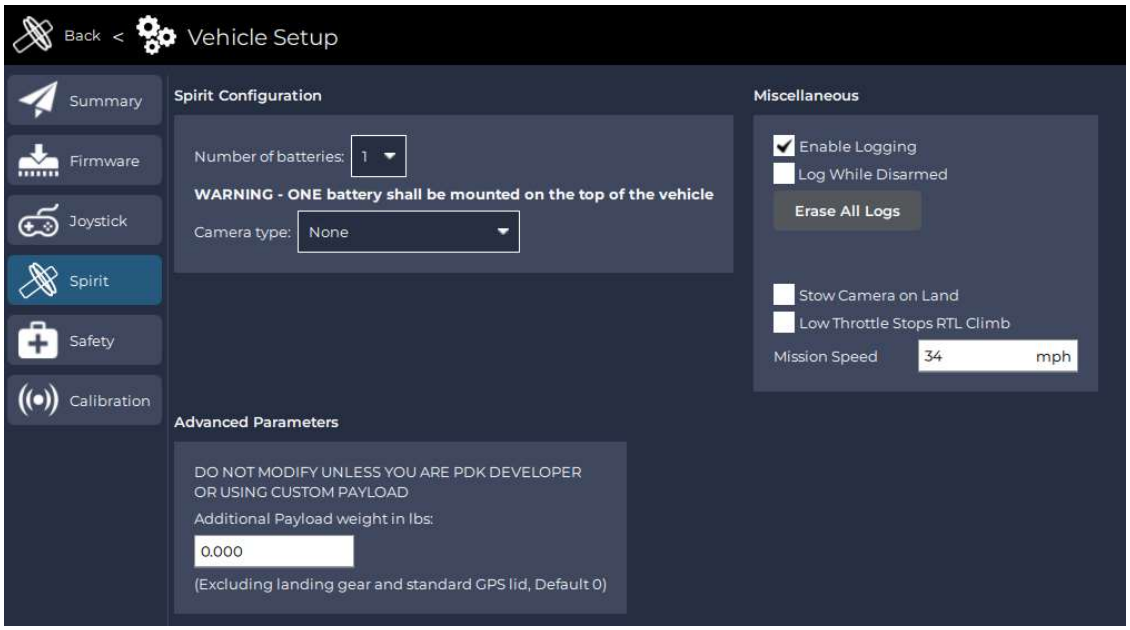



*Figure 22: Spirit Tab*

*Spirit Configuration* – Number of batteries should be set to reflect the current setup of the vehicle. This value should always be either a 1 or 2. If only one battery is used it should be mounted to Spirit's top interface.

If the vehicle is equipped with an Ascent provided payload the correct camera type should be selected. Setting the incorrect camera type can make the aircraft unstable in flight and cause the camera to not function properly. Spirit's Core will need to be rebooted if a camera change is made.

If uncertain how to set these values, do not fly. Contact support@ascentaerosystems.com

*Advanced Parameters* – Intended for manufacturers of custom payloads. This is an advanced setting and should be set to zero for most operators. For operators using custom payloads or attachments, this value should be increased to account for the added weight of the custom payload. Contact support@ascentaerosystems.com if integrating payloads not provided by Ascent.

## Safety Tab

This tab configures failsafe actions as well as the geofence. The details of the vehicle's failsafes and geofence are discussed in later sections.

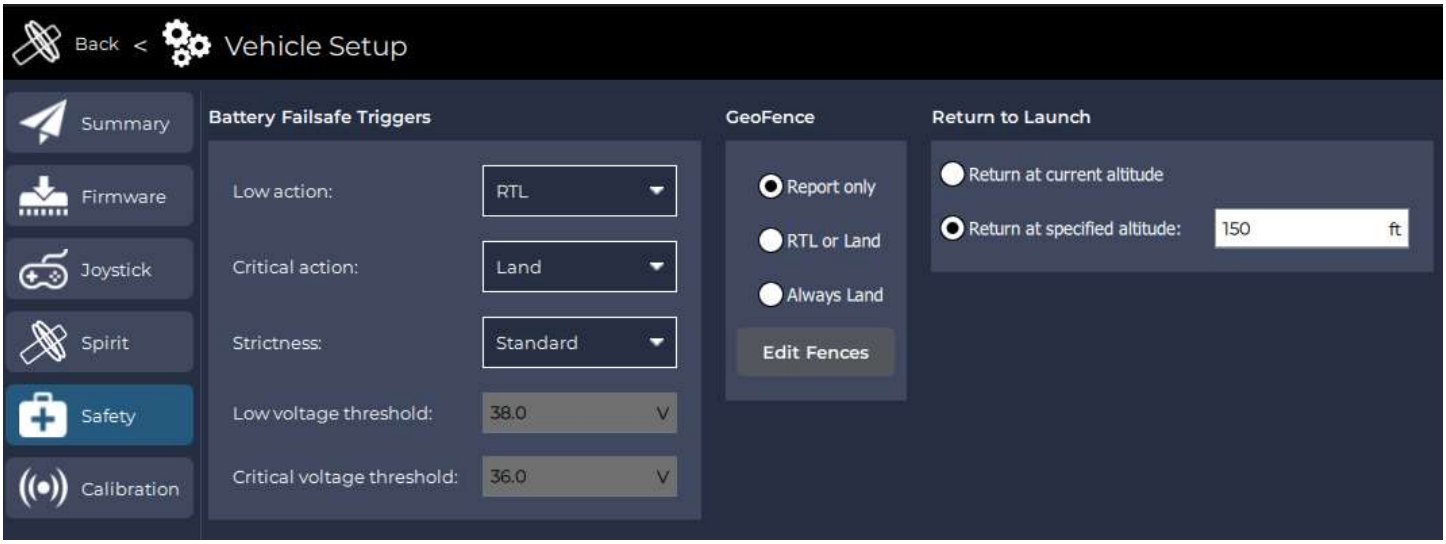



*Figure 23: Safety Tab*

Battery Failsafe Triggers – These settings control when a low battery failsafe activates and what actions are taken. The voltage levels which will trigger failsafes are displayed and can be modified by the 'Strictness' setting. Pilots should consider setting the strictness to 'Conservative' if flying at long ranges, in high winds or if the return leg of a flight will be upwind.

Geofence – The radio buttons set the action taken if the vehicle violates a geofence. Geofences are setup and enabled/disabled with the 'Edit Fences' button.

Return to Launch – Set the minimum altitude the vehicle will climb to when autonomously returning to HOME or to a preset Rally Point.

## ARMING AND DISARMING

When first powered, Spirit is in a state known as 'Disarmed'. In the disarmed state, Spirit's rotor blades do not spin and the two rear-facing LEDs on the Core flash continuously. Before taking off the pilot must 'Arm' Spirit. This function of arming an aircraft before flight is common in UAV operation.

### Arming

Once a pilot commands Spirit to arm, its flight control computer will run a series of self-checks known as 'pre-arm checks'. If all checks pass, Spirit will arm and spool up its top rotor blades followed shortly after by its bottom rotor blades and wait for a command to takeoff.

### Arming with On-Screen Controls

Tap the Spirit Aircraft symbol next to the telemetry pane to access the Spirit vehicle controls. Press and hold the arm button to see a countdown. Continue holding until the countdown disappears, and you hear **"Armed"** called out from the GCS. The pilot can only arm Spirit once completing the on-screen pre-flight checklist.

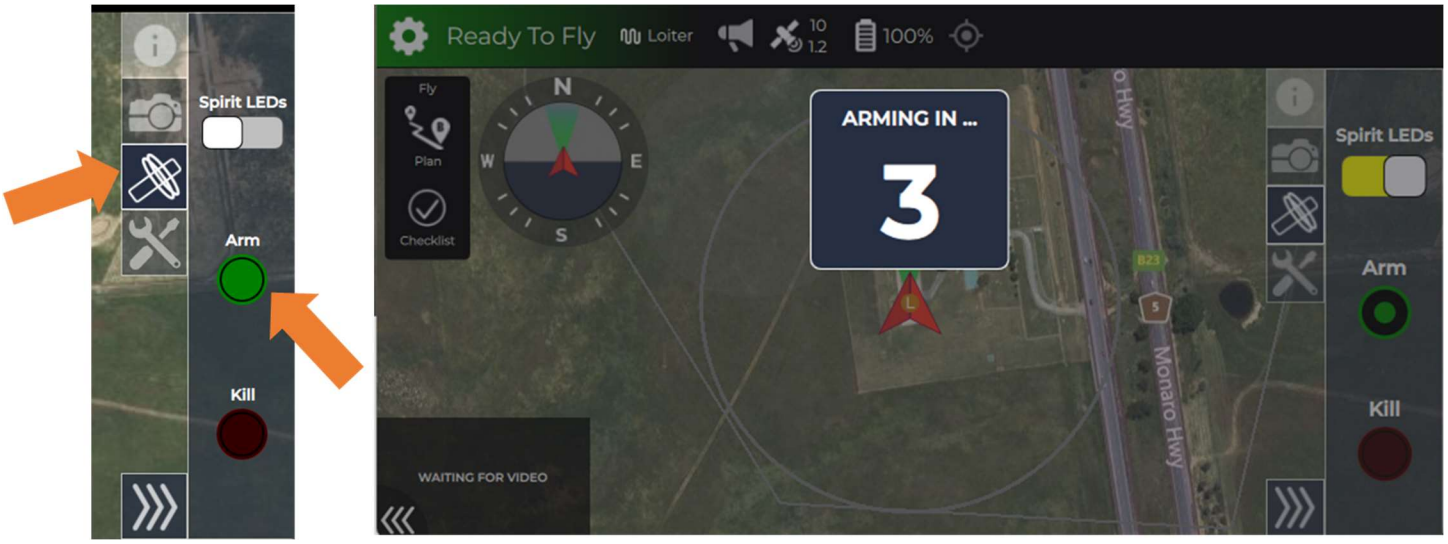



*Figure 24: On-Screen Arming*

### Arming with the Ground Controller Joystick

All Ascent ground controllers will arm Spirit by holding the left joystick down and to the right for 3 seconds. When using AscentQ, a pilot can arm with this method regardless of if the pre-flight checklist is complete.

| CAUTION |
| --- |
| It is not recommended to operate the spirit without completing the preflight checklist. |

While holding the joystick down and to the right, the LEDs on Spirit will rapidly flash yellow-green to indicate the pilot is attempting to arm the aircraft. Recentering the joystick before the 3 seconds have passed will abort the arming process. Once armed, the LEDs will become solid green (or blue if no GPS fix is available) at which point the pilot should recenter the joystick and prepare to takeoff.

## Disarming

When disarmed Spirit stops its rotor blades from spinning and puts the aircraft into a safe, non-propulsive state. In most cases, the only check Spirit will perform before disarming is to ensure it is landed.

## Disarming from Time Out before Takeoff

If Spirit has just been armed but no takeoff command is received for 8 seconds, Spirit will automatically disarm.

## Manually Disarming

Disarming can be performed manually either via a ground controller button or using a GCS's on-screen interface. The 'Arm' button in the Spirit vehicle controls pane will change to a 'Disarm' button after takeoff. Spirit will reject the disarming command if it does not believe it has landed and may still be flying. The throttle should be held down after landing until the aircraft is disarmed.

## Disarming from Time Out after Landing

Spirit will automatically disarm when landed and left to idle on the ground for more than 8 seconds. The throttle should be held down after landing until the aircraft disarms.

| CAUTION |
| --- |
| Failing to hold the throttle completely down after landing but before disarming does not minimize the vehicles thrust and can risk toppling or takeoff. |

## Emergency Shutdown

There are certain situations which will automatically disarm Spirit regardless if the aircraft has landed. These include:

- Toppling while attempting to land.
- Being low to the ground with over 100 degrees of attitude error.
- Having a lean angle over 30 degrees during takeoff.

Beneath the Arm/Disarm on-screen button is a button labeled “Kill”. This is an emergency shutdown button which will deactivate Spirit’s motor’s regardless of its state.

| WARNING |
| --- |
| ACTIVATING THE VEHICLE KILL SWITCH WILL TURN OFF THE MOTORS AND CREATE AN UNCONTROLLED FALL THAT CANNOT BE REVERSED. |

## CHANGING FLIGHT MODES

Flight modes are a fundamental concept in UAV operation. They dictate how the aircraft will respond to pilot input. Some flight modes require manual inputs via joysticks while others can autonomously navigate the aircraft on predetermined paths. *Pilots should be very familiar with a particular flight mode before entering that mode*. For details on Spirit supported modes see the Flight Modes section of this manual.

### Flight Mode Availability

Several flight modes have restrictions on when they can be used. Flight modes such as RTL cannot be used for takeoff and flight modes such as LOITER and AUTO require an accurate GPS lock to use. Flight mode restrictions are detailed in their respective pages.

### Changing Mode on the Screen

Spirit's current flight mode can be seen in the toolbar across the top of the screen. A pilot can change the mode by pressing on the current flight mode to access a drop-down list of available flight modes. Selecting a mode from the drop-down list will activate the new flight mode.

After switching modes, the pilot should always look at the GCS and confirm that the vehicle entered the new flight mode. Flight mode changes may be rejected by the flight computer if the conditions needed to enter that mode are not met.

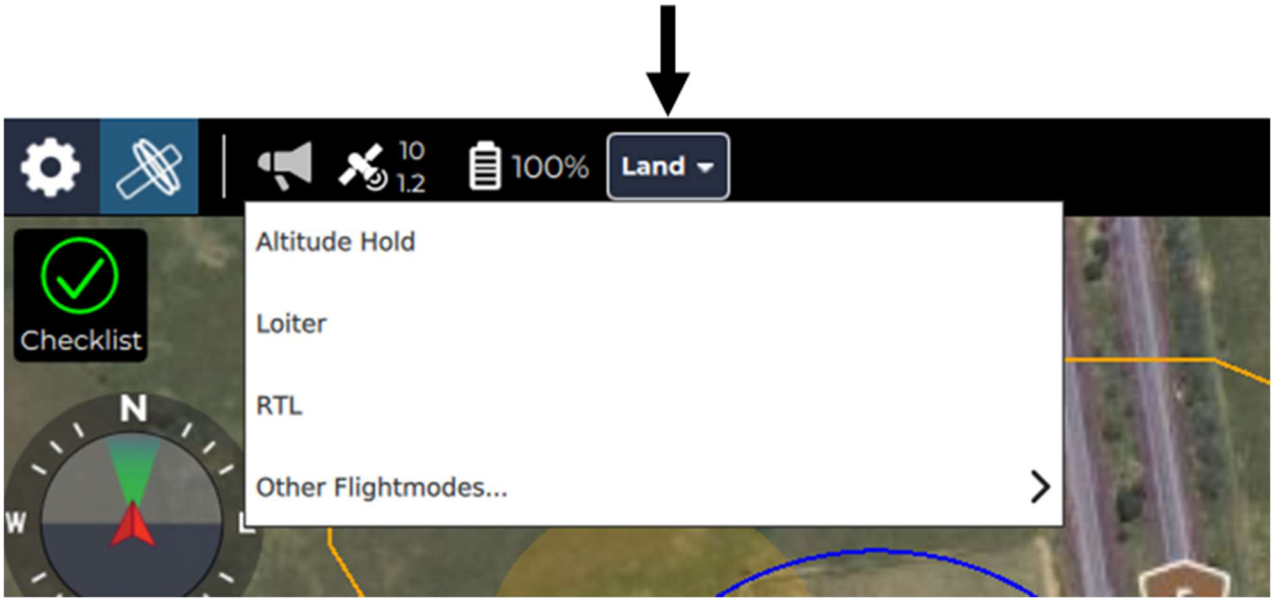



*Figure 25: Flight Mode Dropdown*

### Changing Mode with Physical Buttons

Flight modes can also be changed via physical buttons on most ground controllers. See the appropriate controller supplement for details. After switching modes, a pilot should always look at the GCS and confirm the vehicle entered the new flight mode.

### Changing Mode Due to Failsafes

The action taken when failsafes trigger is most often to switch flight modes. For example, a low battery failsafe will typically switch the aircraft into the Return-to-Launch (RTL) flight mode. Failsafe actions are set in the Vehicle Settings screen on the Safety tab. Pilots should be familiar with any flight modes selected as failsafe actions. For more detail on vehicle failsafes see the Failsafe Section of this manual.

### Failing to Change Flight Mode

If a Flight Mode is unavailable and the pilot attempts to switch into it, Spirit will remain in the previous flight mode. The pilot is notified by double flashing yellow LEDs and a message stating "flight mode change failed" sent to the GCS.

## CAMERA OPERATION

### On-Screen Controls

Several camera controls are available to the pilot via the widget on the right side of the screen by selecting the camera icon. These controls are tailored to the particular camera installed and require that the correct camera has been selected when configuring Spirit.


*Figure 26: Camera Controls*

Some cameras may have several pages of controls. The pilot can toggle between pages using the arrows at the top of the widget. These on-screen camera controls may also be assigned to buttons on the pilot's controller. See the appropriate controller supplement for details on button assignments.

## Tracking Functions

Several cameras available to Spirit have the ability to track an object in the frame. To start tracking, ensure the camera image is the primary display, then press on the part of the image to track. Most cameras will display a box around the subject then center the camera on the subject. The track can be continuously updated, corrected or refined by the pilot by repeatedly pressing on the image.

To break the track, the pilot only needs to manually pan or tilt the camera. Centering the camera will also break an active track. Zooming in or out will not break track.

## Fly the Camera

Fly-the-Camera is a setting that can be engaged anytime the pilot is flying manually with the sticks. It locks the vehicle's nose to the camera. With Fly-the-Camera engaged, aircraft controls are always relative to the video feed from the camera. This creates intuitive pilot inputs and is particularly helpful when manually tracking an object on the ground.

Fly-the-Camera can be engaged and disengaged using the 'camera lock' widget on the top right corner as shown in Figure 27.

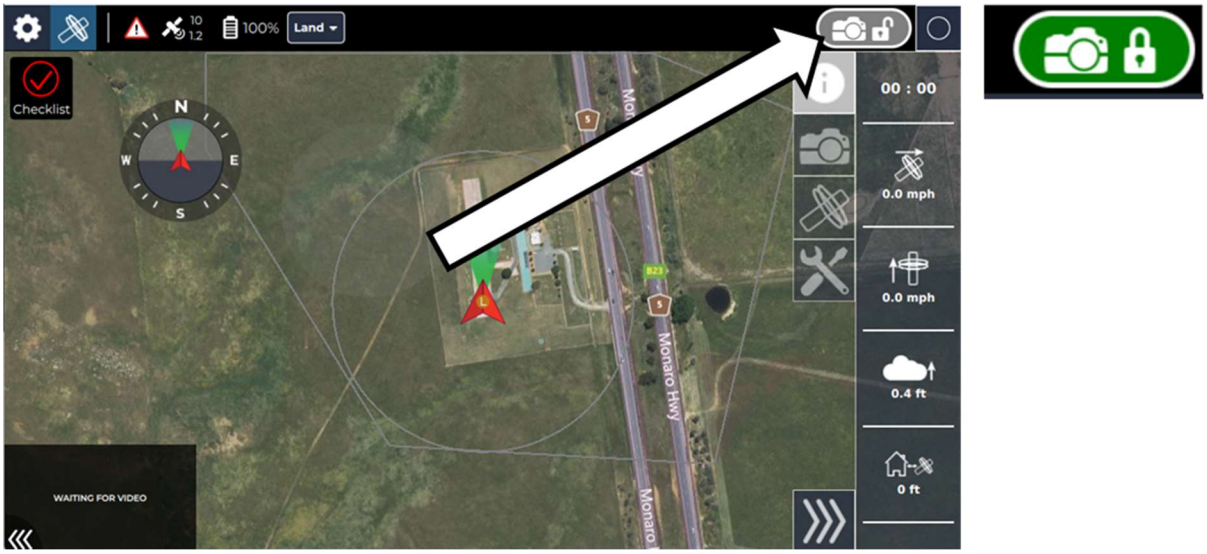



*Figure 27: Fly-the-Camera Setting*

**CAUTION**

In this mode the aircraft takes yaw and heading commands from the camera payload. If a pilot ever experiences uncommanded pirouetting or yaw instabilities Fly-the-Camera should be disengaged.

**CAUTION**

Pilots should be aware that with Fly-the-Camera engaged the vehicle will only yaw as quickly as the camera will pan. Because camera pan speed often decreases with increased zoom, pilots can experience a range of yaw performance during a mission.

## GEOFENCES

Sometimes known just as 'fences', geofences are predefined boundaries set by a pilot that a UAV will avoid crossing. These boundaries help prevent an operator from accidentally piloting Spirit into an area deemed off limits to the operation. Geofences should be considered as part of any flight operation.

Spirit's firmware, ArduCopter, supports a wide range of geofences and geofence options. This section discusses how to access these settings via AscentQ and assumes operators are already familiar with how ArduCopter implements and reacts to geofences.

ArduCopter geofence documentation (https://ardupilot.org/copter/docs/common-geofencing-landing-page.html).

| CAUTION |
| --- |
| Geofence options and behavior may differ depending on Spirit's ArduCopter firmware version. Contact support@ascentaerosystems.com for latest firmware files. |

| WARNING |
| --- |
| THERE IS NO GUARANTEE SPIRIT WILL NOT VIOLATE A SET GEOFENCE. DO NOT RELY ON GEOFENCES ALONE TO STAY AWAY FROM HARZARDS OR RESTRICTED AIRSPACE. |

Accessing Geofences

Geofence settings are in the 'fences' tab on the Plan View screen of AscentQ. Enter the Plan View by pressing on its icon in the top left of the Fly View. Then select the fences tab on the right.

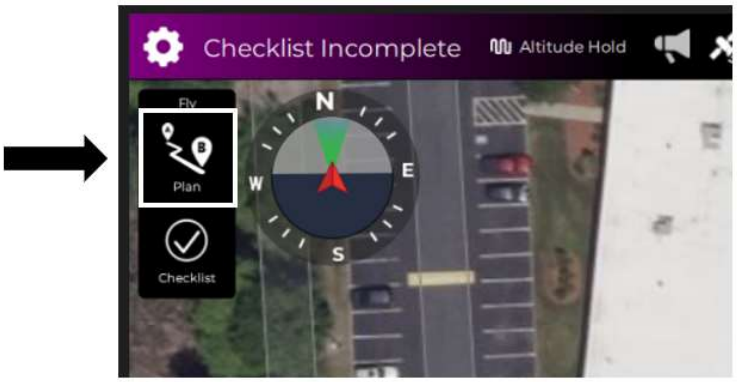



*Figure 28: Plan View Icon*

Geofence settings are also accessible in the Safety tab of the Vehicle Setup Screen, see Figure 29 below. Settable here is the action the vehicle should take if a geofence is violated. Pressing the 'edit fences' button opens the Plan View screen with the fences tab selected.

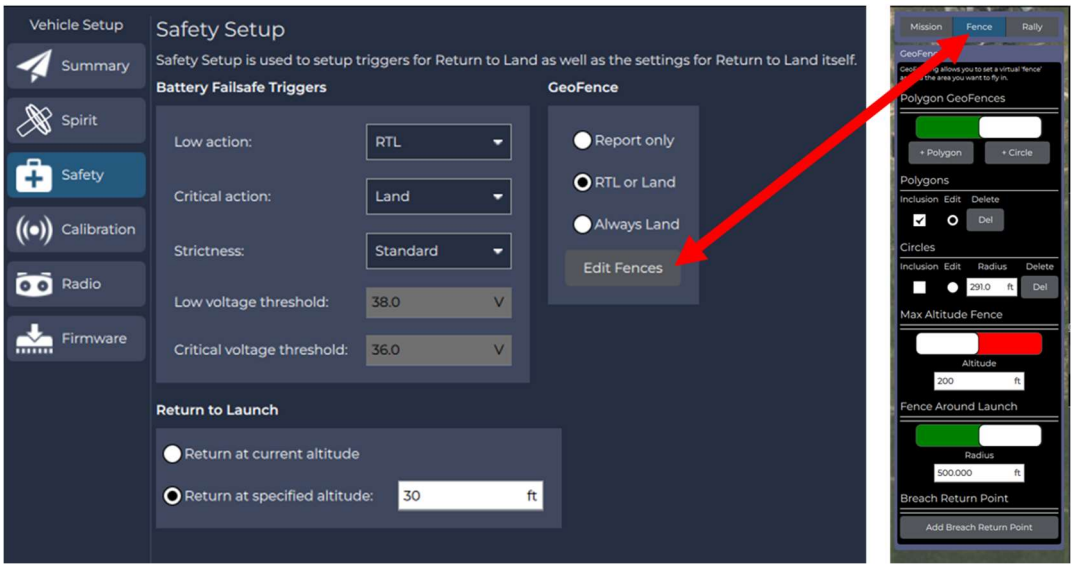



*Figure 29: Edit Fences Button and Fences Tab*

Three types of fences can be set: fence around launch, maximum altitude, and polygon. To enable a fence, toggle its associated slider to the right so it turns green.

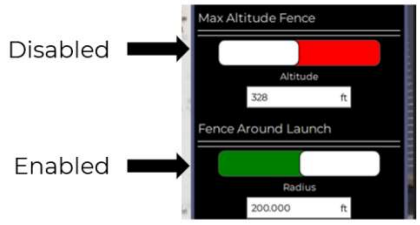



*Figure 30: Enable/Disable*

When enabled, the fence will appear as a blue boundary on the map. A disabled fence will be shown in grey. Altitude fences are not displayed.

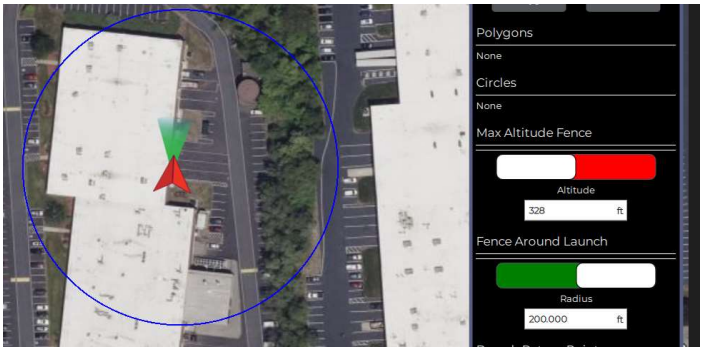



*Figure 31: Enabled 200ft Radius Fence*

It is good practice to test geofence settings at a location free of hazards prior to an operation to ensure fences are set correctly and will behave as expected.

## BATTERY FAILSAFE TRIGGERS

Battery failsafe triggers can be customized based on operational conditions and are accessible in the Safety tab of the Vehicle Setup Screen, see Figure 32 below. The user can set the actions for Low and Critical battery failsafe (see SECTION 6: for more information on battery failsafes). The user can also set the strictness of the battery failsafe between SAFEST, STANDARD, and RELAXED. The voltage thresholds will be automatically adjusted based on the strictness selected.

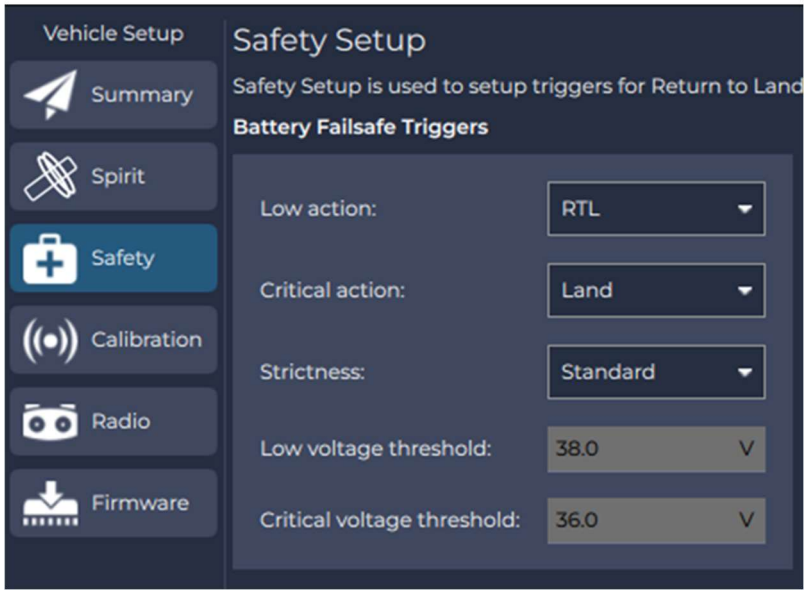



*Figure 32: Battery Failsafe Trigger Settings*

## CUSTOMIZING CONTROLLER BUTTONS

Most controllers can have their buttons and switches reassigned to create a custom setup for the pilot. The factory settings for each controller are discussed in their controller supplement to this manual.

Modifying Spirit's button and switch functions are done with the Button Assignment screen. This page is reached by opening the Vehicle Setup Page -> Joystick Tab -> Button Assignment.

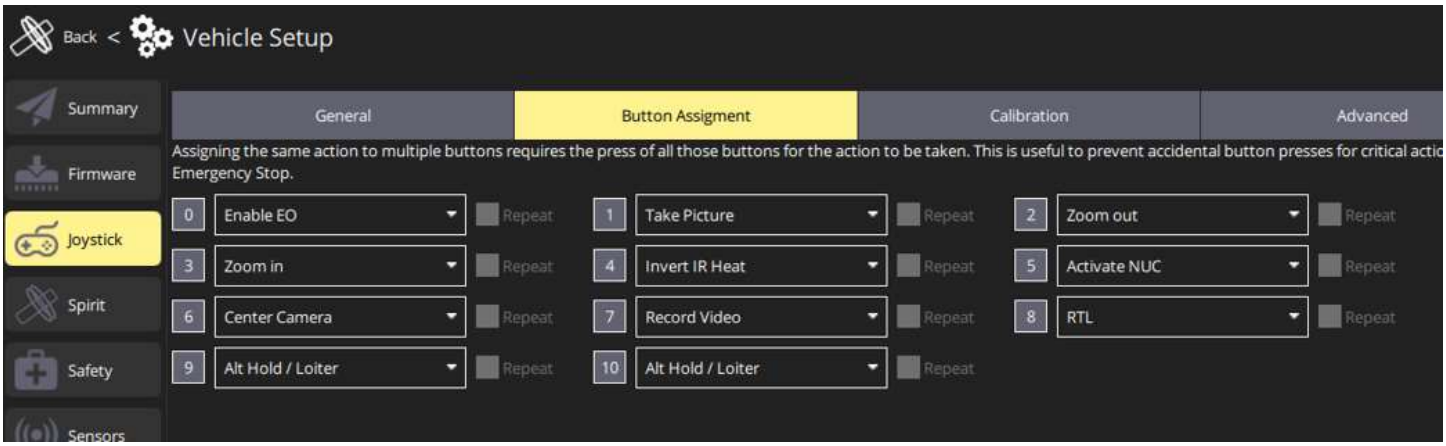



*Figure 33 Button Assignment*

Before reassigning a button, the pilot should be familiar with both the new function being assigned as well as the old function being replaced.

To determine which button on the controller is mapped to which drop-down menu, simply press the button and it will illuminate the corresponding drop-down list.

| WARNING |
| --- |
| NEVER REASSIGN A BUTTON WHILE IN FLIGHT |
| ALWAYS TEST A NEW BUTTON FUNCTION WHILE ON THE GROUND PRIOR TO FLIGHT |
| NEVER ASSIGN AN UNFAMILIAR FUNCTION TO A BUTTON |

## ADVANCED MODE

To access advanced functions and settings, AscentQ must be put into Advanced Mode. While connected to Spirit, press the gear icon in the top left corner of the screen to bring up the Tool menu. Then tap on the AscentQ version number displayed on the menu until a popup appears. Select 'yes' when prompted to enter Advanced mode.

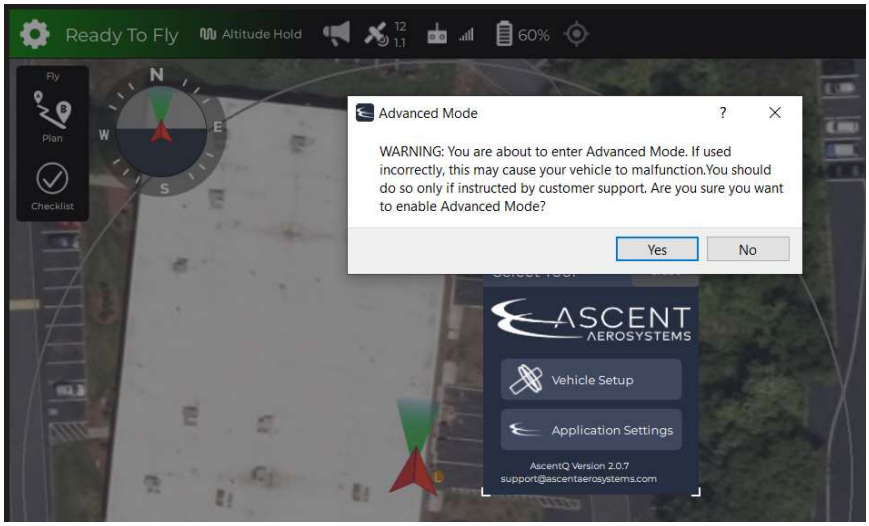



*Figure 34: Accessing Advanced Mode*

| WARNING |
| --- |
| THE FUNCTIONALITY ENABLED BY ADVANCED MODE SHOULD ONLY BE USED ACCORDING TO PROVIDED INSTRUCTIONS. |

## FLIGHT LOGS

Logs are saved on an SD card installed in the flight computer which is not physically accessible to an operator without disassembling the aircraft. However, these logs can be accessed electronically via the vehicle's USB port or wirelessly through a connected GCS. Once accessed, the logs can typically be saved, viewed, or deleted.

Spirit's default settings record this flight data once the vehicle is armed and stops recording when disarmed. A new log file is created each time Spirit's power is cycled.

### Accessing Logs

Once in Advanced Mode, press on the gear icon at the top left of the screen and then select Analyze Tools from the Select Tool menu.  Select the Log Download tab on the left, then press the Refresh button on the right to see the list of logs currently stored on Spirit.


*Figure 35: Flight Log Download Interface*

## VEHICLE PARAMETERS

Vehicle settings are known as parameters. Parameters which are frequently changed by a pilot are often incorporated into dropdown menus or text fields for easy manipulation on the GCS. However, there are hundreds of parameters, and all can be accessed and changed. Typically, parameters are displayed in a table as shown in Figure 36.

| | | |
|---|---|---|
| BAT_A_PER_V | 15.39103031 | Battery current per volt (A/V) |
| BAT_CAPACITY | -1 mA | Battery capacity |
| BAT_CNT_V_CURR | 0.00080566 | Scaling from ADC counts to volt on the ADC inp |
| BAT_CNT_V_VOLT | 0.00080566 | Scaling from ADC counts to volt on the ADC inp |
| BAT_CRIT_THR | 7 % | Critical threshold |
| BAT_EMERGEN_THR | 5 % | Emergency threshold |
| BAT_LOW_THR | 15 % | Low threshold |
| BAT_N_CELLS | 3S Battery | Number of cells |
| BAT_R_INTERNAL | -1.000 Ohms | Explicitly defines the per cell internal resistance |
| BAT_SOURCE | Power Module | Battery monitoring source |
| BAT_V_CHARGED | 4.05 V | Full cell voltage (5C load) |
| BAT_V_DIV | 10.17793941 | Battery voltage divider (V divider) |
| BAT_V_EMPTY | 3.40 V | Empty cell voltage (5C load) |
| BAT_V_LOAD_DROP | 0.30 V | Voltage drop per cell on full throttle |

*Figure 36: Parameter Table*

### Accessing Vehicle Parameters with AscentQ

To access vehicle parameters, enter Advanced Mode as explained above. Enter the Vehicle Setup screen. Note a new tab has populated named Parameters.

| WARNING |
|---|
| INCORRECTLY SETTING A VEHICLE PARAMETER CAN LEAD TO LOSS OF CONTROL DURING FLIGHT OR UNPREDICTABLE VEHICLE BEHAVIOR. USE EXTREME CAUTION WHEN MODIFYING PARAMETERS. ONLY MODIFY PARAMETERS IF THE EFFECTS ARE WELL UNDERSTOOD. |

## COMPASS CALIBRATION

Regardless of GPS quality, a healthy, well calibrated compass is critical for Spirit to hold its position or fly autonomous waypoints. Therefore, it is important for a pilot to assess the health of the compass both before and during operation. The best indication of compass health is if the vehicle's heading is being reported accurately. Pilots should check before takeoff if their heading is reported accurately on the GCS.

Note that this is part of the Spirit's preflight checklist. If the vehicle's actual heading and reported heading deviate by more than 15 degrees or if a pre-arm warning such as "inconsistent compasses" is reported on the GCS the operator should perform a compass calibration.

A compass calibration is performed using AscentQ by selecting the 'Calibrate' tab in the 'Vehicle Setup' page then pressing 'Compass' and 'Ok', see Figure 36 below. Compass calibration should be performed in an area free of metal or other sources of magnetic interference and the vehicle should be setup in its flight configuration with all batteries and payloads attached. Once started, the vehicle's LEDs will flash blue, green and red indicating that the calibration is running. While the calibration is running, the operator should pickup and rotate Spirit around each of its three axes. Continue to rotate Spirit until AscentQ reports that the calibration is complete, and the LEDs stop flashing their blue, green and red pattern. After calibration, the vehicle should be restarted. During the calibration, try not to rotate the vehicle's rotor blades as the magnets in the electric motors can compromise the calibration.

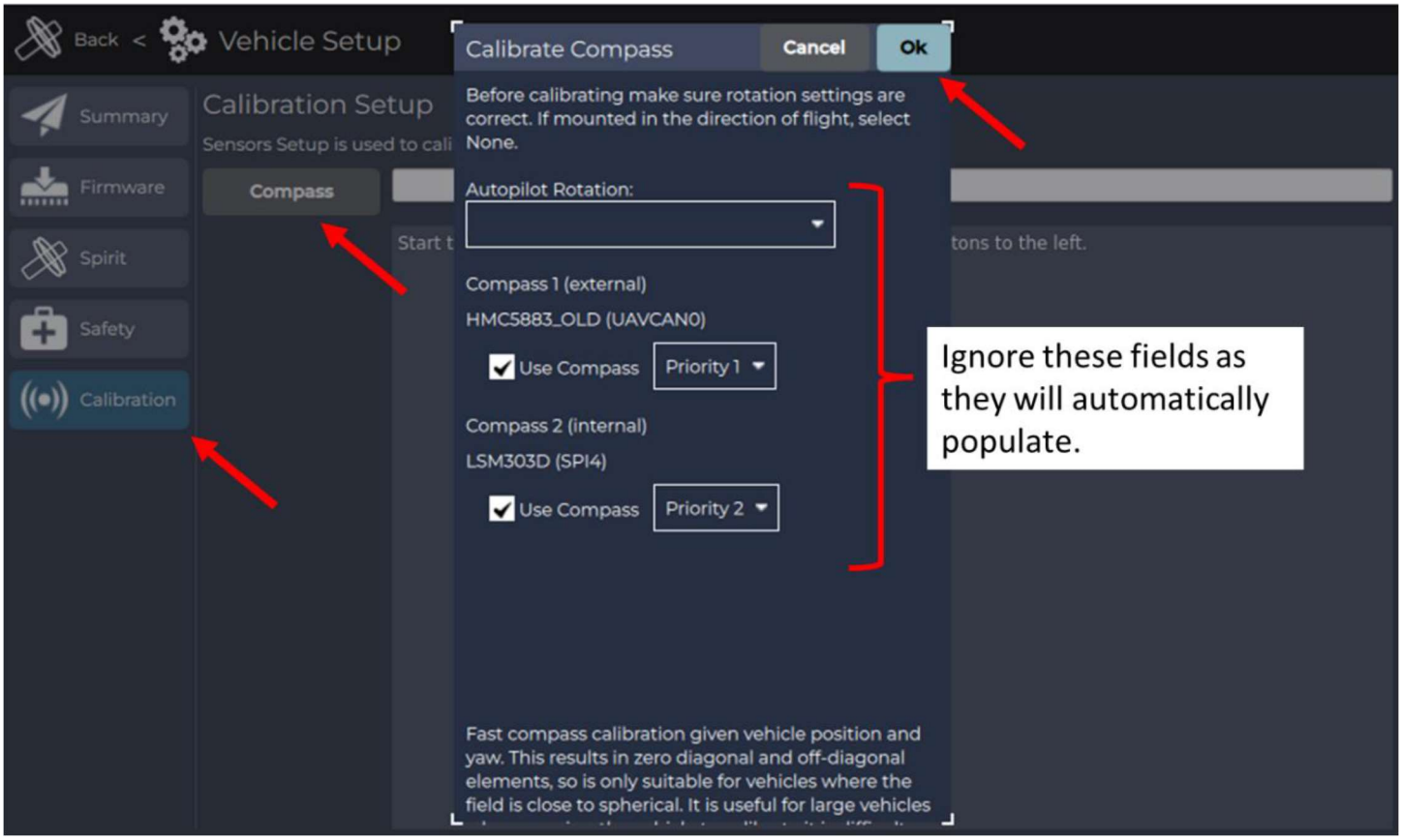



*Figure 37: Parameter Table*

# SECTION 5: FLIGHT BATTERIES

Flight batteries consist of 18650 Lithium-Ion cells and a Battery Management System (BMS) which ensures safe charging. Flight batteries mount to either the top or bottom of the Spirit Core. See Section 1 for proper placement of flight batteries.

## STATE OF CHARGE INDICATOR

On the bottom of each flight battery module is a state of charge (SoC) indicator made up of four LEDs and a red push button. The SoC indicator is activated by pressing and holding the red button, LEDs will illuminate to indicate the state of charge. The meaning of the LEDs can be seen in Figure 37 below.

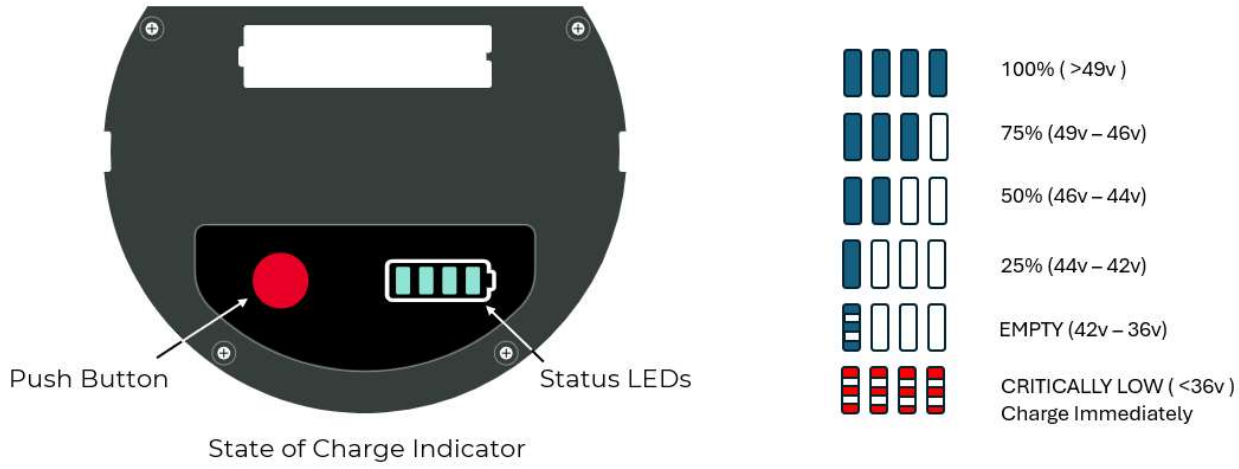



*Figure 38: State of Charge Indicator*

The battery's internal BMS draws a small amount of power as it monitors the cells. To prevent excessive drain of the battery, the BMS will power down once the battery voltage falls below a certain value. Batteries will not charge when the BMS is powered down. To wake up the BMS and enable charging the user must press the red SoC button.

| CAUTION |
| --- |
| Do not place batteries into storage at a state of charge less than 25%. Periodically check stored batteries to make sure their charge does not fall into the critically low range (<36v). Top-off batteries as necessary to 50%. Avoid storing fully charged batteries. |

| WARNING |
| --- |
| DO NOT STORE BATTERIES IN EXCESSIVELY HOT OR COLD ENVIRONMENTS.<br><br>USERS SHOULD FAMILIARIZE THEMSELVES WITH PROPER HANDLING AND STORAGE OF LITHUM ION BATTERIES.<br><br>SHIPMENT OF LITHIUM-ION BATTERIES IS LIMITED BY LAW. FOLLOW ALL REGULATIONS FOR PREPARATION, PACKING AND SHIPPING BATTERIES. |

## CHARGING

Spirit flight batteries should only be charged using Ascent provided chargers. These chargers provide up to 6A at 50.4v.

Prior to operating an Ascent provided charger:

- Inspect the charger and its cords for damage.
- Ensure the dip switch on the charger is properly set for either 220v or 110v AC.
- Ensure the rocker power switch is set to the OFF position.

To charge a Spirit flight battery:

- Plug the charger into an AC outlet and turn the charger ON with the rocker switch.
- Once powered, LED1 (red) and LED2 (green) will illuminate on the front of the charger.
- Press the red SoC button on the battery.
- Plug the charger's barrel connector into the barrel port on the battery.
- After approximately 5 seconds, the charger's internal fan will start and LED2 will turn red indicating the battery is being charged.

Periodically, the charger will pause charging so the battery's BMS can check the status of its cells. During this time LED2 will turn green for approximately 2 seconds.

Periodically, the battery's BMS may need to balance its cells or wait for the pack to cool if its temperature is elevated. During this time, LED2 on the charger will turn green indicating that charging is interrupted.

Charging is complete when LED2 remains green for longer than 5 minutes and the battery's SoC indicator illuminates four blue LEDs.

If LED2 remains green for an extended period while the charger is connected to a battery and the SoC indicator does not indicate a full battery, it may indicate an error state with the battery. Discontinue use of the battery and charger and contact Ascent support.

| CAUTION |
| --- |
| Before powering the charger, make sure the proper AC voltage is set using the dip switch on the back of the charger. |

| WARNING |
| --- |
| CHARGING BATTERIES SHOULD NOT BE LEFT UNATTENDED.<br><br>THE USE OF A FIREPROOF CONTAINER OR BAG WHILE CHARGING IS RECOMMEDED. |

# SECTION 6: FAILSAFES & VEHICLE RECOVERY

Spirit failsafes are triggered by the following conditions:

- Low battery
- Critical battery
- Loss of communication between the aircraft and GCS
- Loss of position estimate

Some settings associated with these failsafes can be viewed and modified in the Safety tab on the Vehicle Setup Screen.

This section assumes the reader is familiar with the failsafes implemented in ArduCopter firmware. Do not operate Spirit unless you understand these failsafes and their settings (https://ardupilot.org/copter/docs/failsafe-landing-page.html).

| CAUTION |
| --- |
| A common response to a failsafe is for the vehicle to switch into the RTL flight mode. A pilot must be aware:<br><br>If Spirit does not have adequate 3D position lock, RTL will fail to activate, and Spirit will switch into the LAND flight mode.<br><br>RTL will fly in a straight line back to HOME regardless of obstacles in the way. The RTL altitude must always be set higher than the highest obstacle in the possible flight area. |

| CAUTION |
| --- |
| The default actions initiated in the event of a failsafe event can be altered by the Operator at any time in the vehicle settings. Before each flight be sure to verify the failsafe action selected for each error is appropriate for the location and conditions. Inappropriate or delayed response by the Operator can result in loss of control of the aircraft. |

## BATTERY FAILSAFE

Spirit's battery failsafe is triggered when available battery power falls below preset thresholds. The first threshold is known as a 'Low Battery Failsafe' and should be set to activate well before the battery is exhausted with enough remaining power to fly HOME and safety land with some reserve. The second threshold is known as a 'Critical Battery Failsafe' and should be set to activate when there is just enough power remaining to immediately land.

Battery failsafes are triggered by the battery voltage dipping below a preset value for more than 5 seconds. They are not triggered by an estimate of the power needed to return HOME or by the percentage displayed on the AscentQ toolbar. While Spirit comes with default failsafe voltage levels, it should not be assumed these are appropriate for your operations. Operators should also understand that environmental factors can evolve during a flight that might significantly change how much battery power is required to safely return and land.

WARNING

FAILSAFE MODES ARE TRIGGERED BY THE BATTERY VOLTAGE LEVEL ONLY, WITH NO CONSIDERATION GIVEN TO THE ENERGY REQUIRED TO RETURN TO THE HOME POSITION OR LAND.

Figure 38 below shows a simulated flight battery discharge curve for a Spirit with a TOW of approximately 9.5 lb flying with a single battery. This figure is presented only to facilitate this discussion and should not be assumed accurate. Assuming battery failsafes are set to their default values, the Low Battery failsafe would trigger at 38v leaving approximately four minutes before total battery exhaustion. The Critical Battery failsafe would trigger with approximately 2 minutes remaining before total battery exhaustion. For a Spirit set with the default speed limit of 15 m/s forward velocity and 2 m/s decent rate

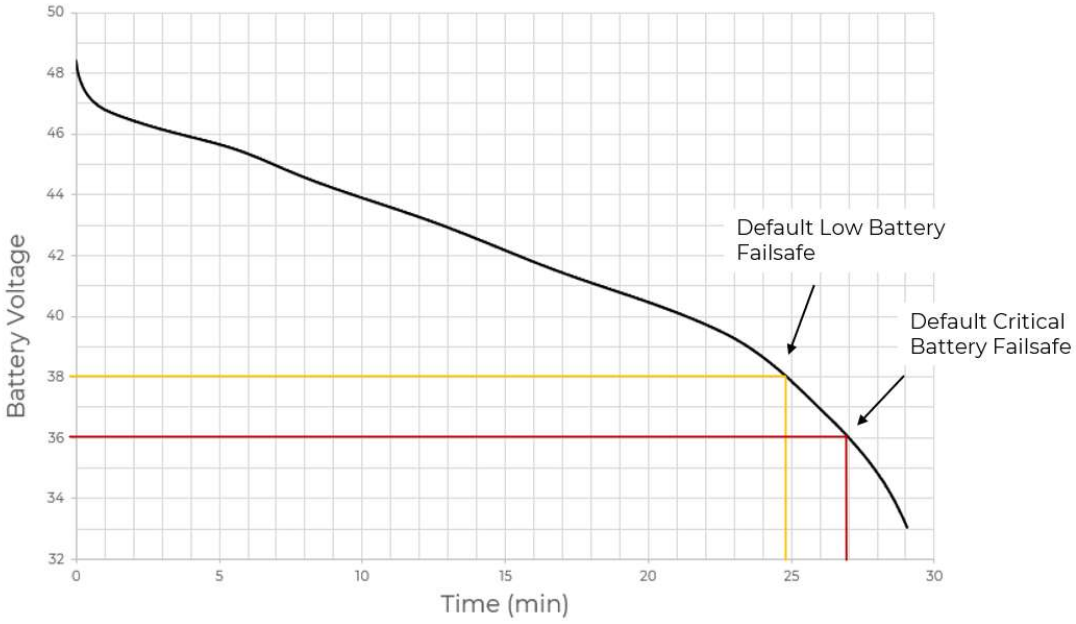



*Figure 39: Flight Battery Discharge*

Vehicle default action, Low Battery: Flight Mode Change -> Return-to-Launch (RTL)

Vehicle default action, Critical Battery: Flight Mode Change -> LAND

## LOSS OF LINK

This failsafe is triggered if communication is lost between the aircraft and the GCS, even briefly. If lost, it is common for the vehicle to reestablish communication quickly after losing it. If a Loss-of-Link is experienced at short range with no reasonable explanation a pilot should assume a malfunction and land even if connection is restored.

Vehicle default action: Flight Mode Change -> Return-to-Launch (RTL)

## LOSS OF POSITION ESTIMATE

To hold position or navigate between waypoints requires sensors that can provide a global position estimate and a vehicle heading. The sensors that typically provide these measurements are a GPS receiver and a digital compass. If either is compromised, a loss-of-position failsafe may trigger.

The default action: Flight Mode Change -> ALT-HOLD

## VEHICLE RECOVERY

Operators should be familiar with basic in-air vehicle troubleshooting and recovery. These skills are necessary if the orientation, position, or flight path of the vehicle is at any point uncertain or if the pilot experiences confusion about the vehicle's behavior.

### Gather Information

Often, confusion about vehicle behavior can be cleared by examining the GCS. When conducting in-air troubleshooting the pilot should start by checking the following items in order:

1. Radio Link Status
2. Current Flight Mode
3. Active Failsafes

Checking the radio link first ensures the data you'll be checking on the GCS is up to date. If the radio link status is not clear, checking if telemetry values are updating.

### Recovery Techniques

If confusion remains, the pilot should consider the following recovery techniques.

1. Press the RTL button

   If the radio link to Spirit is still active, GPS is available and flight is stable, activating the RTL flight mode is likely the best option. After activating RTL, confirm on the GCS that the flight mode has switched and closely monitor Spirit to ensure it is behaving as expected. Note, that if below the minimum RTL altitude (default 30 meters), Spirit will climb before returning. It might take several seconds for Spirit to begin flying HOME.

   Consider the next recovery technique if:

- Spirit fails to enter RTL
- RTL flight behavior is abnormal
- RTL is unavailable due to poor GPS fix

2. Take Manual Control with ALT-HOLD

   The ALT HOLD flight mode requires only a limited number of sensors to operate, making it a good candidate flight mode to perform vehicle recovery.

   - Switch to ALT-HOLD flight mode
   - Yaw Spirit until its back if facing the pilot. Confirm with GCS telemetry or using Spirit's onboard orientation LEDs. While in flight, Spirit's front two LEDs are white and the back two LEDs are either blue or green. Active failsafes may change these colors.
   - Pull back on the right joystick to fly Spirit back to the operator. Climb as necessary to avoid objects along the flight path.

# SECTION 7: FLIGHT MODES

Spirit's flight control software is organized around *flight modes*. It is essential that a Spirit pilot understands the details of these modes. Spirit pilots should review ArduCopter's documentation on all flight modes discussed in this manual prior to operation: https://ardupilot.org/copter/docs/flight-modes.html

While dozens of flight modes are available, Ascent only supports the subset listed below:

- ALT-HOLD
- LOITER
- AUTO
- GUIDED
- CIRCLE
- RTL

## ALT-HOLD

Control Type: Manual Joystick control

GPS Required: No

The altitude hold (ALT-HOLD) flight mode is the default flight mode Spirit enters on boot up.

As the name suggests, altitude hold will hold the Spirit's current altitude if the left joystick remains centered. Raising the joystick will command Spirit to climb, while lowering the joystick will command Spirit to descend. The climb and descent rate are proportional to the deflection of the joystick.

Climb and decent speeds are software limited but can be modified.

**Climb Speed:** 4.0 m/s

**Decent Speed:** 2.0 m/s

In ALT-HOLD, the right joystick commands roll and pitch lean angles. The greater the joystick deflection the larger the commanded angle the vehicle will lean to a maximum of 30 degrees. When the joystick is centered Spirit will remain upright with zero roll or pitch lean angle.

| CAUTION |
| --- |
| This flight mode does not utilize GPS or other navigation sensors during flight, and thus, Spirit will drift primarily due to the wind, and not hold a geographic position without constant input from the pilot using the right joystick. |

A strength of the ALT-HOLD flight mode is its simplicity. Because it is not dependent on a GPS fix and a healthy compass, it is less vulnerable to failing sensors or nearby sources of interference. This makes it the recommended flight mode for takeoff or if problems are encountered during flight. Altitude Hold is

typically a default physical button on a Ground Controller so it is quickly assessable to the pilot.  All Spirit operators should be confident flying in ALT-HOLD.

### Takeoff

Once Spirit is armed, a pilot in ALT-HOLD commands takeoff by raising the left joystick above mid-stick. The greater the deflection, the higher and more aggressive the takeoff. A pilot should be prepared to take immediate manual control as the vehicle will not automatically hold its position.

ALT-HOLD is a good option for takeoff when:

- there are light winds.
- magnetic interference may be high at the takeoff site.
- there is poor GPS coverage at the takeoff site.

## LOITER

### Control Type:  GPS-aided joystick control

### GPS Required: Yes

LOITER is a GPS assisted, manual flight mode. While in LOITER, Spirit will maintain its current altitude and location if both joysticks are centered.

Raising and lowering the left joystick will cause Spirit to climb or decent proportional to the joystick's deflection. Climb and decent speeds are software limited but can be modified.

**Climb Speed:** 4.0 m/s

**Decent Speed:** 2.0 m/s

Moving the right joystick will command the vehicle to move horizontally at a speed proportional to the joystick's deflection. Releasing the joystick will cause Spirit to slow to a stop and maintain its current position. Ground Speed is software limited but can be modified.

**Ground Speed:** 15.0 m/s

The strength of LOITER is its ease of use. While in LOITER, a pilot only needs to leave the right joystick centered to maintain a location even in high winds.

Being a GPS dependent flight mode leaves LOITER susceptible to failing sensors or environmental influences. If a pilot experiences Spirit not properly maintaining its location or appears to excessively wonder from or orbit that location, the pilot should switch to ALT-HOLD until the problem can be resolved.

### Takeoff

A pilot in LOITER commands takeoff by raising the left joystick above mid-stick. The greater the deflection the higher and more aggressive the takeoff. LOITER will work to maintain the vehicle's 2D position during the takeoff.

LOITER is a good option for takeoff when:

- wind speeds are high.
- there is good GPS coverage at the takeoff site.

| CAUTION |
| --- |
| A pilot taking off in LOITER should be prepared to switch to ALT-HOLD if the vehicle's GPS or compass fails during takeoff. |

## RETURN TO LAUNCH (RTL)

Control Type: Fully Autonomous

GPS Required: Yes

This flight mode takes control of Spirit and flies it back to its takeoff location, then lands and disarms the aircraft.

Climb Speed: 4.0 m/s

Decent Speed: 2.0 m/s (0.75 m/s at final phase)

Ground Speed: 15.0 m/s

RTL can be activated by the pilot as a convenient way to have Spirit return and land. RTL can also be activated by Spirit's flight computer as the result of a triggered failsafe. When RTL is activated, Spirit will stop forward travel and climb to a predefined altitude then briefly pause before returning HOME. Once it is hovering over its takeoff location, Spirit will descend at 2.0 m/s until 12.0 meters from touchdown where it will slow to 0.75 m/s.

| CAUTION |
| --- |
| If spirit does not appear to slow when approaching the ground, the pilot should take manual control and complete the landing. Pilots should always monitor RTL and be prepared to take manual control at any moment. |

While landing RTL allows pilot input via the right joystick to modify the landing spot. Also, raising the throttle while landing in RTL will cancel the landing and switch Spirit to the LOITER flight mode.

The return altitude can be set by the pilot prior to takeoff via the ‘Safety’ tab in AscentQ. The return altitude should be set to ten meters above the highest object in the operational area.

| WARNING |
| --- |
| RTL WILL NOT AVOID OBSTACLES WHILE RETURNING. SPIRIT WILL TAKE A DIRECT PATH FROM ITS CURRENT LOCATION TO ITS TAKEOFF LOCATION. TAKE IMMEDIATE MANAUL CONTROL IS SPIRIT'S RETURN PATH IS OBSTRUCTED. ALWAYS CHECK THAT THE RTL MINIMUM ALTITUDE AS BEEN SET TO A VALUE HIGHER THAN THE TALLEST OBSTACLE IN THE FLIGHT AREA. |

Being a GPS dependent flight mode leaves RTL susceptible to failing sensors or environmental interference. Always monitor RTL's return flight and take manual control with ALT_HOLD if problems arise.

RTL is typically a default physical button on a Ground Controller so it is quickly assessable to the pilot.

## AUTO

Control Type: Fully Autonomous

GPS Required: Yes

This flight mode takes control of Spirit and flies a predefined mission constructed from waypoints. Only yaw control is available via the pilots joysticks.

Please see QGC's documentation on preprograming waypoints:
https://docs.qgroundcontrol.com/master/en/PlanView/PlanView.html

Speeds are software limited but can be modified.

**Climb Speed:** 4.0 m/s

**Decent Speed:** 2.0 m/s

**Ground Speed:** 15.0 m/s

## GUIDED

Control Type: Fully Autonomous

GPS Required: Yes

This flight mode takes control of Spirit and flies it to a location identified on the GCS map. To activate, press on a location on the GCS map and swipe to confirm.

Speeds are software limited but can be modified.

**Climb Speed:** 4.0 m/s

**Decent Speed:** 2.0 m/s

**Ground Speed:** 15.0 m/s

Most Ground Control Station (GCS) Software allows the pilot to select a point on a map and autonomously send the UAV to that location. When commanded, Spirit will enter the GUIDED flight mode, ignore all joystick inputs and proceed at the current altitude. Spirit will exit the GUIDED flight mode once reaching its destination.

# SECTION 8: WEIGHT AND BALANCE

While generous and not easily exceeded using typical combinations of batteries and payloads, the Operator must ensure that the center of gravity is within limits before each flight.

## RECOMMENDED CG RANGE

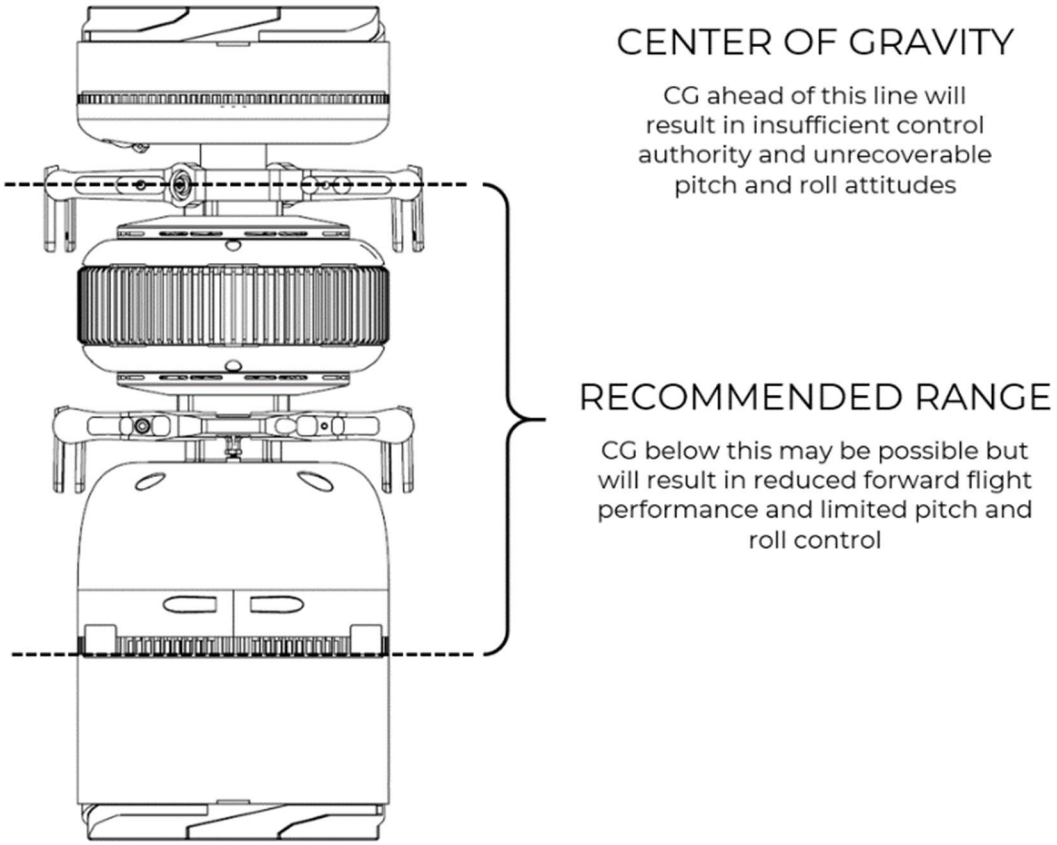



*Figure 40: Aircraft CG Range*

# SECTION 9: HANDLING, SERVICING & INSPECTION

This section contains the factory recommended procedures for proper ground handling, routine care and regular inspection of Spirit. These procedures must be followed if the aircraft is to maintain its designed performance and reliability. It is important to follow a planned schedule of inspections and preventative maintenance based on the climatic and flying conditions in the areas in which the aircraft is operated and stored. Recommended inspections are detailed in the Field Inspection Manual.

Support is available via email at: support@ascentaerosystems.com

This Aircraft Flight Manual describes the Spirit as it was manufactured. It is a highly configurable system, and Ascent AeroSystems has no way of knowing the status of the aircraft after it has entered service with the Operator. For this reason, the operating procedures and information provided in this manual may no longer be accurate for the modified aircraft. Note that the procedures provided in this section do not apply to accessories or products manufactured by other parties. Refer to the information provided by the OEM for each product.

## DISASSEMBLY

There are no user-serviceable parts inside the Spirit Core. Do not remove the forward or aft covers. Contact Ascent AeroSystems for technical support.

## NORMAL HANDLING

| CAUTION<br><br>Keep hands and face away from a Spirit core when a flight battery is installed. |
|---|

The Spirit is designed to be operated in difficult environments, but reasonable care must be taken to prevent damage to the aircraft and its accessories. To help keep your core, batteries, payload modules and accessories in proper operating condition, please observe the following:

- If indoors, remove the rotor blades before powering the core with a flight battery.
- Prevent the Core, batteries, and all modules from falling onto a hard surface.
- While resistant to particulates and water when assembled, the electrical contacts and mating interfaces of the Core and modules are not waterproof when disassembled.
- Do not manually deflect (back drive) the servos.
- Do not leave the core powered and idle for extended periods of time.
- Do not immerse core, batteries, payload modules and accessories in water.
- Do not allow the aircraft to remain in a wet or high-humidity environment for extended periods.

## ROUTINE INSPECTIONS

See the Field Inspection Manual for details about the routine inspection of Spirit.

# SECTION 10: ABBREVIATIONS & ACRONYMS

AGL.....Height Above Ground Level
EKF.....Extended Kalman Filter[4]
ESC.....Electronic Speed Controller
GCS.....Ground Control Station
GPS.....Global Positioning System
MSL.....Height above Mean Sea Level
RTL.....Return to Launch (flight mode)
SBAS.....Satellite based Augmented System
UAS.....Unmanned Aerial System
UAV.....Unmanned Aerial Vehicle

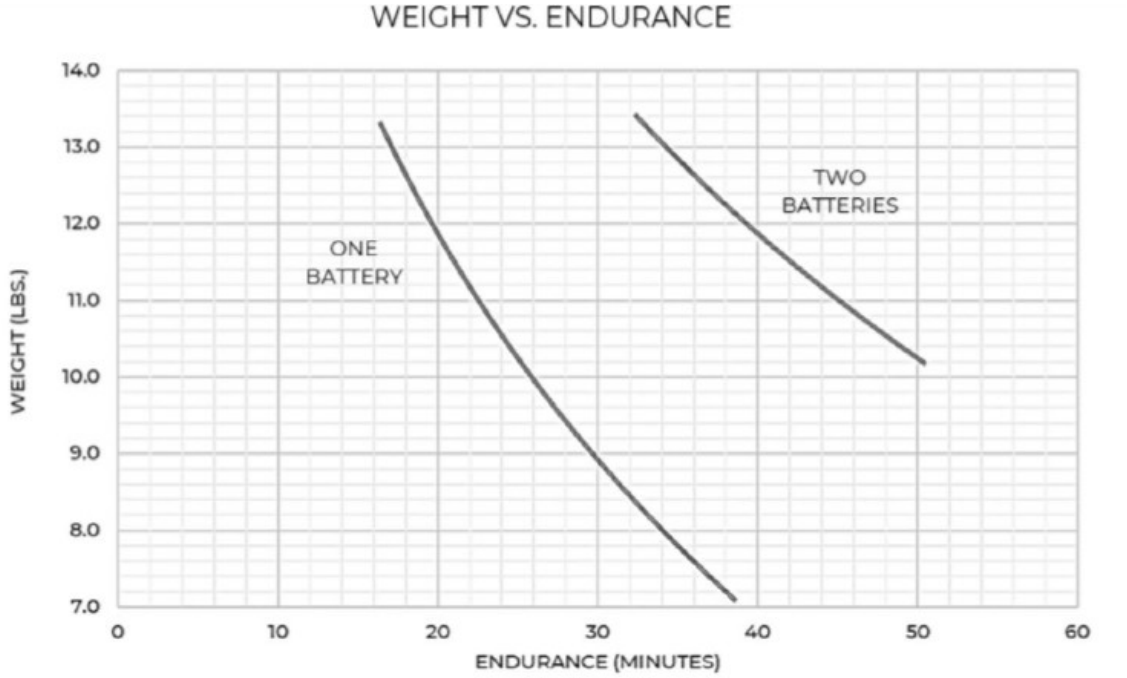
[4] algorithm to estimate vehicle position, velocity and angular orientation based on rate gyroscopes

# SECTION 11: REVISION LOG

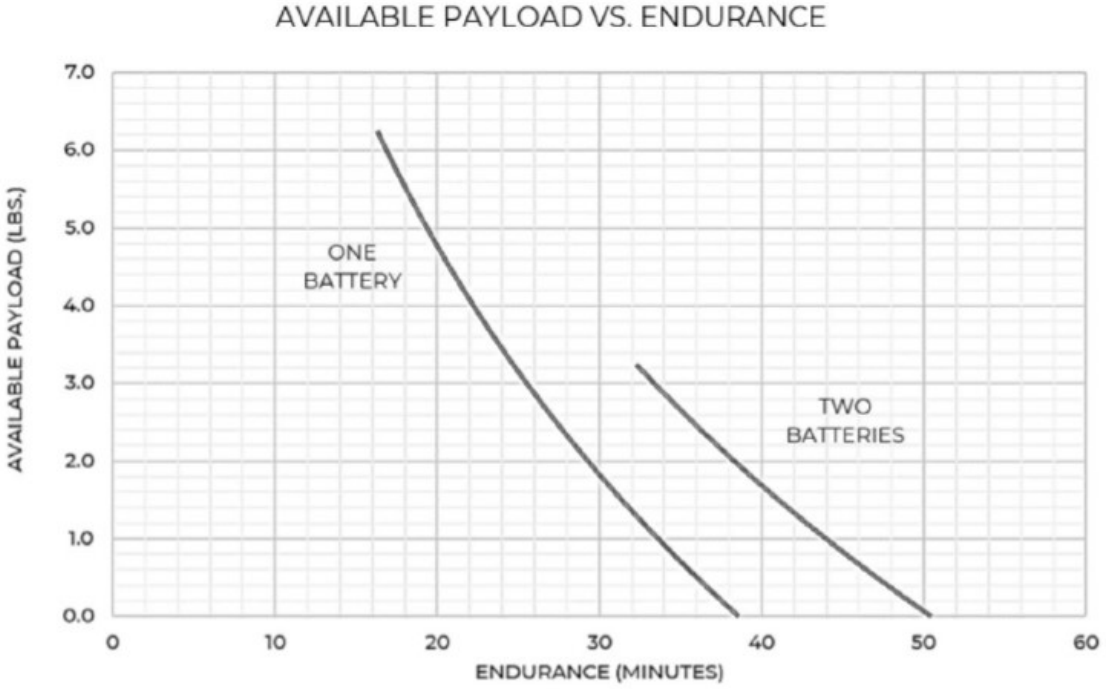
| Revision | Date | Change Type |
|---|---|---|
| 2.0.0 | 12/21/2023 | Initial release of 2.0.0 |
| 2.1.0 | 07/09/2024 | Addition of battery and charger section. Addition of Supplements. |
| 2.1.1 | 10/1/2024 | Added Compass calibration to AscentQ Section |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

# SUPPLEMENTAL 1: BSLI-6000, BATTERY PERFORMANCE

The following performance curves are for Spirit's 270 Watt-Hour flight batteries. Note that these curves assume the aircraft is discharging the batteries to exhaustion.




SEA LEVEL, ISA, NO WIND, AIRSPEED 7 M/S - 15 M/S, NO RESERVE POWER




SEA LEVEL, ISA, NO WIND, AIRSPEED 7 M/S - 15 M/S, NO RESERVE POWER

# SUPPLEMENTAL 2: NAVIGATOR TAB3 GROUND CONTROL STATION

## DESCRIPTION

The Navigator Tab3 Ground Control Station (GCS) provides integrated flight control and video display in a single unit. This GCS is built on top of the Samsung Galaxy Tab Active3 tablet, running an Android operating system in an IP65 case. Operator input is captured with two joysticks, two 5-direction buttons and two momentary push buttons all identified in Figure 40.


SUPPLEMENTAL 1:

*Figure 41: UXV Navigator Tab3 GCS*

## NAVBAY RADIO MODULE

A Navigator Tab3 is typically paired with a bolt-on radio module known as the NavBay also manufactured by UXV Technologies. This module contains a radio, antenna connectors (SMA) and a pair of lithium-ion batteries for power. The NavBay can accommodate various radios. For radio details please reference the appropriate radio supplement. The NavBay for a Microhard pMDDL is shown in Figure 41.


*Figure 42: NavBay with Antennas*

## OPERATION

| WARNING |
| --- |
| NEVER TURN ON THE NAVIGATOR TAB3 *WIFI* WHILE IN FLIGHT.<br>ENABLING WIFI WILL CAUSE LOSS-OF-LINK WITH THE AIRCRAFT. |

| WARNING |
| --- |
| MINIMIZING OR EXITING ASCENTQ WILL CAUSE LOSS-OF-LINK WITH THE AIRCRAFT. |

| CAUTION |
| --- |
| Never power the NavBay without antennas installed.<br>Do not remove or install antenna when the NavBay is powered. |

### Powering On

The Tab3 GCS and the NavBay Radio Module have separate power buttons.

*Tab3 GCS*

Press and hold the power button. On bootup, the Tab3 will prompt the operator for login credentials. As shipped, these credentials are set to the defaults shown below. It is highly recommended that operators change these default login credentials to unique values consistent with their security policies.

Password: pilot

*NavBay Radio Module*

The NavBay cannot be powered until *after* the Tab3 GCS has booted up. Hold the power button on the radio module down until the BLUE light comes on (middle Status LED), which indicates the radio is on. Note, the radio module will automatically power off when the tablet is turned off. It is recommended to power down the NavBay when not operating the Spirit to conserve battery.

## Default Button Assignments

| INPUT | FUNCTION |
|---|---|
| 1 | Activate RTL Flight mode |
| 2 | Toggle between Alt-Hold and Loiter Flight Modes |

| Left D-Pad | FUNCTION |
|---|---|
| ↑ | Tilt Camera Up |
| ↓ | Tilt Camera Down |
| → | Pan Camera Right |
| ← | Pan Camera Left |
| PRESS | Center Camera |

| Right D-Pad | FUNCTION |
|---|---|
| ↑ | Zoom In |
| ↓ | Zoom Out |
| → | IR Camera Calibration (NUC) |
| ← | Toggle EO/IR cameras |
| PRESS | Take Picture |

## Charging

Both the Tab3 GCS and NavBay charge though a single USB-C port on the side of the TAB3. While charging, the state of charge of the table will be displayed on its screen and the state of charge of the NavBay will be displayed by its four green State of Charge LEDs. Note, the first of these green LEDs is grouped with the Status LEDs (see Figure 41).

# SUPPLEMENTAL 3: HERELINK GROUND CONTROL STATION

## DESCRIPTION

The Herelink is an android based ground station controller which provides flight control and video display in a single, lightweight unit. The system has an integrated proprietary radio, battery and antennas. The Herelink is shown in Figure 42 below.

*Figure 43: Herelink GCS*

The Herelink is supported by its manufacturer CubePilot. Details including operating instructions, limitations, warnings, handling, and maintenance can be found at the OEMs' website. Operators should be familiar with the OEM's documentation.

https://docs.cubepilot.org/user-guides/herelink/herelink-overview

| CAUTION |
| --- |
| Only update the software installed on the Herelink at the direction of Ascent AeroSystems. |
| Do not change the Herelink's default settings without the direction of Ascent AeroSystems |

## OPERATION

### Powering On

The Herelink is powered on and off by pressing and holding the power button on the front of the unit.

## Default Button Assignments

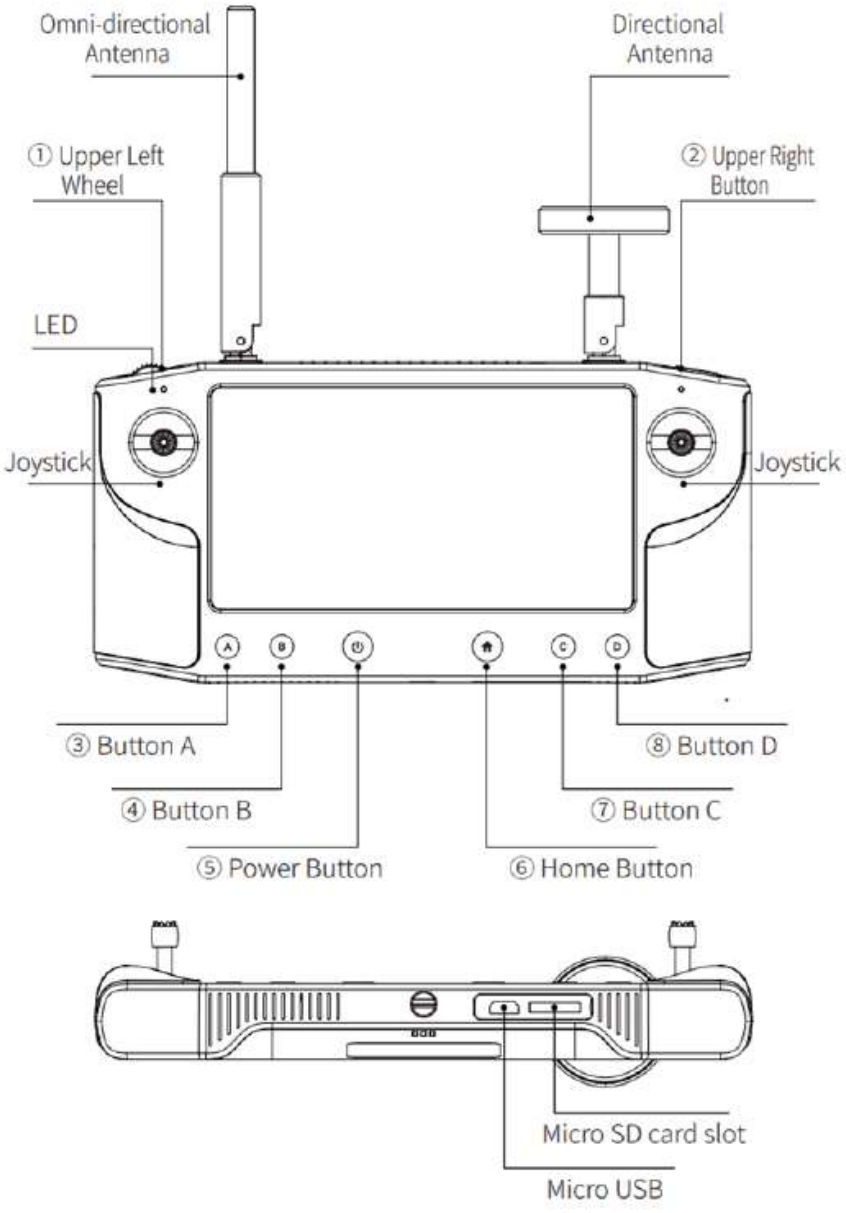



*Figure 44: Button Identification*

| Button | Short Press | Long Press |
|---|---|---|
| A | Center Camera | Enable/Disable Spirit LEDs |
| B | EO/IR Camera Sensor | NUC IR Sensor |
| C | Toggle between Alt-Hold and Loiter | Guided Mode |
| D | N/A | **DISARM |

** Requires the throttle joystick to be held down while disarming

The button with an icon of a House will switch the vehicle to the RTL flight mode (see AFM).

## Camera Operation

Pressing and holding the Upper Right Button (see Figure 44) allows the operator to pan and tilt an attached camera with the left joystick. The scroll wheel on the left side of the controller controls camera zoom level.

*Figure 45: Herelink Camera Control*

| CAUTION |
| --- |
| While the Upper Right Button is depressed for camera control, the pilot will not be able to manually yaw or change the aircraft's altitude with the left joystick. |

## Charging

The Herelink is charged via the micro-USB connector on the bottom of the unit.

## Herelink WiFi

The Herelink will only connect to 5GHz networks.

## Video and Telemetry Tethering

The Herelink can be tethered via WIFI or a USB cable to stream video and telemetry data to GCS software running on a PC. CubePilot documents the process for streaming to QGroundControl, MissionPlanner and VLC. https://docs.cubepilot.org/user-guides/herelink/herelink-user-guides/share-video-stream

# SUPPLEMENTAL 4: PMDDL2450, MICROHARD RADIO

## DESCRIPTION

The pMDDL is a digital data link manufactured by Microhard for data and video communications between the Spirit and GCS. While many frequencies are available, Ascent typically integrates the pMDDL2450 version on 2.4GHz.

Ground-side radios are often integrated with the UXV Navigator Tab3 GCS via the NavBay. See the Navigator Tab3 Supplemental for more details about these components. The air side radio is often integrated into a radio module that is then connected to the Spirit.


*Figure 46: pMDDL2450*

Notable features:

- 2X2 MIMO
- Adjustable power up to 1 watt
- 128/256 bit AES Encryption

Additional details can be found at Microhard's website: https://www.microhardcorp.com/pMDDL2450.php

## ACCESSING RADIO SETTINGS

The pMDDL radio settings can be modified via a web browser interface. This interface is accessed by entering the IP address of the radio into a web browser of a connected computer, i.e. the GCS tablet. Each radio requires login credentials to access their interface. Ascent ships with the default credentials given below. It is highly recommended that operators change these default login credentials to unique values consistent with their security policies. Do not change the radio's IP addresses.

| CAUTION |
| --- |
| Contact Ascent AeroSystems support before changing radio settings. Modifying radio settings can degrade radio performance or prevent them from connecting. |

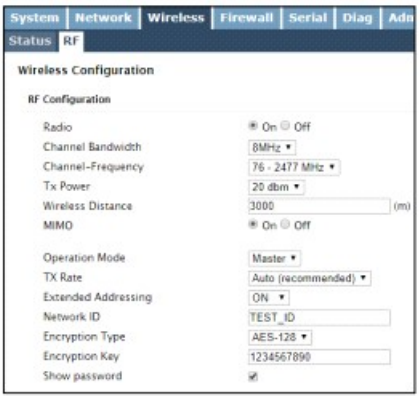



*Figure 47: pMDDL Web Interface*

*GCS Radio*
IP: 192.168.2.1
Username: admin
Password: microhard

*Air Radio*
IP: 192.168.2.8
Username: admin
Password: admin

The details of the pMDDL web interface are beyond the scope of this document. Operators should familiarize themselves with the most recent version of Microhard's pMDDL Operating Manual. Operating manuals are available directly from Microhard: https://www.microhardcorp.com/contact.php

## AscentQ Microhard Settings Page

Several radio settings can be viewed and changed directly from AscentQ. To access the settings, select the Setup Menu -> Application Setting -> Microhard. Figure 47 below shows the Microhard settings page.

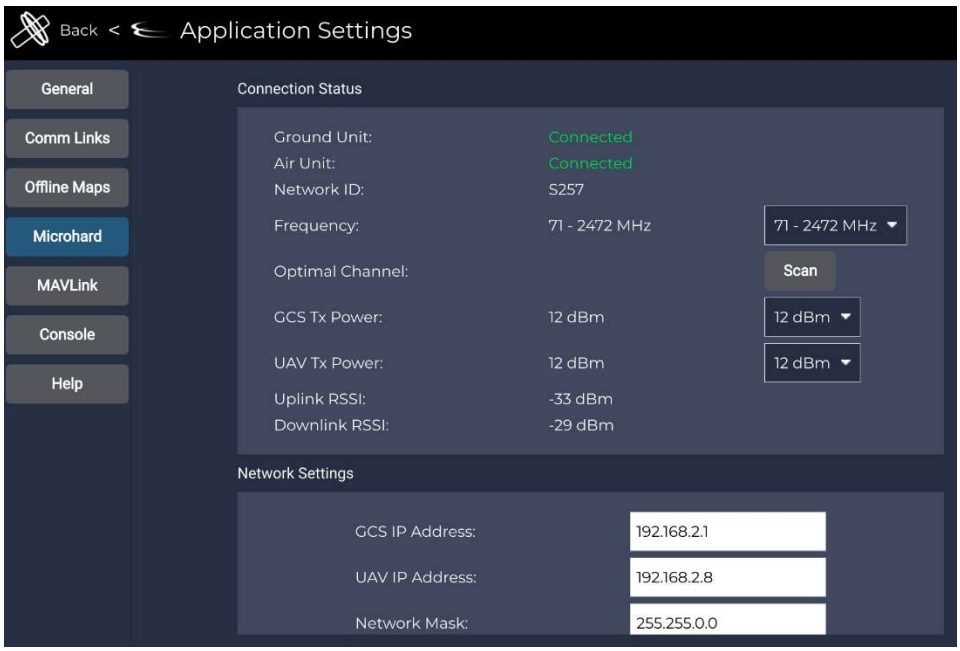



*Figure 48: Microhard Settings Page*

## Frequency

The pMDDL2450 has 75 channels ranging from 2405MHz to 2479MHz. A pair of radios must be on the same frequency to connect with each other. If multiple pairs of pMDDL2450 radios are operating in close proximity, operators should space out their frequencies as much as practical to reduce interference.

When changing frequencies via the Microhard web interface, the frequency of the air radio must be changed first, then the frequency of the ground radio should be updated to match.

When selecting a new frequency via the AscentQ interface, frequency changing on both radios will be handled automatically.

| CAUTION |
| --- |
| Never change frequencies while in flight. This will cause loss of link with the aircraft. |

pMDDL radios can scan their frequency range and then suggest a channel with low noise to help improve performance. A frequency scan can be activated by pressing 'Scan' on the Microhard settings page in AscentQ. Once a low noise channel is found, the radios will display the channel number and frequency.

Never perform this scan while the aircraft is airborne as it will result in a radio failsafe.

## Power

The transmit power of the pMDDL radios are adjustable from 7dBm (5 mW) to 30dBm (1 W). Radio powers can be adjusted through AscentQ Microhard settings page via the Tx power drop down boxes.

# SUPPLEMENTAL 5: NEXTVISION CAMERA MODULES

NextVision Systems offers a line of NDAA compliant cameras which Ascent integrates into a payload module for the Spirit. The camera is paired with NextVision's Trip computer which offers features such as object tracking and video encoding. Operators should review NextVision's user manuals for both their camera and Trip computers for full details on specifications and limitations. Manuals are available by contacting NextVision Systems (sales@nextvision-sys.com).

*Figure 49: NextVision Camera Modules*

NextVision camera modules are terminal modules that are designed to mount to the bottom of the aircraft. These modules typically contain mounting points for the aircraft's landing legs.

| CAUTION |
| --- |
| When powered but not in flight, NextVision requires a fan to actively cool their cameras. |

## TRIP COMPUTER ACCESS

Camera settings can be viewed and modified by accessing the Trip computer's web interface. This is done by entering the IP address of the computer into a web browser on a device connected to the Trip. The device's IP address is given below. Typically, this device will be a GCS that is actively connected to the aircraft. The Trip computer will require login credentials. Ascent ships with the default credentials given below. It is highly recommended that operators change these default login credentials to unique values consistent with their security policies. Do not change the Trip's IP address.

Trip Computer Access:
- IP: 192.168.2.203
- Username: admin
- Password: microcam

CAUTION

NextVision computers and cameras are configured to work with the system's radio and GCS. Modifying settings can disable or degrade the system's performance.