# H2.2 Airplane Flight Manual (AFM)

# Aircraft Description Document

KITTYHAWK

HEAVISIDE

**Aircraft Description**

20 September 2021



**General:** Heaviside is a composite-airframe, all-electric, single-seat, eight-motor, tiltrotor aircraft developed by Kitty Hawk Corporation to provide an initial entry into the Electric Vertical Takeoff and Landing (EVTOL) market.

The aircraft has evolved through three models - Heaviside 1, Heaviside 2 (Block 1 and Block 2), with future revisions planned to incorporate continued learnings.

- **Heaviside 1** was a prototype to demonstrate the feasibility of the design.
- **Heaviside 2 (Block 1)** was a remotely-operated-only aircraft designed to meet high-performance milestones, with a single retractable landing gear.
- **Heaviside 2 (Block 2)** is the current design incorporating a dual, taildragger type landing gear, battery improvements, and a ballistic recovery parachute; it is currently being flown remotely as a public aircraft through the Northern Plains UAS test site, but will be equipped and tested as the first Heaviside aircraft capable of human flight by a remote pilot. As of the writing of this document, 13 copies of this aircraft have been built with total planned ~26 until the next revision.
- **Heaviside 2 Future Revisions** will use an interactive approach to expand capabilities, safety, and manufacturability.

Heaviside 1 (2017)

Heaviside 2 Block 1 (2018)

Heaviside 2 Block 2 (2019)

**Airframe:** The Heaviside airframe is currently produced by Advanced Aerospace of Auckland, New Zealand.

The fuselage is a monocoque design (Heaviside 2 and beyond) of carbon fiber construction with a conventional tail (Heaviside 1 and 2) or T-tail (Heaviside 3) and a canard carrying two tiltrotor motors forward of the cockpit. It is approximately 18 feet 5 inches long (5.6m).

The forward-swept, high-mounted, laminar flow wing is also made of carbon fiber, with carbon fiber fore and aft spar caps, and stressed skin. The wing is attached to the fuselage via (4) mounting lugs and bolts, supports six tiltrotor motors, and has a span of approximately 23 ft (6.5 m).

**Batteries:** Heaviside aircraft use both high-voltage (HV) and low voltage (LV) batteries. The HV batteries power the motors, while the LV batteries, or the HV-LV converter, power the other systems (flight computers, servos, instruments, lights, etc). Both the HV and LV battery systems are redundant, with the loss of a HV battery causing a loss in range and endurance, but not total system thrust.

Currently, the aircraft carries four 528V HV battery packs, but this will be increased to five battery packs on Heaviside 3 aircraft.

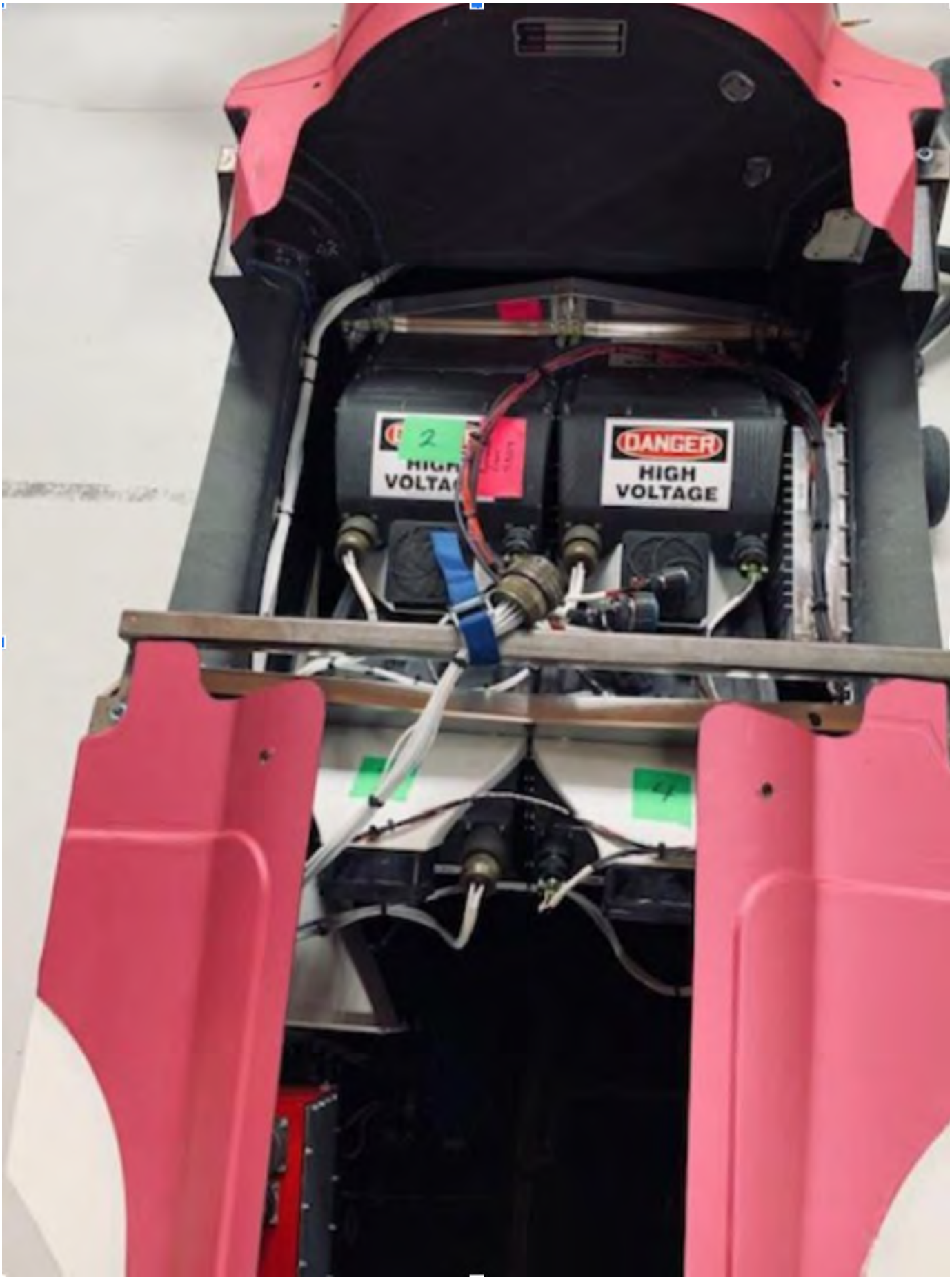
Four HV battery packs provide approximately 39 Amp-hours (Ah) or 18 kilowatt-hours (kWh), while five battery packs will increase that to approximately 49 Ah or 22 kWh, pending any changes in cell selection. If the aircraft is flown on an optimal profile, this gives it a range of 50 nautical miles (NM) while maintaining battery or motor failure fault tolerance. [For layman's reference, an eGolf has a 35kWh battery, while the Tesla Model S battery is 100kWh, but it weighs 1375lb (625kg) or roughly 50% more than a fully loaded and crewed Heaviside.]

The HV battery packs are mounted in the fuselage aft of the cockpit. Each battery pack consists of 20 sub-modules in series, and each submodule contains 12 Lithium Polymer(LiPo) cells in a six series, two parallel (6s2p) configuration. Cell voltage is 3.8V nominal, and 4.4V fully charged. The voltage and temperature of each submodule are independently monitored for conditions that could cause a thermal runaway, and the packs are designed to prevent propagation in the event any single cell enters thermal runaway.

There are two 24V LV batteries. They are currently located in the nose of the aircraft, in front of the cockpit, but will be located under the seat for CG purposes in human carrying configuration. The LV batteries provide LV power during the initial power-on, and act as a backup as well as a transient-load power source, while the HV-LV converter is the main source for LV power during flight.

HV Battery Pack

Battery Sub-Module


DANGER
HIGH
VOLTAGE

HV Battery Packs mounted in the fuselage


LV Battery

**Motors and Propellers:** Heaviside uses Distributed Electric Propulsion (DEP) a system of electric motors and batteries providing a significant safety advantage over conventional single- or multi-engine aircraft. Heaviside is equipped with eight direct-drive Permanent Magnet Synchronous Machine (PMSM) (60 N-m, 5000RPM, 28kW ) motors linked to variable pitch propellers with carbon fiber blades and an aluminum and titanium hub. Each motor is controlled by its own motor controller, mounted in the corresponding pylon.

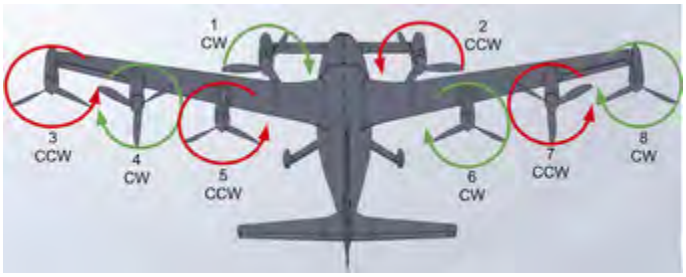
A linear actuator tilts each motor/propeller, and the propeller pitch is mechanically linked to the tilt angle. The pitch of the propellers is relatively fine when in a hover, and becomes more coarse as the motor tilts towards cruise. The motors can tilt from 0° in cruise to 90° degrees in a hover. The canard and center span wing motors go to 84° while the inner and outer wing motors go to 90° in order to maintain yaw authority. Tilt is automatically adjusted a few degrees across all motors to aid in yaw authority. The motor tilt is controlled manually by the remote pilot when in external pilot control modes. While flying in remote pilot modes, such as an automated flight plan, tilt is automatically controlled.. Any linear actuator can fail in any mode without impacting the ability to safely fly and hover the aircraft, and linear actuators will be dually sensed prior to human flight to ensure detection of any failures.

Motors are numbered 1-8 from front to rear, and port to starboard.

> The software still uses the “old” numbering which is 0-5 port to starboard on the main wing, and 6 and 7 port to starboard on the canard.
>
> If you want the mapping, you can also look at `heavisoft/avionics/deploy/screenrc.template`.

There are two types of propellers - clockwise (CW) rotating and counter-clockwise (CCW) rotating, as described from the rear of the aircraft, in cruise flight (i.e. 0° tilt). They are otherwise identical.

The aircraft is capable of normal operations with one failed motor, and degraded operations with multiple failed motors. If more than one motor fails, the aircraft may need to make a landing with sufficient forward airspeed (roughly 30 kts) to maintain a portion of the lift from aerodynamic surfaces.



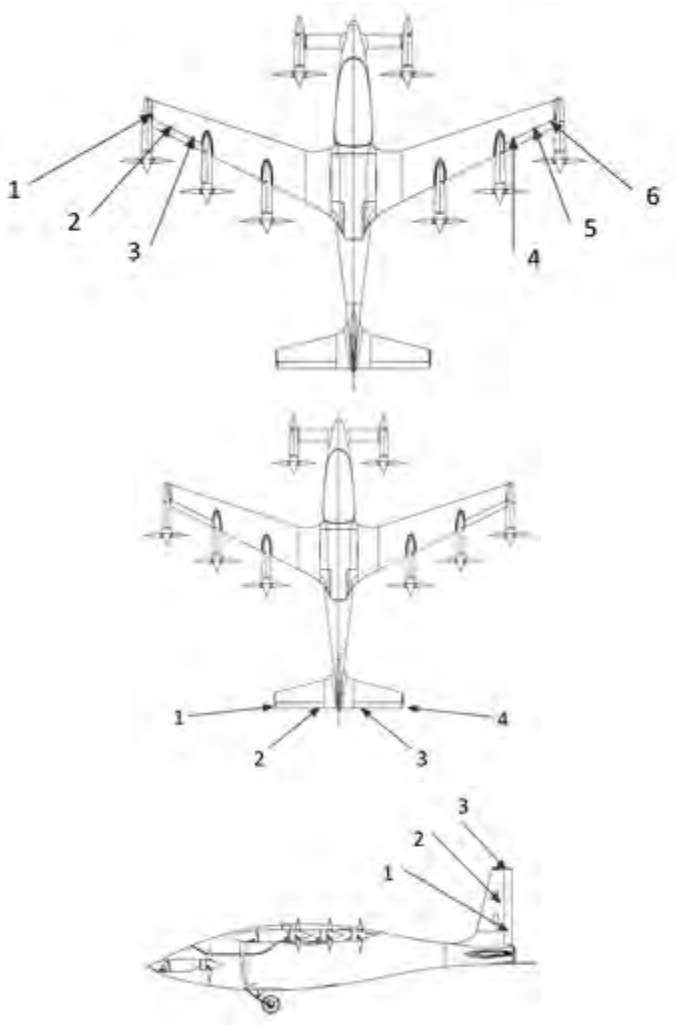

Heaviside Motor/Propeller Names and Rotation Direction

Engineering Drawing of Heaviside Propeller

Motor, propeller, linear actuator, and motor controller.

**Control Surfaces:** Heaviside aircraft have a “fly-by-wire” system, with no mechanical linkages to the control surfaces. The control surfaces are redundant, with each controlled by a single electronic servo. Specifically, Heaviside has the following surfaces, categorized by the common names for conventional control surfaces:

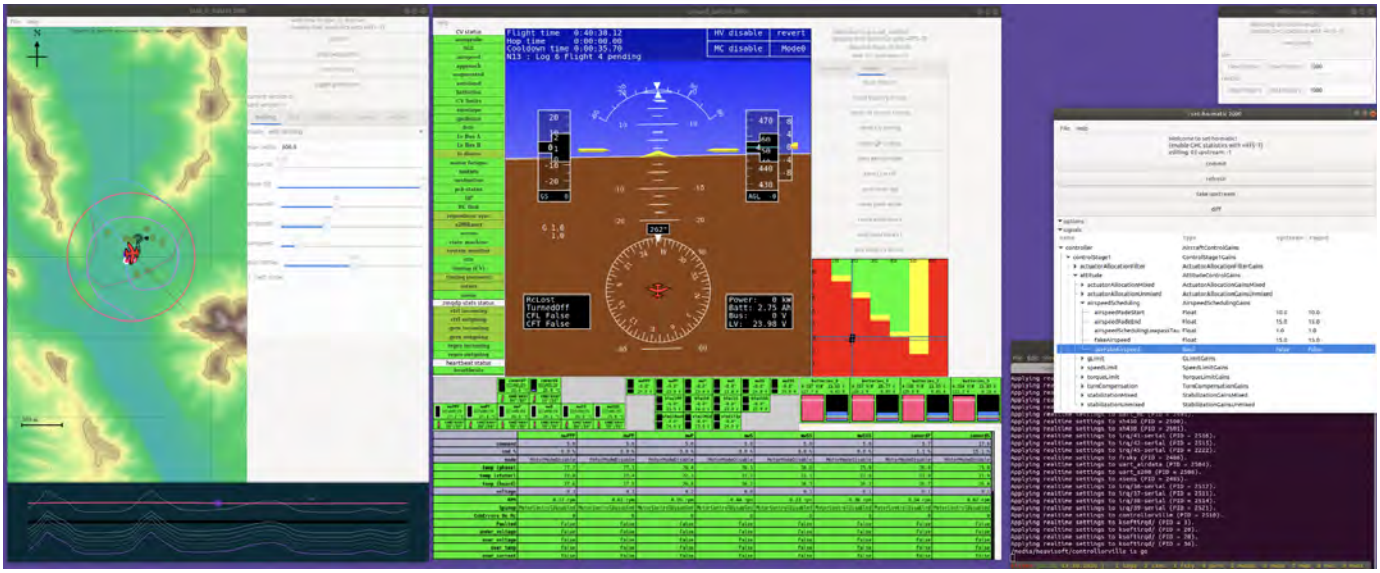
- Ailerons: (3) per wing, total of (6)
- Elevators: (2) per rear horizontal stabilizer, total of (4).
- Rudder: (3) on the vertical stabilizer




Unlike conventional control surfaces, however, Heaviside flaps are not restricted to providing simple pitch, roll, or yaw moments. The flight computer(s) determine the desired effect on the aircraft based on control inputs or the preplanned flight path. Then, by knowing the location and condition of the control surfaces, the flight computer(s) calculate and command the optimal control surface deflections to achieve that effect.

Control surfaces are segmented by flight computers - for example each of the three ailerons on a wing is controlled by a separate FCU and servo. “Voting” in forward flight is carried out aerodynamically - a failure that causes any control surface to fail to a faulty setting, even full-throw in the wrong direction, can be overcome by the surfaces that are still operating correctly.

**Controls:** Currently, Heaviside is either remotely operated using an RC controller, or flown automatically using a flight plan uploaded to the onboard flight computer. A Ground Control Station (GCS) configured laptop computer receives and displays telemetry from the aircraft.

**Cockpit:** For aircraft intended for human flight (Heaviside 2 Block 2 and beyond), the cockpit will be minimally equipped for passenger safety with devices such as:

- Five-point harness
- Footrests
- Emergency parachute deployment actuator
- Radio communication with the remote pilot
- Future: Interactive display

**Electronics and Sensors:** Heaviside 2 Block 2 has a triplex flight computer and triplex sensors. Triplex components include

- Flight Control Computers
- Air Data Sensors
- Laser Rangefinders (for measuring AGL altitude)
- GPS - Inertial Measurement Unit (IMU) Combinations
- Control Surfaces

Triplex flight computers operate synchronously and share inputs and state. Each receives input from one of the three sets of critical sensors. The three flight computers share their sensor information during each control cycle (100Hz). This means that any single flight computer or its associated sensors can fail while maintaining safe flight and hover landing capabilities.

Heaviside is designed to maintain safe continued flight and hover landing capabilities in the event of any single electrical failure of any given part not deemed extremely unlikely to fail, at any point in a typical operating profile.

**Landing Gear:** Heaviside 1 and Heaviside 2 Block 1 aircraft had a single wheel in the center of the aircraft, with wingtip outriggers to keep the aircraft relatively level. On Heaviside 2 Block 1 aircraft, the center wheel was retractable. Heaviside 2 Block 2 aircraft and beyond have a conventional, or "taildragger" landing gear, with two wheels located forward of the center of gravity, and a tail skid.

Currently, the wheels are used only to reposition the aircraft and for run-on landings during compound emergencies - they ride on bushings, not bearings, and the aircraft has no wheel brakes.

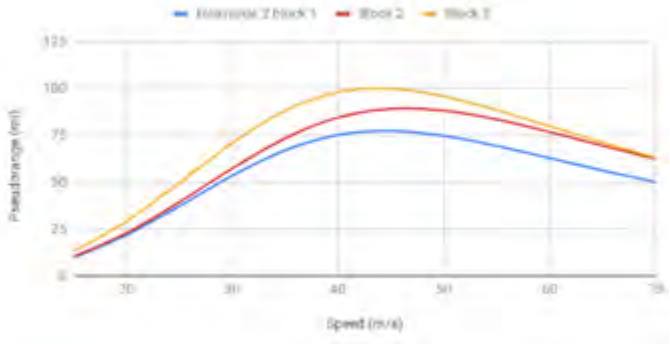
**Aircraft Recovery Parachute:** For human flight aircraft (Heaviside 2 Block 2 and beyond), the aircraft will be equipped with a ballistic aircraft recovery parachute to be used in the unlikely event of a catastrophic failure preventing continued flight. The parachute system has been optimized for Heaviside's aircraft design to minimize altitude loss, providing full coverage within the aircraft's cruise flight envelope, and through some of the departure and arrival transition.

**Weight:** Heaviside 2 Block 2 aircraft with Puma motor controllers will have an empty weight of approximately 682 lbs (310 kg), and a payload of 176 lbs (80 kg). MGW of a Heaviside 2 Block 2 is 880 lbs (400 kg).

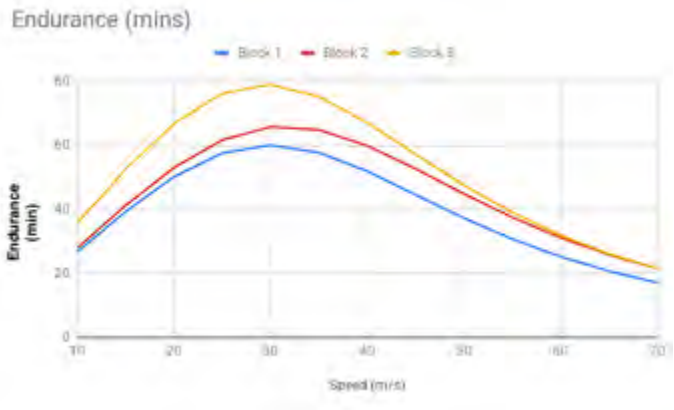
**Performance and limitations:** *Note: Aircraft performance is still under development, and will change as the aircraft evolves. The following is informational only. The current approved limitations sheet should be used for flight activities.* Limitations

The following performance parameters are calculated, but flight tests have shown that they are conservative; during test flights, the Block 2 aircraft has flown 100 miles plus minimal reserve.

- Range (Block 2): ~80 miles at 96 Kts (48 m/s) (estimated from the graph below)
- Maximum Cruise Speed (V_H):
  - 107 KTAS (Heaviside 2 Block 2
- Wing Stall Speed: approximately 60 kts
- G-Limits: +4.4 / -2.4
- Crosswind: 20 kts
  - Crosswind (1 motor out): 10 kts
- Tailwind: 10 kts
  - Tailwind (1 motor out): 3kts
- Audible Signature @1K AGL, 45 m/s cruise: 38dB (a 78dB helicopter emits approximately 100X the acoustic intensity, and is perceived as 16X as loud)



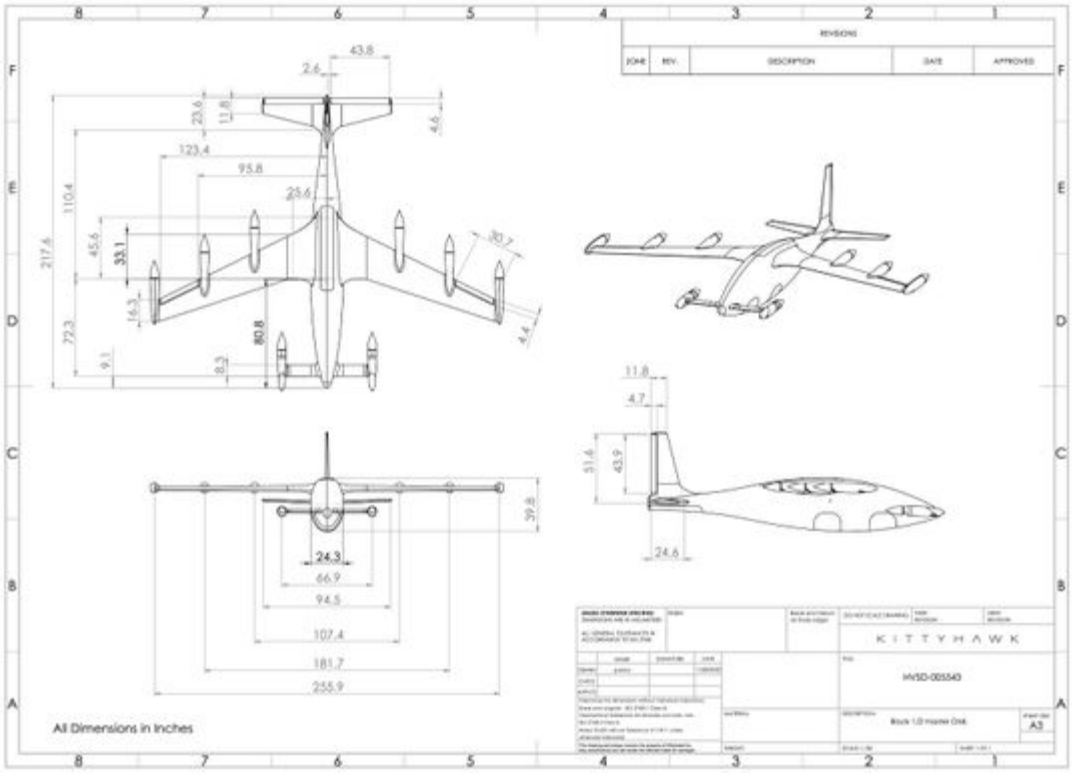

Heaviside Speed vs Range (Calculated)




Heaviside Speed vs Endurance (Calculated)

**Aircraft and System Diagrams:**

Architecture Diagrams


REVISIONS
ZONE
REV.
DESCRIPTION
DATE
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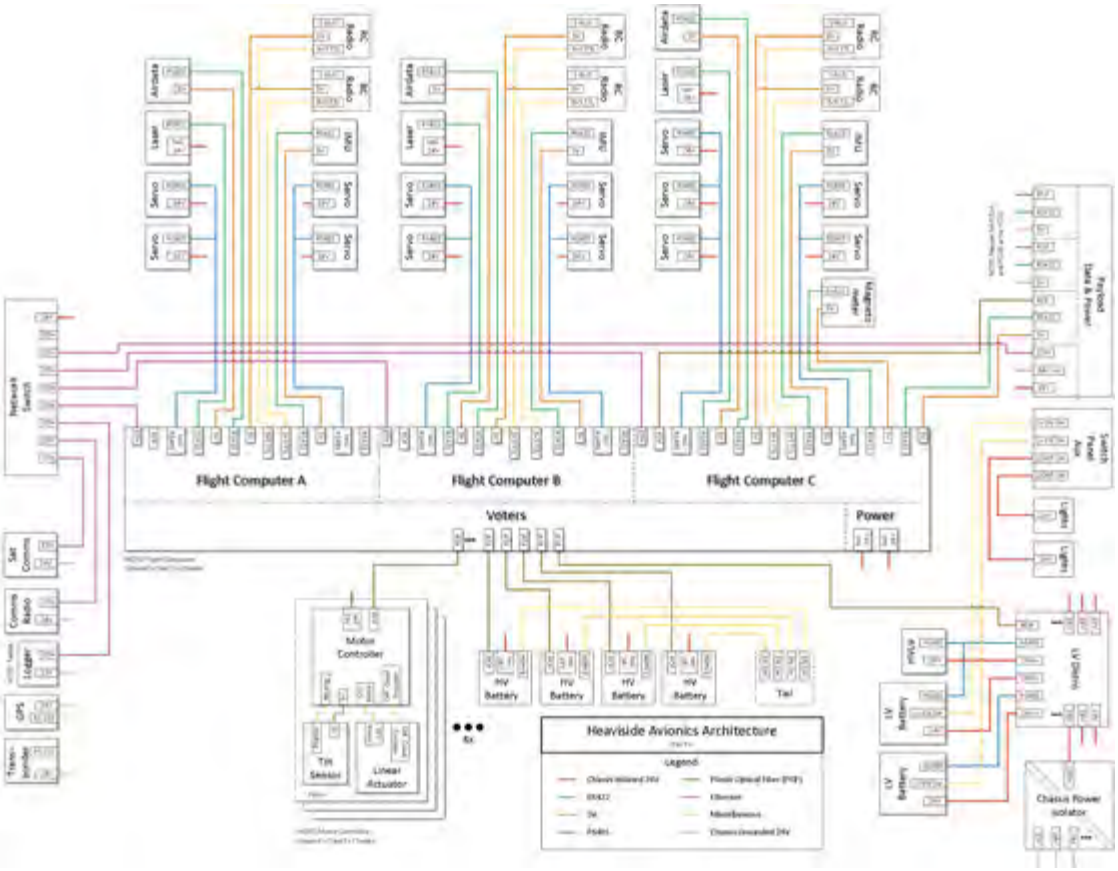
43.8
2.6
23.6
11.8
4.6
123.4
95.8
25.6
110.4
217.6
45.6
33.1
16.3
72.3
9.1
8.3
80.8
30.7
4.4
11.8
4.7
51.6
43.9
24.6
39.8
24.3
66.9
94.5
107.4
181.7
255.9
All Dimensions in Inches
KITTYHAWK
HVSD-005543
Block 1.0 Inside Disk
A3


Flight Computer A
Flight Computer B
Flight Computer C
Voters
Power
Motor Controller
TPS Sensor
Linear Actuator
HV Battery
Tail
Heaviside Avionics Architecture
Legend
Chassis Power Isolator
Payload Data & Power
Switch Panel I/O
Lights
Lights
Sat Comms
Comms Radio
Logger
GPS
Transponder
Network Switch
Airdata
Laser
Servo
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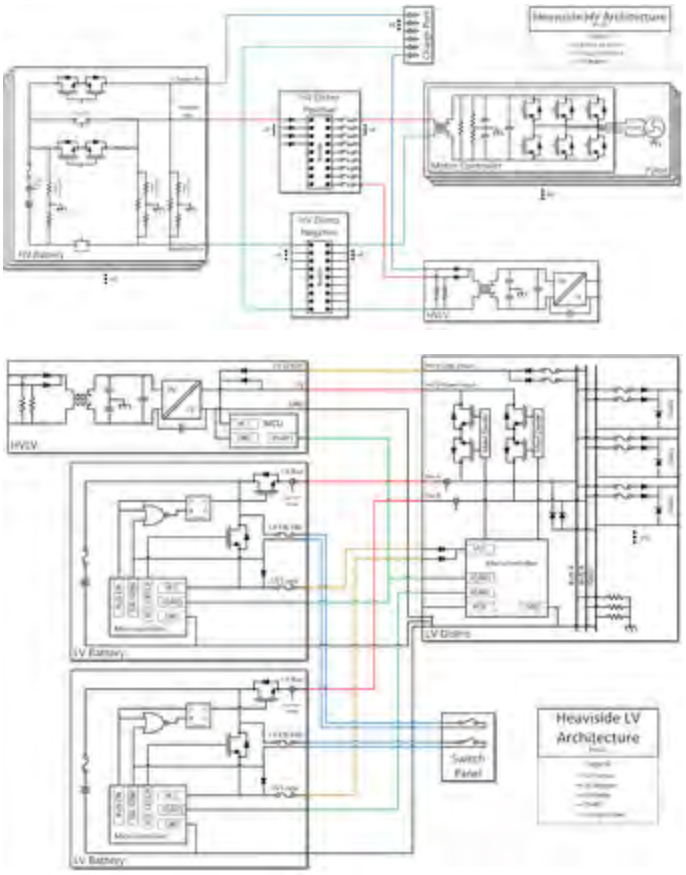
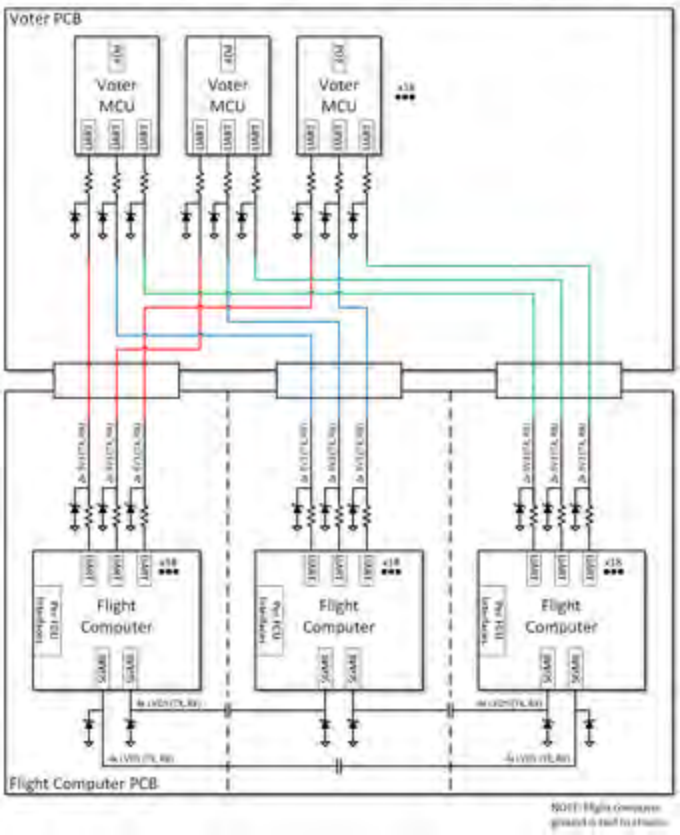
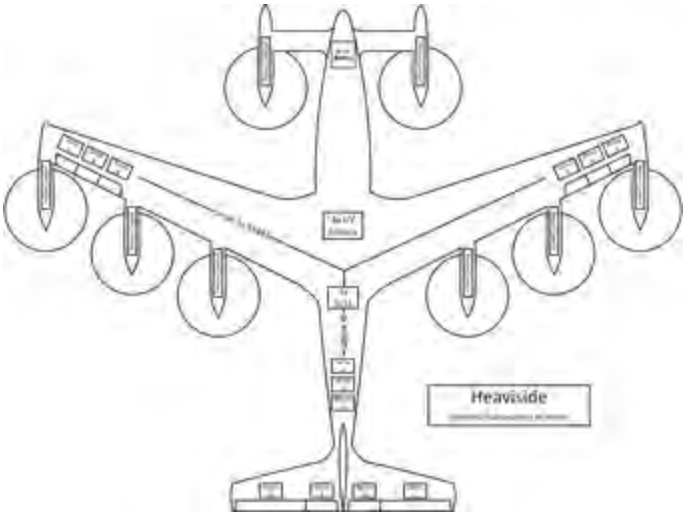



Triplex Flight Computer and Voter Communication Architecture






Heaviside 2 Block 2 Subsystem Locations

# Aircraft Control and Logic

| Revision | Date | Changes |
|---|---|---|
| 0.17.0-0 | 20210919 | 0.17.0 initial release |
| | | |



## Aircraft Control Sources

The aircraft can be controlled from two sources. These two sources are called External Pilot (EP) and Remote Pilot (RP) based on their respective crewmember positions. The EP manipulates an FrSky radio controller to control the aircraft. There can be up to two EPs, one at the departure location and one at the arrival location. The RP is located at a Ground Control Station (GCS) and controls the aircraft via a graphical user interface (GUI) consisting of a primary flight display and flight path planning and control interface.

See “Control Mode Changes” for information regarding switching sources and their associated modes.

### External Pilot

The EP controls the aircraft via a FrSky radio controller with controls as described here: RC Transmitter. Up to two EPs can be used per aircraft. See “Dual External Pilot” for more information. The EP control source has two different modes available, Manual and Autohover

#### Manual Mode

Manual control mode allows the external pilot to control the aircraft via direct throttle control, pitch and roll attitude, and yaw rate. Attitude and yaw rate commands are proportional to the stick deflection with full stick deflection commanding the aircraft’s attitude or yaw rate limit based on phase of flight. The external pilot also proportional control of the motor tilt position.

See Manuevers and Limitations for the appropriate application of tilt commands relative to airspeed and desired maneuvers. Additionally, envelope protection described below helps ensure aircraft limits are not exceeded.

Manual mode is the primary mode of control for the EP.

Motors are not automatically disabled upon touchdown.

Manual mode does leverage GPS and is used to land the aircraft in the event of a GPS failure.

#### Autohover Mode

Autohover control mode allows the EP to control the aircraft via velocity commands. Deflection of the stick commands a proportional speed up to 10kts (5 m/s). Center the sticks will command the aircraft to hold a three dimensional position and heading as well as compensate for disturbances such as wind. The motor tilt position is automatically set to the hover position.

Autohover is secondary control mode for the EP and is typically only used for hover testing or landing assistance.

Motors are not automatically disabled upon touchdown.

> Autohover requires GPS. In the event GPS is lost during Autohover, the aircraft position will slowly drift. Additionally, the failure will be annunciated via the GCS. The EP should switch to Manual and land the aircraft.

### Remote Pilot

The RP controls the aircraft via the Ground Control Station (GCS). The GCS is a suite of applications consisting of an attitude and heading reference system (AHRS), system health monitoring, flight planning and control, aircraft gains and settings control, and sensor data plotting. More information can be found in here GCS Operators Handbook. The RP has several control modes available; Automated, Autopilot Control Panel, and Quick Hold.

#### Automated Mode

Automated mode is controlled via a pre-planned mission package which consists of the following:

- Main flight path
- Lost Link Return flight path
- Geofence

The Main flight path consists of five phases. These phases in order are: Departure, Enroute, Holding, Approach, and Go Around. While lost link plans consist of Enroute, Holding, Approach and Go Around.

Flight paths and corresponding lost link paths are created before flight and can be modified in flight by the RP, which is described in more detail in the Automated Flight Planning document.

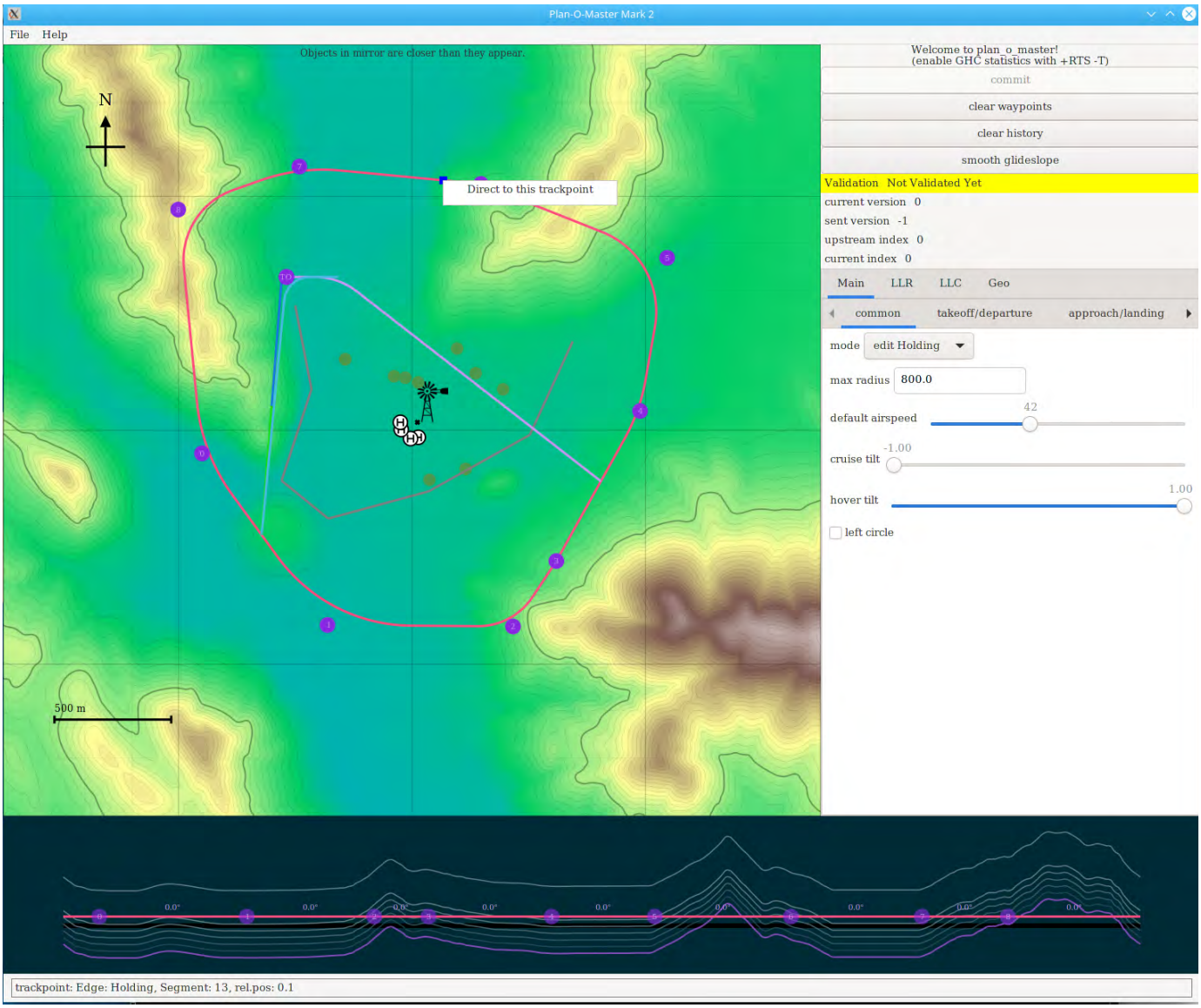
## Takeoff

A takeoff in Automated mode is initiated via the Clear for Takeoff button in the GCS. The aircraft motors will immediately spin at idle power for minimum of four seconds. The reported aircraft heading must be within 45 degrees of the flight plan for the aircraft to proceed to lift off. The reported position must be within 15 m of the programmed take off point. During this time, or if the heading check fails, the Abort button can be used to cancel the takeoff.

## Go To Trackpoint

Clicking on any spot on the flight path and selecting “Direct to this trackpoint” will command the aircraft to fly directly to the selected point. It will overfly the selected point and then turn to intercept the path. The operator can select any point on the Enroute or Holding portion of the Main flight plan, as the location is not limited to specific waypoints.

Go To Trackpoint is limited to the Main flight path. Ensure the Main tab is selected when using this feature.




## Landing

Once the aircraft enters the holding pattern, the RP must select Cleared to Land in the GCS. This is indicated by the Cleared for Landing (CFL) indicator in the GCS. Once the aircraft reaches the approach breakout point with a heading offset less than 30 degrees and within 15 m of the approach point of the flight plan, it will exit the holding path and track the approach segment. The approach continues through transition to hover and touchdown upon which the aircraft motors will automatically disable.

## Aborted Landing

An approach can be cancelled at anytime using the Abort button in the GCS. Once abort is selected, the aircraft will track the go around path and accelerate to the airspeed and minimum altitude set in the flight plan.

The aircraft can also perform automated aborted landings. The aircraft will automatically abort the landing if the airspeed delta is greater than 10 kts (5 m/s), an elevation delta greater then 50 ft (15 m), or heading delta greater than 25 degrees.

> The aircraft will immediately turn to track the closest point on the go around path. This may cause the aircraft to fly over undesired locations depending on the flight plan design.

#### Autopilot Control Panel (ACP)

The Autopilot Control Panel (ACP) interface allows the RP to control the path of the aircraft without modifying a flight plan. The ACP controls barometric altitude, indicated airspeed, and magnetic heading.

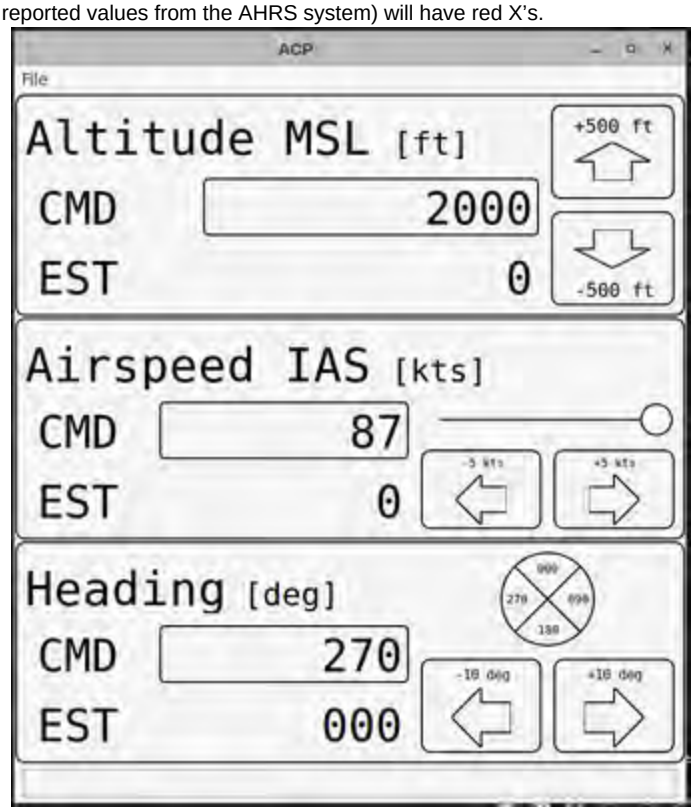
ACP is available when the motor tilt position is within 10% of cruise tilt and not in the Approach phase of a flight plan. To enter ACP during Approach, the RP must first select Abort in the GCS.

The aircraft will follow all three settings as a single command, requiring the RP to validate all values when using ACP. The set values can send the aircraft outside the geofence which will trigger a lost link contingency described in this document.

Altitude and airspeed commands are bounded to a minimum ~328 ft (100 m) above take off altitude and >74 kts (38 m/s). If the aircraft is below either of these values when ACP is enabled, it will climb and accelerate as necessary to meet this minimum values.

Altitude changes are prioritized over commanded airspeed. This may result in accelerating above the command during a descent. Envelope protect ensures aircraft limits are not exceeded. Heading changes will take the most efficient turn direction to acquire the commanded heading.

Commanded changes will turn red until telemetry from the aircraft acknowledges the new value. If telemetry is stale or absent, the estimated values (which represent the current reported values from the AHRS system) will have red X's.




To return to Automated mode, select "Direct to this trackpoint" on the desired flight plan.

**Quick Hold**

The RP can select a right or left turning Quick Hold. Upon activating the quick hold, the aircraft will begin a turn to hold in a circle with a 800 ft radius at the current airspeed. The altitude, airspeed, and radius can be modified within the flight planning interface.

## Contingency Modes

### Lost Link

Lost link mode is activated in the event the active control source link is lost or if the aircraft exits the geofence. When activated, the GCS will display the current mode is set to Lost Link and the aircraft will execute the lost link contingency. The response is dependent on the current phase of flight and describe in the sections below.

here can be up to two lost link flight plans with a minimum of one to upload a mission plan. The two plans are labeled Lost Link Continue (LLC) and Lost Link Return (LLR) flight paths. The LLC is typically setup to land at the Main flight path's destination while LLR is setup to return to the departure point.

When lost link mode is activated, the aircraft determines which path to use by comparing the shorted distance to each enroute segment. The aircraft then fly direct to the closest of the two points and continue to follow the path until automatically landing. The CFL flag is set to true automatically causing the aircraft to intercept the approach path once it reaches the breakout point in holding.

As soon as the aircraft enters the lost link mode, it will automatically changes the settings switch to revert mode on the flight computer causing all settings on the flight computer to revert default (known safe) values in the event custom values were being actively used during the mode change.

#### External Pilot Lost Link

The aircraft will switch to lost link when the aircraft's control source is set to external pilot (manual mode and authover) the FrSky system reports no link for three seconds. In order to support BVLOS, there is no change in state if the FrSky loses link when the active control source is the remote pilot.

- If IAS is < 49 kts (25 m/s), switch to autohover down and land in place. Motors will disable upon touchdown
- If IAS is >49 kts (25 m/s), intercept the lost link flight plan. If below the minimum lost link altitude, climb straight ahead then turn to intercept.

The RP is able to take control of the aircraft using the ACP or the go to trackpoint function. If link is restored, the EP can take back control by toggling the mode switch to RP then back to the desired mode.

#### Remote Pilot Lost Link

The aircraft will switch to lost link when the aircraft's control source is set to remote pilot (Automated, ACP, and Quick Hold) and the aircraft does not receive a heartbeat from the GCS for 10 seconds. When the active control source is the external pilot, there is no change in state when the GCS loses link.

- If the aircraft is on the departure or go around path, it will continue until reaching enroute or holding segment respectively, then switch to the lost link plan.
- If the aircraft is on the approach segment, the aircraft will continue landing on the current flight plan.

A round trip heartbeat protects against asymmetric link conditions (telemetry is not coming down from the aircraft but it is going up from the GCS). Aircraft sends heartbeat then GCS replies. If the aircraft heart beat fails and the GCS reply stops the 10 second lost link timeout starts in this condition.

The EP is able to take control during this time if the aircraft is in line of sight, the FrSky has link, and mode switch is set to manual or autohover. If link is restored, the RP can take back control via ACP, go to track point, or quick hold.

### Geofence

All mission packages include a keep in geofence to bound the flight area of the aircraft in phases and modes of flight. The RP can edit the vertices and ceiling of the Geofence during flight planning or in flight if necessary. If the aircraft leaves the geofence area it will trigger Lost Link mode.

The RP or EP can not take control until the aircraft re-enters the geofence.

> The geofence is only enforces when the aircraft has a valid GPS position.

### GPS Lost

When the control source is RP and a loss of GPS is detected, the autopilot will switch to ACP. The aircraft will continue on the current heading, altitude, and airspeed or accelerate and climb based on minimums required for ACP. It will continue to hold this state until the RP issues a new ACP command, such as a change in heading when in BVLOS to return to VLOS.

Once in VLOS the EP can switch to manual control to land the aircraft.

If GPS is lost when the control source is EP in Autohover mode, the aircraft will continue to track its estimated position based on the INS and begin to drift.

The GCS will continue to display the INS's estimated position of the aircraft.

> At this time, if GPS is lost in flight, return to automated flight or quick hold is not approved. Only a combination of ACP and Manual modes are currently approved.

### Flight Termination

> **The aircraft cannot be recovered and will forcibly crash when Flight Termination is activated in air.** This mode should only be used to quickly end flight when doing so is paramount and the loss of the aircraft is acceptable.

Flight termination is activated when the following is met:

- GCS link is lost for 10 seconds
- FrSky 1 and 2 is lost for 3 seconds
- GPS is lost

or

- The RP initiates flight termination via the GCS

This mode is “latching” and cannot be cancelled once activated. The GCS button is protect by its own tab and confirmation window.

Flight termination mode commands full roll right, yaw right, and pitch up. The motors and high voltage batteries are disabled.

## Control Source & Mode Changes

### EP to RP

The switch from External Pilot to Remote Pilot control source is a two step process. First, the flight mode switch on the FrSky must be moved all the way up to the External Pilot position. The aircraft will remain in the previous mode (manual or autohover) until the RP activates the desired mode by:

- Activating ACP
- Commanding a direct to trackpoint
- Commanding a quick hold

### RP to EP

The EP can take immediate control using manual or autohover modes at anytime as long as the following is procedurally true:

- The aircraft is within line of sight
- The FrSky RC controller has link
- The aircraft is within the Geofence

### Switch Debouncing

The switch signals from the EP FrSky are protected against erroneous signals by a debouncing filter which protects the High Voltage, Motor, and Tilt switches against 0.5 second momentary glitches. Also, the Gains and Mode switches are protected against 0.3 second glitches.

## Dual External Pilot (EP) Operation

The aircraft supports the use of up to two FrSky RC controllers to support landing at a site not colocated with the takeoff point. These two controllers are referred to as EP FrSky 1 and EP FrSky 2. If both EP FrSky units have link, the EP FrSky 1 will have control priority.

Typical workflow of Dual External Pilot handoff between locations.

1. The EP FrSky 1 link is confirmed and the RP launches the aircraft in Automated mode. EP FrSky 1 is ready to take control if necessary.
2. The RP retains control of the aircraft during the BVLOS portion of flight.
3. FrSky 1 is turned off while in RP control source. This does not activate the lost link mode since the RP is in control of the aircraft.
4. FrSky 2 sets switches to correct state to match flight conditions (motor/HV on, tilt enabled and set to cruise, mode switch set to remote pilot, vert/revert, ).
5. FrSky 2 is turned on
6. RP uses the GCS to confirm link
7. Remote Pilot clears the aircraft to land. EP FrSky 2 is ready to take control if necessary.

The return flight is performed identically, with the EP FrSky 2 handing off to EP Frsky 1.

If custom settings are enabled via the “Vert” switch on the controller, these settings will stay enabled when the EP FrSky is turned off to hand over to the receiving EP FrSky. Only the activation of the lost link mode will cause a revert when in this condition.

## Envelope Protection

The aircraft envelope is protected by three main functions. These functions are activated during all phases of flight. Their respective limits are set to the current aircraft limitations found here: Limitations

**Airspeed Protection:** The aircraft’s maximum IAS is limited via reduction in power and/or increase in pitch attitude while descending.

**Rotor Torque Protection:** The maximum torque command allowed is limited based on motor tilt position and IAS. Torque is limited based on the estimated crossflow and RPM. As such, torque will be limited at lower airspeeds as the motor tilt approaches hover. This function is designed to ensure a sufficient total lift (thrust plus wing lift) is always available in hover and transition.

**G Limit:** A G limit is enforced to ensure the aircraft's approved wing loading is not exceeded by limiting pitch commands based on airspeed.

## Controlling Aircraft Settings

A majority of aircraft settings can be manipulate in flight to support testing via the settings application. These settings are only active when the EP FrSky settings switch is set to "vert". These settings can immediately be changed back to the stock settings by moving the switch to "revert". The stock settings cannot be modified and can only be updated via a new software release.

In the event lost link mode is activated, the aircraft will immediately revert any settings.

## Additional Information

### Active Tilt for Yaw Control

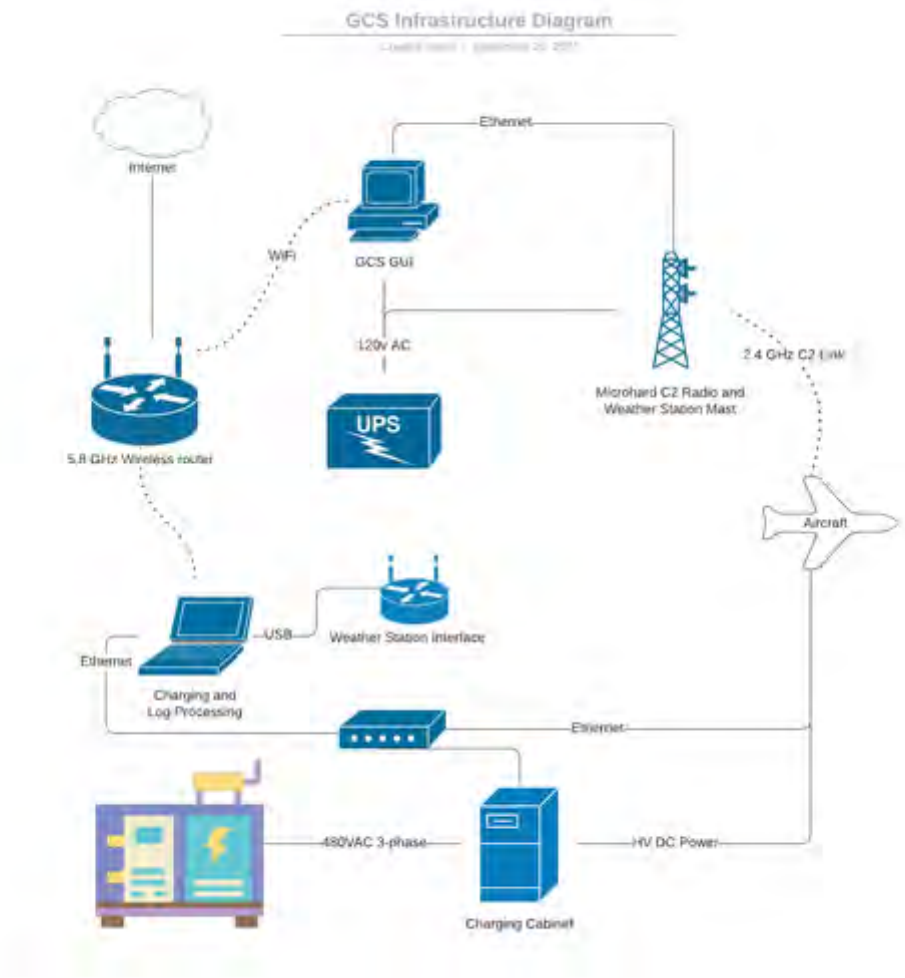
To aid in yaw performance the flight computer will vary the hover tilt position of the motors by a few degrees as necessary to respond to yaw commands. This active thrust vectoring greatly improves the responsiveness of yaw commands, particularly in motor out scenarios. Additionally, it reduces noise during sustained heading changes in hovers since differential torque between motors is reduced and more moment is generated by the vectored thrust.

# GCS Operators Handbook

## GCS Overview

The ground control station (GCS) consists of multiple hardware and software components which forms a system to monitor and control the aircraft from the ground. The primary components of the GCS include:

- Primary Linux computer
    - Heaviside proprietary GUI
    - Multi-monitor support
- Microhard C2 radio
    - Additional information: Network and Data Link
- Uninterruptable power supply
- Weather station
- Secondary Linux computer
    - Heaviside proprietary charging and log processing interface




## GCS Software Interface

https://docs.google.com/presentation/d/1CweZ1uIqiB_kO82mdwiFfwk__4gBbB9vOAKv80krWuA/edit#slide=id.g641887eb4b_0_444

## GCS web browser useful bookmarks:

Download this file and use chrome's bookmark manager to import to your bookmarks.
This contains links to the flight cards, test plans, daily summary etc.


GCS_9_9_21.html

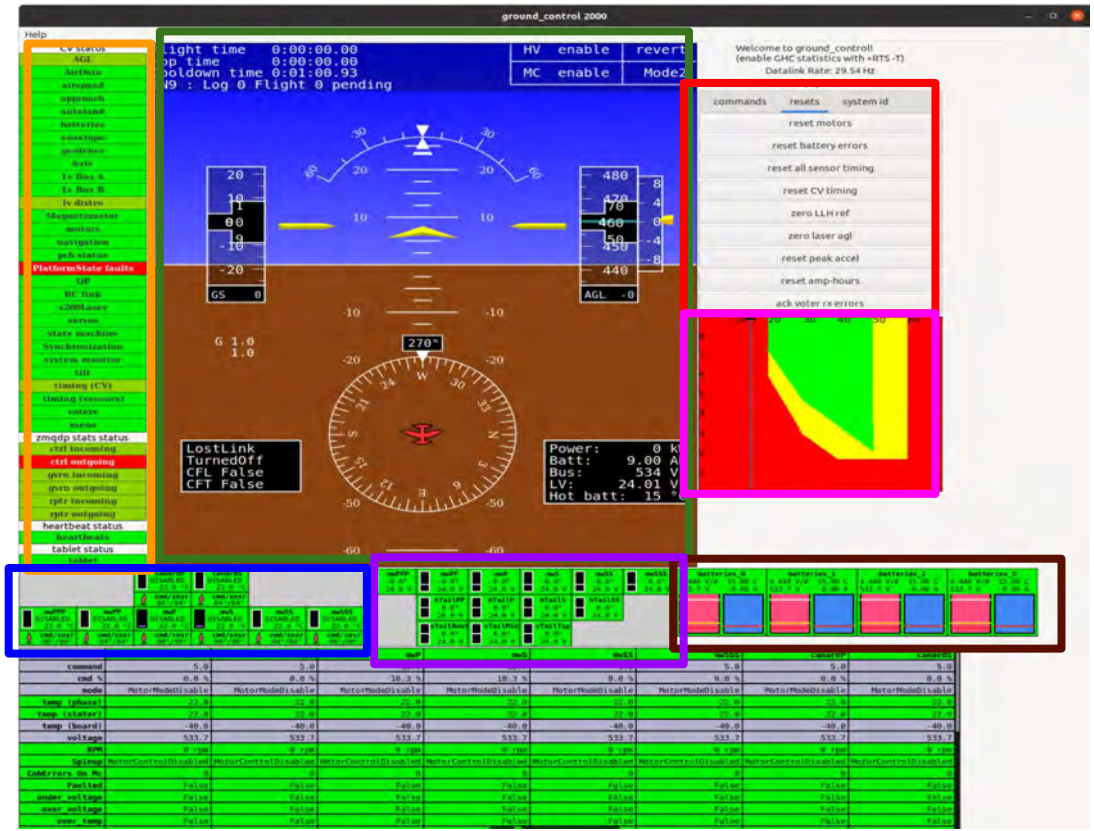
# GCS Operators Handbook

# Change log

| Rev | Date | Changes |
|---|---|---|
| 0.17.0-0 | 20210919 | 0.17.0 initial release |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

# Contents

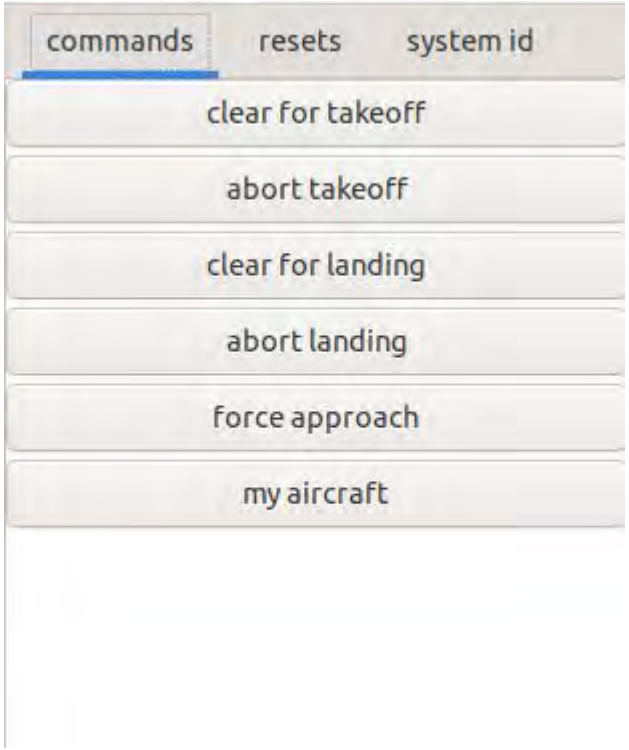
# ground_control 2000, GCS Display




[Command/resets/sets panel]
[Annuciators]
[Motor throttle/pylon tilt]
[Servo command]
[Batteries]
[HUD/AHRS]
[HV Battery SOC & Temp Chart]

[Emergencies]

# ground_control 2000, Command panel




clear for takeoff
: Starts motors and has aircraft depart on go-around path when in autonomous mode

abort takeoff
: Can only be engaged during initial idle/spin up prior to leaving the ground

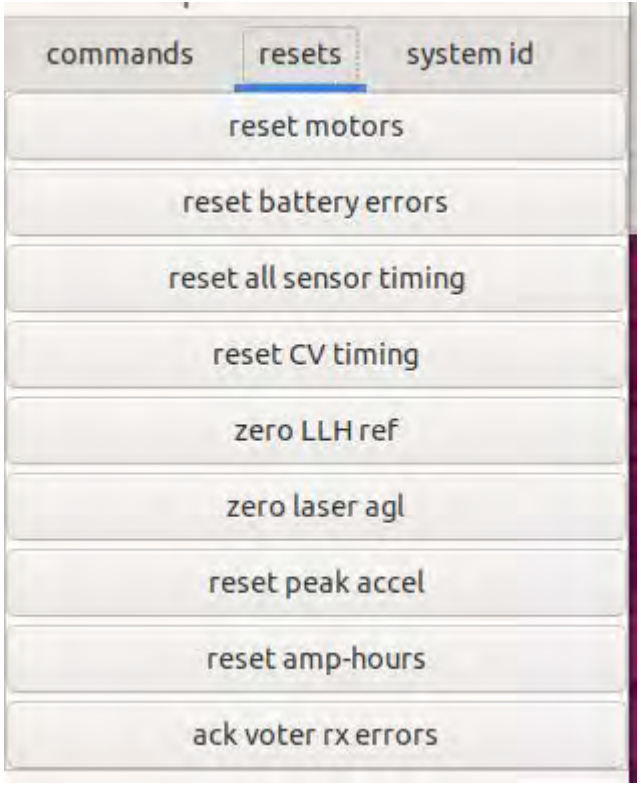
clear for landing
: Clears the aircraft for landing. If conditions are met it will enter the approach when in autonomous mode and continue to autoland

abort landing
: Sends the aircraft on the go around path (and clears clear for landing)

force approach
: Forces the aircraft from holding onto the approach path. Use immediately after the approach is not captured. Delayed activation may cause undesired behavior.

my aircraft
: Transfers aircraft control to the GCS after the External Pilot Sets the RC flight mode switch to automated. Only works when the RC flight mode switch is in the automated position.

# ground_control 2000, Resets panel




reset motors
: Resets/clears motor errors. May need to be done on startup.

reset battery errors
: Resets/clears errors on HV batteries. May need to be done on startup.

reset all sensor timing
: Resets/clears errors on sensor timing annunciator

reset CV timing
: Resets/clears errors on sensor timing(CV) annunciator

zero LLH ref
: Zeroes and sets the origin of the North-East-Down cartesian frame. Must be done in RCLost (Turned off) or Autonomous (Turned off) mode.

zero laser AGL
: Sets the current laser reading to 0. Must be done in RCLost (Turned off) or Autonomous (Turned off) mode.

reset peak accel
: Zeros the peak accel displayed on the HUD/AHRS.

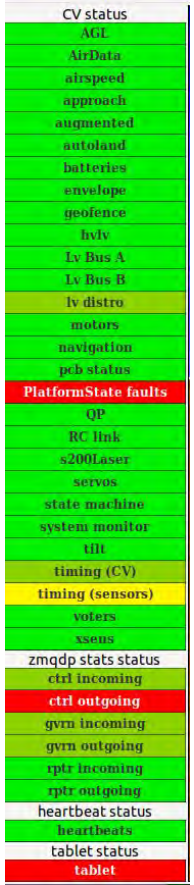
reset amp-hours
: Sets amp-hours to serial number specific value.

Ack voter rx errors
: Turns red voter annunciators to puke green.

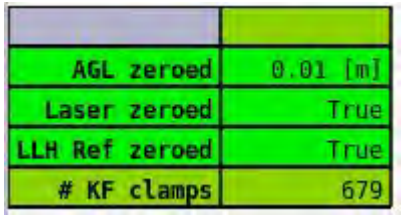
# ground_control 2000, system id


step up
    ???
step down
    ???
step left
    ???
step right
    ???
step forwards
    ???
step backwards
    ???
step clockwise
    ???
step counter clockwise
    ???
dump sim state
    ???

# ground_control 2000, Annunciators



# ground_control 2000, Annunciators, AGL



| | |
|---|---|
| AGL zeroed | 0.01 [m] |
| Laser zeroed | True |
| LLH Ref zeroed | True |
| # KF clamps | 679 |

AGL Zeroed
: Shows the zeroed reading.

Laser zeroed
: Goes true once zeroed. Goes false each time the controller is started (./start_controller).

LLH Ref zeroed
: Goes true once zeroed. Goes false each time the controller is started (./start_controller).

# KF clamps
: Puke green as there is unknown threshold. This is not cause for concern unless the number is very, very large or continues to grow.

# ground_control 2000, Annunciators, airdata

| | FcuA | FcuB | FcuC |
|---|---|---|---|
| AirDatasZeroed | True | True | True |
| Valid.absPressure | True | True | True |
| Valid.dynamicPressure | True | True | True |
| PressureClips.absPressure | 0 | 0 | 0 |
| PressureClips.dynamicPressure | 0 | 0 | 0 |
| InvalidReadings.absPressure | 0 | 0 | 0 |
| InvalidReadings.dynamicPressure | 0 | 0 | 0 |

AorDatasZeroed

Goes true once zeroed. Does not go false unless power is cycled.

# ground_control 2000, Annunciators, airspeed

| | airspeed |
|---|---|
| indicated airspeed | 0.0 |
| INS speed | -0.0 |
| use fake airspeed | False |

Indicated Airspeed

Airspeed calculated from the ram air in the three airdata sensors.

INS speed

Airspeed calculated from the INS (Xsens), m/s

use fake airspeed

Indication if “fake airspeed” is committed in the settings app

# ground_control 2000, Annunciators, approach

| | conditions |
|---|---|
| HeadingErrorDeg | -30.00 < (-8.06e-06) < 30.00 |
| DistanceFromApproachPoint | ( 832.62) <= 25.00 |
| ClosestPointPathDistanceFromApproach | 0.00 < ( 2009.27) < 15.00 |

Conditions to be met to break out on the approach path. Annunciator turns blue in the panel when “clear for landing” is engaged. Not needed for operator.

# ground_control 2000, Annunciators, autoland

| | conditions |
|---|---|
| kAlrMaxAzimuthalErrorDeg.oAlrGains, AzimuthalErrorDeg | (-15.00) < (-157.43) < ( 15.00) |
| kAlrMaxElevationErrorDeg.oAlrGains, ElevationErrorDeg | (-15.00) < ( 173.83) < ( 15.00) |
| kAlrMaxHeadingDeviationDeg.oAlrGains, HeadingDeg | (-25.00) < ( 0.37) < ( 25.00) |
| kAlrMaxSpeedDelta.oAlrGains, PathSpeedClose | (-5.00) < ( 0.00) < ( 5.00) |
| FinalDistanceSpec, PathDistance | (-294.50) < ( 74.54) < 0.00 |
| Agl, kAlogAglThreshold.oAlogGains | ( 1.17e-02) < ( 0.50) |
| AglRef | ( 1.17e-02) < 0.00 |
| ModeActive | (False) |
| SetdownStage | (TransitionStage) == SetdownStage |
| ThrottleFraction, kAlogMaxThrottleFraction.oAlogGains | ( 0.00) < ( 0.15) |
| SatisfiedTime, kAlogSatisfiedTime.oAlogGains | ( 0.00) > ( 0.50) |

Conditions to be met to engage autoland. Not needed for operator.

# ground_control 2000, Annunciators, batteries

| | batteries_0 | batteries_1 | batteries_2 | batteries_3 |
|---|---|---|---|---|
| amp-hours | 8.40 Ah | 8.40 Ah | 8.40 Ah | 8.40 Ah |
| amps | -0.00 A | -0.00 A | -0.00 A | -0.00 A |
| volts | 533.7 V | 533.7 V | 533.7 V | 533.7 V |
| volts/cell | 4.45 V/s | 4.45 V/s | 4.45 V/s | 4.45 V/s |
| enable | True | True | True | True |
| charge | False | False | False | False |
| balance | False | False | False | False |
| min cell temp | 15.00 C | 15.00 C | 15.00 C | 15.00 C |
| max cell temp | 15.00 C | 15.00 C | 15.00 C | 15.00 C |
| min cell volt | 4.45 V/s | 4.45 V/s | 4.45 V/s | 4.45 V/s |
| min cell volt seen | 4.45 V/s | 4.45 V/s | 4.45 V/s | 4.45 V/s |
| cell voltage delta | 0.00 V | 0.00 V | 0.00 V | 0.00 V |
| contactor closed | True | True | True | True |
| contactor working | 533.7 V / 533.7 V | 533.7 V / 533.7 V | 533.7 V / 533.7 V | 533.7 V / 533.7 V |
| kill switch fly | True | True | True | True |
| faults.discharge_overcurrent | False | False | False | False |
| faults.precharge_error | False | False | False | False |
| faults.charge_temp | False | False | False | False |
| faults.charge_overvoltage | False | False | False | False |
| faults.charge_overcurrent | False | False | False | False |

amp-hours
: Remaining amp-hours

volts
: pack voltage

volts/cell
: Average voltage of the cells in the pack

max cell temp
: Maximum cell temperature in the pack

min cell volt
: Minimum voltage of one cell

min cell volt seen
: Minimum cell voltage that latches

cell voltage delta
: Maximum difference between all the battery cells

contactor closed
: True enables HV on the vehicle

# ground_control 2000, Annunciators,envelope

| | envelope |
|---|---|
| Speed limit throttle | free |
| Speed limit roll | free |
| Speed limit pitch | free |
| G limit ddtRefOmega x | free |
| G limit ddtRefOmega y | free |
| G limit ddtRefOmega z | free |
| Torque limit on any rotor | free |

Annunciators read “true” when envelope protections are active.

# ground_control 2000, Annunciators, geofence

| | lateral | ceiling |
|---|---|---|
| separation | 4443 [m] | 1294 [m] |

Geofence boundaries.

# ground_control 2000, Annunciators, hvlv

| | hvlv |
|---|---|
| Voltage | 0.00 |
| Current | 0.00 |
| Bias Voltage | 14.00 |
| Die Temp | 22.20 |
| Enabled | True |
| errors.input_overvoltage | False |
| errors.input_undervoltage | False |
| errors.input_overtemp | False |
| errors.output_overvoltage | False |
| errors.output_overcurrent | False |
| errors.output_overtemp | False |
| errors.comparator_fault | False |
| errors.comms_timeout | False |
| warnings.input_overvoltage | False |
| warnings.input_undervoltage | False |
| warnings.input_overtemp | False |
| warnings.output_overtemp | False |

Status of the hvlv unit. Gives voltage and current seen as well as if the hvlv is enabled.

Useful errors and warnings.

# ground_control 2000, Annunciators, Lv Bus A

| | lv battery a |
|---|---|
| bus voltage | 24.00 |
| bus current | 2.00 |
| switch temp | 40.00 |
| cell temp | 20.00 |
| balance state | 0 |
| logic power | True |
| user switch | True |
| bus enable | True |
| bus state | LVBusStateOn |
| cell volts.0] | 3.70 |
| cell volts.1] | 3.70 |
| cell volts.2] | 3.70 |
| cell volts.3] | 3.70 |
| cell volts.4] | 3.70 |
| cell volts.5] | 3.70 |
| errors.discharge_overcurrent | False |
| errors.charge_overcurrent | False |
| errors.cell_overtemperature | False |
| errors.cell_undertemperature | False |
| errors.cell_overvoltage | False |
| errors.cell_undervoltage | False |
| errors.cell_delta | False |

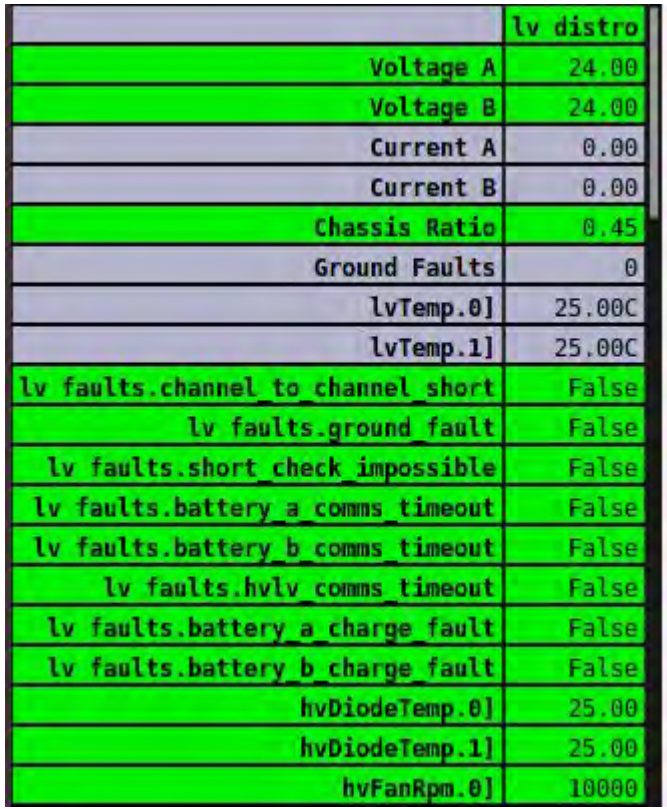
Status of the Bus for LV Battery A. Note that this is stale data.

# ground_control 2000, Annunciators, Lv Bus B

| | lv battery b |
|---|---|
| bus voltage | 24.00 |
| bus current | 2.00 |
| switch temp | 40.00 |
| cell temp | 20.00 |
| balance state | 0 |
| logic power | True |
| user switch | True |
| bus enable | True |
| bus state | LVBusStateOn |
| cell volts.0] | 3.70 |
| cell volts.1] | 3.70 |
| cell volts.2] | 3.70 |
| cell volts.3] | 3.70 |
| cell volts.4] | 3.70 |
| cell volts.5] | 3.70 |
| errors.discharge_overcurrent | False |
| errors.charge_overcurrent | False |
| errors.cell_overtemperature | False |
| errors.cell_undertemperature | False |
| errors.cell_overvoltage | False |
| errors.cell_undervoltage | False |
| errors.cell_delta | False |

Status of the Bus for LV Battery B. Note that this is stale data.

# ground_control 2000, Annunciators, lv distro



| | lv distro |
|---|---|
| Voltage A | 24.00 |
| Voltage B | 24.00 |
| Current A | 0.00 |
| Current B | 0.00 |
| Chassis Ratio | 0.45 |
| Ground Faults | 0 |
| lvTemp.0] | 25.00C |
| lvTemp.1] | 25.00C |
| lv faults.channel_to_channel_short | False |
| lv faults.ground_fault | False |
| lv faults.short_check_impossible | False |
| lv faults.battery_a_comms_timeout | False |
| lv faults.battery_b_comms_timeout | False |
| lv faults.hvlv_comms_timeout | False |
| lv faults.battery_a_charge_fault | False |
| lv faults.battery_b_charge_fault | False |
| hvDiodeTemp.0] | 25.00 |
| hvDiodeTemp.1] | 25.00 |
| hvFanRpm.0] | 10000 |

Voltage A
    LV battery A
Voltage B
    LV battery B
Current A
    Current from battery A
Current B
    Current from battery B
lv faults.channel_to_channel_short
    This could be red on startup if `/deploy_controller` without restarting the flight computer (power down)

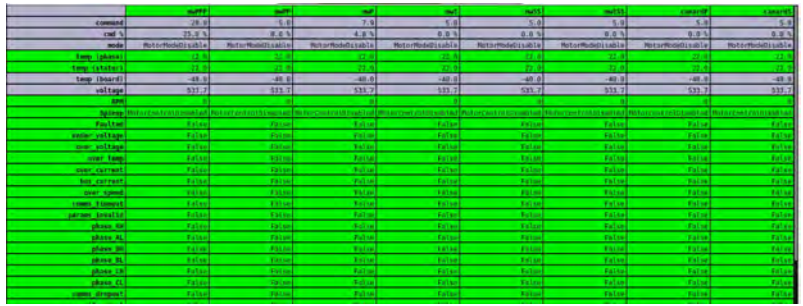
# ground_control 2000, Annunciators, Magnetometer

| | Mag |
|---|---|
| self test | True |
| checksum failures | 0 |
| parse failures | 0 |
| Num Errors.InvalidPeriod | 0 |
| Num Errors.InvalidMessage | 0 |
| Num Errors.TimerOverflow | 0 |
| Num Errors.InvalidBaudrate | 0 |
| Num Errors.InvalidParameter | 0 |
| Num Errors.DeviceError | 0 |
| Num Errors.Overflow | 0 |
| Num Errors.OtherError | 0 |

Shows the current state of the magnetometer and self test.

Useful errors are also displayed.

# ground_control 2000, Annunciators, motors



Command
: The commanded power setting in kW

command %
: Commanded power in percentage of total power available

Mode
: Displays if the motor is enabled or disabled.

temp (phase)
: Temperature of the phase portion of the motor, Celsius

temp (stator)
: Temperature of the stator portion of the motor, Celsius

RPM
: RPM of motor

# ground_control 2000, Annunciators, navigation

| | navigation |
|---|---|
| cross-track position | 45 [m] |
| cross-track speed | 0 [m/s] |
| altitude | s: 503 r: 455 v: 455 |
| climb rate | s: 0 r: -0 v: -0 |
| airspeed | s: 42 r: -0 v: -0 |
| path heading / ground track / heading | -101 / 44 / -90 [deg] |
| track status | LegNominal |
| carrot track status | LegNominal |
| lateral integrator state | 0.00 / 0.52 |
| lateral integrator saturated | False |
| lateral integrator antiwindup | False |
| energy balance pitch integrator state | 0.00 / 0.35 |
| energy balance pitch integrator saturated | False |
| energy balance pitch integrator antiwindup | False |
| total energy throttle integrator state | -0.51 / 0.70 |
| total energy throttle integrator saturated | False |
| total energy throttle integrator antiwindup | False |

Navigation parameters. How well the aircraft is tracking its flight path. Flickering yellow in this panel is OK but still needs to be communicated to the Safety Pilot.

# ground_control 2000, Annunciators, pcb status

| | pcb status |
|---|---|
| power supply temp | 22.0 [°C] |
| PCB temp | 22.0 [°C] |
| CPU temp | 50.0 [°C] |
| FPGA temp | 50.0 [°C] |
| 3v3 voltage | 3.300 [V] |
| 5v0 voltage | 5.000 [V] |
| 3v3 current | 1.300 [A] |
| 5v0 current | 0.500 [A] |
| thermistor voltage | 0.000 [V] |

Status of the onboard pcb.

# ground_control 2000, Annunciators, QP

| | # |
|---|---|
| small clips | 0 |
| big clips | 0 |
| not solved | 0 |
| not finite output | 0 |
| not finite hess | 0 |
| not finite grad | 0 |
| ldlt numerical issue | 0 |
| ldlt no convergence | 0 |
| ldlt invalid input | 0 |
| dual update clamp | 0 |
| slack update clamp | 0 |
| worst rcond | 7.98e-09 |

Status of the quadratic programming solver. Not needed for operator.

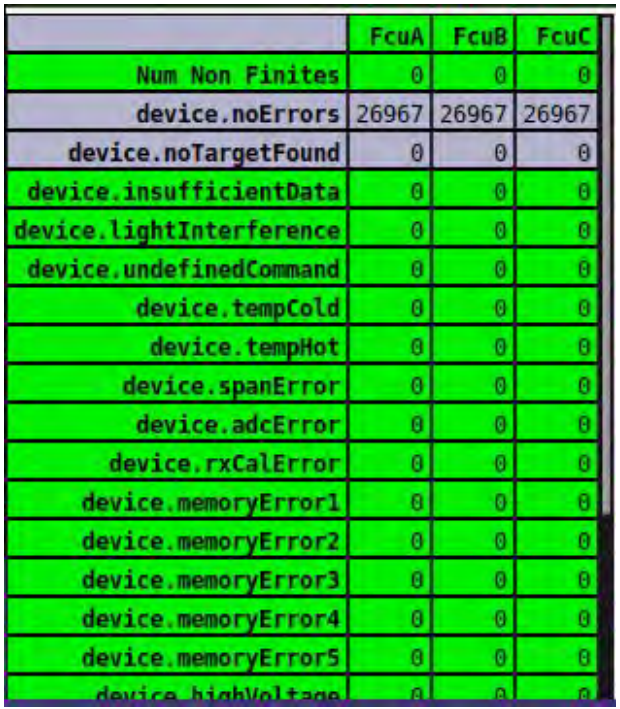
# ground_control 2000, Annunciators, RC Link

| | Primary | Secondary |
|---|---|---|
| timeout | SensorNominal | SensorNominal |
| frame loss status | False | False |
| uart error count | 0 | 0 |
| sbus error count | 0 | 0 |
| frame loss count | 0 | 0 |

uart error count
    RC transmission, <10 is OK
sbus error count
    RC tranmission, <10 is OK
Frame loss count

Primary
    FrSky A
Secondary
    FrSky B

# ground_control 2000, Annunciators, S200Laser



| | FcuA | FcuB | FcuC |
|---|---|---|---|
| Num Non Finites | 0 | 0 | 0 |
| device.noErrors | 26967 | 26967 | 26967 |
| device.noTargetFound | 0 | 0 | 0 |
| device.insufficientData | 0 | 0 | 0 |
| device.lightInterference | 0 | 0 | 0 |
| device.undefinedCommand | 0 | 0 | 0 |
| device.tempCold | 0 | 0 | 0 |
| device.tempHot | 0 | 0 | 0 |
| device.spanError | 0 | 0 | 0 |
| device.adcError | 0 | 0 | 0 |
| device.rxCalError | 0 | 0 | 0 |
| device.memoryError1 | 0 | 0 | 0 |
| device.memoryError2 | 0 | 0 | 0 |
| device.memoryError3 | 0 | 0 | 0 |
| device.memoryError4 | 0 | 0 | 0 |
| device.memoryError5 | 0 | 0 | 0 |
| device.highVoltage | 0 | 0 | 0 |

This is OK to go yellow but needs to be communicated to the safety pilot as manual control may be necessary for landing.

# ground_control 2000, Annunciators, servos

| | mwPPP | mwPP | mwP | mwS |
|---|---|---|---|---|
| count | 54989 | 54989 | 54989 | 54989 |
| command | -0.0 [deg] | -0.0 [deg] | -0.0 [deg] | -0.0 [deg] |
| voltage | 24.0 | 24.0 | 24.0 | 24.0 |
| timeout | Nominal | Nominal | Nominal | Nominal |
| lower bound check | -30.0° <= -30.0° | -30.0° <= -30.0° | -30.0° <= -30.0° | -30.0° <= -30.0° |
| upper bound check | 15.0° <= 15.0° | 15.0° <= 15.0° | 15.0° <= 15.0° | 15.0° <= 15.0° |
| sensor / model | 0.0° / -0.0° | 0.0° / -0.0° | 0.0° / -0.0° | 0.0° / -0.0° |
| fault.Hardware | 0 | 0 | 0 | 0 |
| fault.Crc | 0 | 0 | 0 | 0 |
| fault.IncompleteReply | 0 | 0 | 0 | 0 |
| fault.Other | 0 | 0 | 0 | 0 |
| hardware_errors.input_voltage | False | False | False | False |
| hardware_errors.motor_hall_sensor | False | False | False | False |
| hardware_errors.over_heating | False | False | False | False |
| hardware_errors.motor_encoder_error | False | False | False | False |
| hardware_errors.electrical_shock | False | False | False | False |
| hardware_errors.overload | False | False | False | False |
| hardware_errors.unused1 | False | False | False | False |
| hardware_errors.unused2 | False | False | False | False |
| hardware_errors_counts.input_voltage | 0 | 0 | 0 | 0 |
| hardware_errors_counts.motor_hall_sensor | 0 | 0 | 0 | 0 |
| hardware_errors_counts.over_heating | 0 | 0 | 0 | 0 |
| hardware_errors_counts.motor_encoder_error | 0 | 0 | 0 | 0 |
| hardware_errors_counts.electrical_shock | 0 | 0 | 0 | 0 |
| hardware_errors_counts.overload | 0 | 0 | 0 | 0 |
| hardware_errors_counts.unused1 | 0 | 0 | 0 | 0 |
| hardware_errors_counts.unused2 | 0 | 0 | 0 | 0 |

sensor/model

Comparison of the sensor to model. OK to flicker yellow/red so long as it quickly catches up. Extended red periods are not good.

fault.Hardware

Goes red when there is a hardware fault; for example, something physically blocking the servo travel

# ground_control 2000, Annunciators, state machine

Shows state of the controller.

| | Manual | TurnedOff | Spindown | CheckIdle | Takeoff | Autohover | AutohoverDown | Autoland | Holding | Approach | GoAround |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Manual | | !enabled | | | | | | | True | | |
| TurnedOff | | | | CFT && enabled | | | | | | | |
| Spindown | | spindown complete | | | | | | | | | |
| CheckIdle | | !(CFT && enabled) | | | check idle | | | | | | |
| Takeoff | | | | | | | | | | | AGL threshold |
| Autohover | | !enabled | | | | | | | True | | |
| AutohoverDown | | | | | | | True | | | | |
| Autoland | | | on ground | | | | | | | | wave-off \|\| !CFL |
| Holding | | | | | | | | | | (approach ready && CFL) \|\| force | |
| Approach | | | | | | | | autoland ready && CFL | | | missed \|\| !CFL |
| GoAround | | | | | | | | | went-around | (approach ready && CFL) \|\| force | |

# ground_control 2000, Annunciators, system monitor

| | system monitor |
|---|---|
| Num Diff Processes | 0 |
| status.systemMonitorOk | 0 |
| status.parseStatBadFile | 0 |
| status.parseStatBadTokens | 0 |
| diff.0] | "" |
| diff.1] | "" |
| diff.2] | "" |
| diff.3] | "" |
| diff.4] | "" |
| diff.5] | "" |
| diff.6] | "" |
| diff.7] | "" |
| diff.8] | "" |
| diff.9] | "" |
| Free space | 2.049 GB |
| Total space | 2.980 GB |
| Percent filled | 31.2% |
| Num read errors | 0 |

Displays the state of the tigerboard (Petalinux operating system).

Num Diff Processes

Goes red if a process (or ssh session) not associate with the controller becomes active.

Diff.x]

Shows what the process is that is not supposed to be running

# ground_control 2000, Annunciators, tilt

mode
    Tilt enabled/disabled from RC transmitter
sensor / model
    Measured / commanded tilt angle of motors

| | mwPPP | mwPP | mwP | mwS | mwSS | mwSSS | canardP | canardS |
|---|---|---|---|---|---|---|---|---|
| command (hw units) | 0.4813 [V] | 0.4864 [V] | 0.4796 [V] | 0.2982 [V] | 0.2893 [V] | 0.2960 [V] | 0.4928 [V] | 0.2882 [V] |
| command | 88.00 [deg] | 82.00 [deg] | 88.00 [deg] | 88.00 [deg] | 82.00 [deg] | 88.00 [deg] | 82.00 [deg] | 82.00 [deg] |
| mode | TiltEnable | TiltEnable | TiltEnable | TiltEnable | TiltEnable | TiltEnable | TiltEnable | TiltEnable |
| timeout | Nominal | Nominal | Nominal | Nominal | Nominal | Nominal | Nominal | Nominal |
| sensor / model | 88.0° / 88.0° | 82.0° / 82.0° | 88.0° / 88.0° | 88.0° / 88.0° | 82.0° / 82.0° | 88.0° / 88.0° | 82.0° / 82.0° | 82.0° / 82.0° |
| angle est. | 88.0° | 82.0° | 88.0° | 88.0° | 82.0° | 88.0° | 82.0° | 82.0° |
| fault.over_current | False | False | False | False | False | False | False | False |
| fault.h_bridge_status | False | False | False | False | False | False | False | False |
| fault.comms_timeout | False | False | False | False | False | False | False | False |
| warning.over_current_glitch | False | False | False | False | False | False | False | False |
| warning.h_bridge_status_glitch | False | False | False | False | False | False | False | False |
| warning.comms_dropout | False | False | False | False | False | False | False | False |
| warning.sensor_dropout | False | False | False | False | False | False | False | False |
| warning.sensor_suspend | False | False | False | False | False | False | False | False |

# ground_control 2000, Annunciators, timing (CV)

| | current | lp | worst |
|---|---|---|---|
| samplePeriodMs | 10.005 [ms] | 10.000 [ms] | 24.468 [ms] |
| fullControlLoopMs | 1.785 [ms] | 2.126 [ms] | 21.312 [ms] |
| evalFlightControlTotalMs | 1.100 [ms] | 1.849 [ms] | 20.155 [ms] |
| evalFlightControlBreakdownMs.toArrays | 0.092 [ms] | 0.147 [ms] | 7.061 [ms] |
| evalFlightControlBreakdownMs.evaluation | 0.915 [ms] | 1.584 [ms] | 19.868 [ms] |
| evalFlightControlBreakdownMs.fromArrays | 0.088 [ms] | 0.110 [ms] | 5.187 [ms] |
| publishOnboardTelemMs | 0.074 [ms] | 0.200 [ms] | 17.887 [ms] |
| overheadMs | 0.062 [ms] | 0.057 [ms] | 11.321 [ms] |
| controlLoopDelayMs | 0.012 [ms] | 0.040 [ms] | 9.935 [ms] |

samplePeriodMs

Control loop sample period, should be ~10 ms. <50 ms is OK.

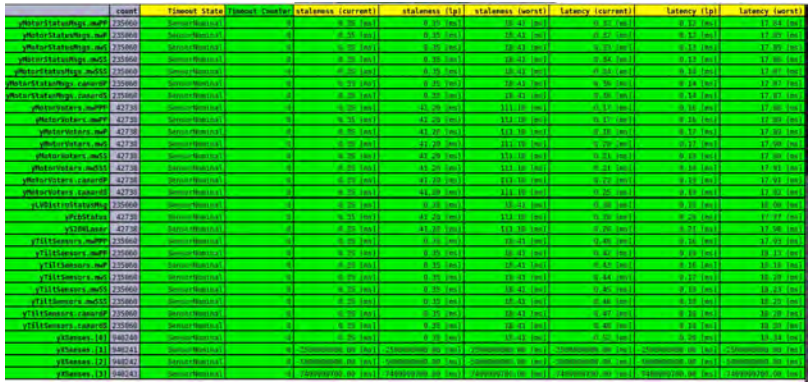
fullControlLoopMs

One run of the control loop. Should be less than 1 ms. <10 ms is OK.

evalStage1TotalMs

This will most likely be yellow.

# ground_control 2000, Annunciators, timing (sensors)



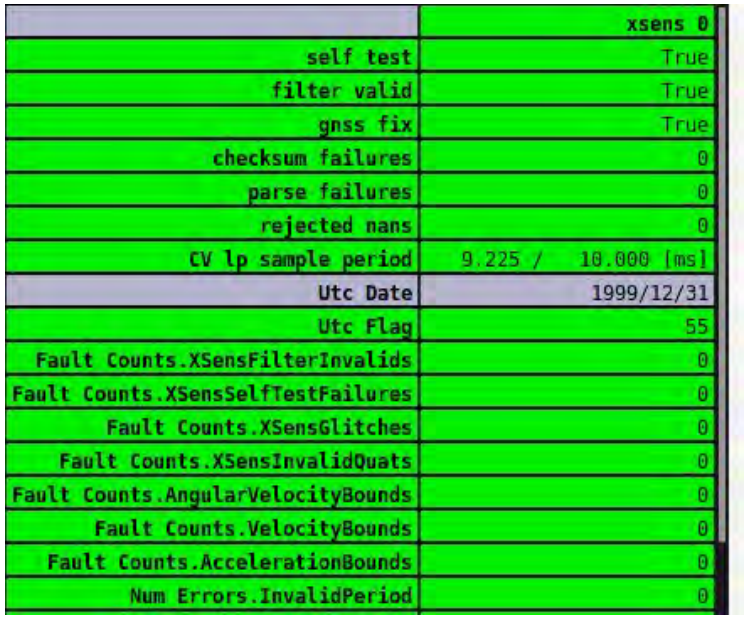
Timing for all the sensors. Motors and Xsens are the most important. Motors time out at 50 ms and Anything over 40 ms for the Xsens is cause for concern.

# ground_control 2000, Annunciators, voters

Intentionally left blank.

| | Voter.VccA | Voter.VccB | Voter.Temp | RxErrors \| AckedRxErrors | resets.v18_domain_reset | resets.brownout_reset | resets.independent_watchdog_reset | resets.low_power_reset | resets.option_byte_loader_reset | resets.pin_reset | resets.power_on_reset | resets.software_reset | resets.windowed_watchdog_reset |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Battery.batteries_0 | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Battery.batteries_1 | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Battery.batteries_2 | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Battery.batteries_3 | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Motor.mwPFP | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Motor.mwPP | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Motor.mwP | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Motor.mwS | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Motor.mwSS | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Motor.mwSSS | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Motor.canardP | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Motor.canardS | 5.20 | 5.30 | 64.0° | 0\|0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# ground_control 2000, Annunciators, xsens



| | xsens 0 |
|---|---|
| self test | True |
| filter valid | True |
| gnss fix | True |
| checksum failures | 0 |
| parse failures | 0 |
| rejected nans | 0 |
| CV lp sample period | 9.225 / 10.000 [ms] |
| Utc Date | 1999/12/31 |
| Utc Flag | 55 |
| Fault Counts.XSensFilterInvalids | 0 |
| Fault Counts.XSensSelfTestFailures | 0 |
| Fault Counts.XSensGlitches | 0 |
| Fault Counts.XSensInvalidQuats | 0 |
| Fault Counts.AngularVelocityBounds | 0 |
| Fault Counts.VelocityBounds | 0 |
| Fault Counts.AccelerationBounds | 0 |
| Num Errors.InvalidPeriod | 0 |

count
: Monotonically increasing time

gnss fix
: Positive fix on GPS position. Need this to be green.

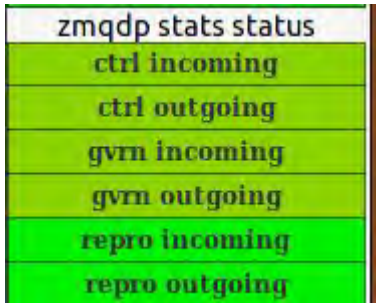
CV lp sample period
: Loop sample period, should be <10 / 10 [ms]

Utc Date
: Matches today's date.

Utc flag
: Do not fly until this is green and 55 indicating that the almanac has been updated.

Num Glitches N Bounds.XsensGlitches
: Can go yellow. Should be communicated but is not alarming unless <10.

# ground_control 2000, Annunciators, zmqdp status




Each of these also have annunciator panels associated with them. Not very relevant for the operator unless they go yellow/red. Needs to be communicated with rPIC.

# ground_control 2000, Annunciators, heartbeats

| | datalink | aircraft |
|---|---|---|
| git hash | 84d97a12be456d6b43a93716db4a16b6e3957916 | 84d97a12be456d6b43a93716db4a16b6e3957916 |
| time since last receive | 0.0 [s] | 0.5 [s] |
| total sent | 1125 | 1411 |
| total received | 1405 | 1125 |
| total dropped | 0 | 0 |

git hash
: datalnk and aircraft should match. Will be red if not. Do not fly on dirty commits.

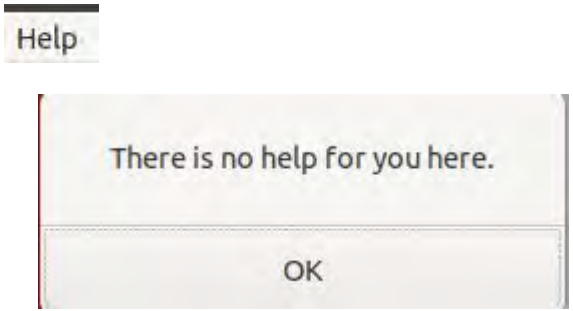
time since last recieve
: Communication health indication.

total sent
: Sent packages.

total received
: Received packages.

total dropped
: Dropped packages.

# ground_control 2000, Annunciators, help




Not functional.

# ground_control 2000, Motor Throttle/Pylon Tilt


Throttle bar, white outline means the command is saturated
Motor name
Mode/Amps being used
Temperature, Celsius
Pylon tilt angle (diagram) and commanded tilt/sensed tilt

# ground_control 2000, Servo command

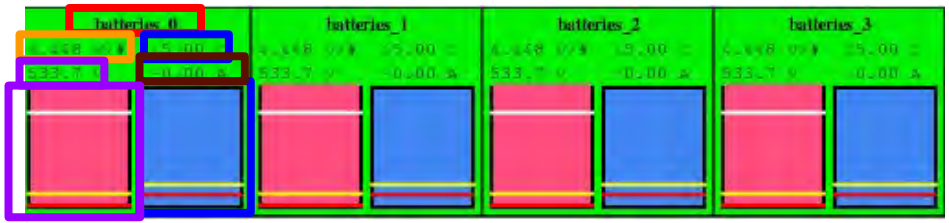

Command bar, white horizontal is set point, white outline when saturated

Servo name

Deflection from set point

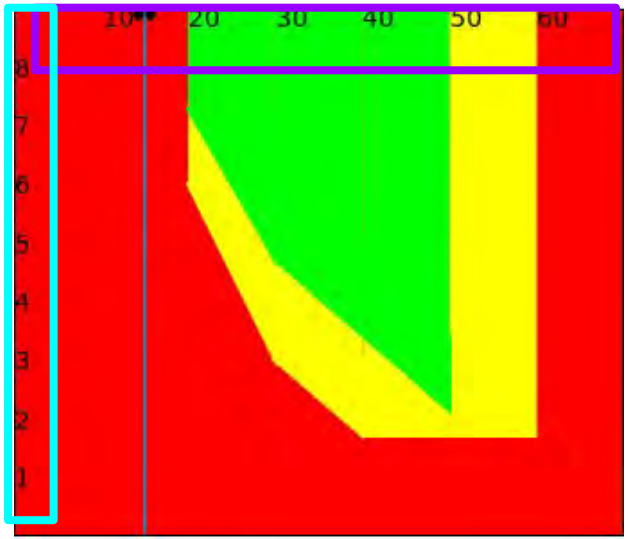
Servo voltage

# ground_control 2000, Batteries




Battery name
Minimum cell voltage
Battery Temperature C
Voltage of battery pack
Amp draw on pack

# HV Battery SOC Chart




Battery Temp

Amp Hours Remaining

If the chart is in the green the aircraft is fault tolerant to a HV battery out scenario. If it is in the yellow it is marginal; and in the red the aircraft is not fault tolerant to a battery out.

# ground_control 2000, HUD/AHRS (Heads up display/Attitude, heading, and reference system)


## Info bar

- Flight time (total flight time for the day)
- Hop time (flight time for current flight)
- Cooldown time (time with motors disabled)
- SN1: Log #, Flight # pending (the next flight that will happen, when motors enable, it is displayed as Flight # active)
- HV disabled (state of high voltage)
- MC disabled (state of motor controller)
- revert/vert (state of settings)
- Mode2 (Flight mode)

# ground_control 2000, HUD/AHRS (Heads up display/Attitude, heading, and reference system) cont.


Airspeed tape with GS (ground speed) in m/s

Altitude tape (mean sea level) with above ground level in m

Vertical speed indicator in hundreds of meters/minute

Current G's and peak G's

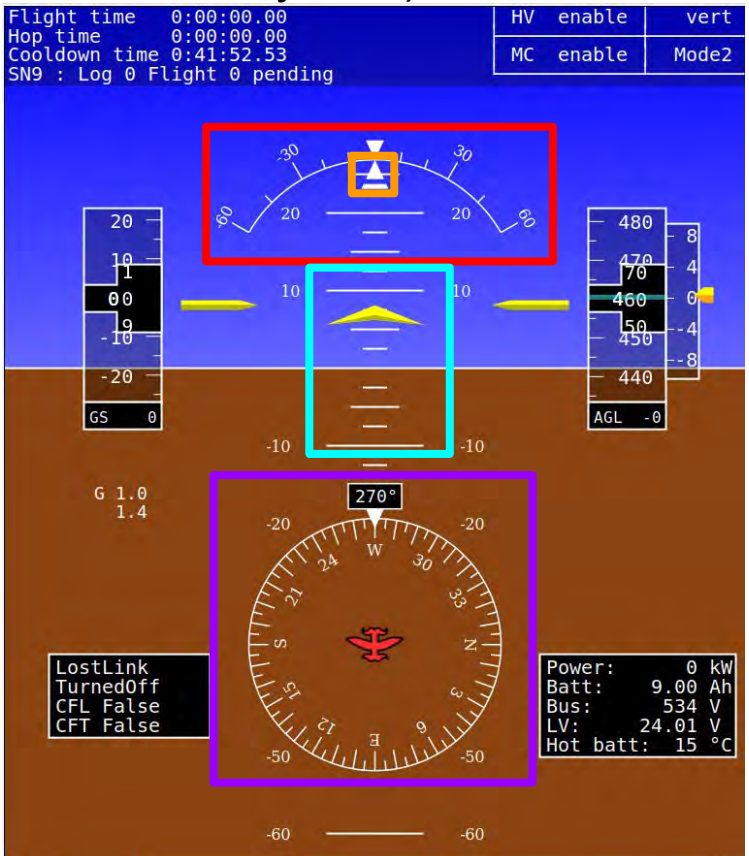
Mode info box

- External Pilot/Remote Pilot/Lostlink
  Turned Off/Manual/Autohover/Departure/EnRoute/Holding/Approach/GoAround/Autoland
- CFL True/False (Cleared for landing)
- CFT True/False (Cleared for takeoff)

Vehicle info box

- Power:
- Batt: Time remaining
- Bus: Motor controller bus voltage (nominal 500 - 530V)
- LV: LV battery level (nominal 22-24V)
- Hot Batt: The "Hottest" HV battery temperature

# ground_control 2000, HUD/AHRS (Heads up display/Attitude, heading, and reference system) cont.




Bank angle
Slip/skid indicator
Pitch
Compass and current heading

# ground_control 2000, Normal Operations

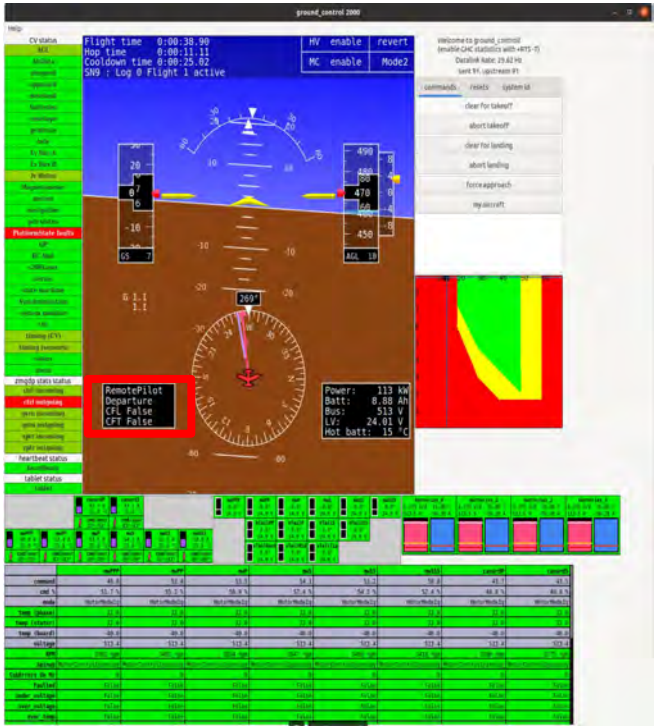
clear for takeoff
Holding
clear for landing
autoland
Augmented
Manual

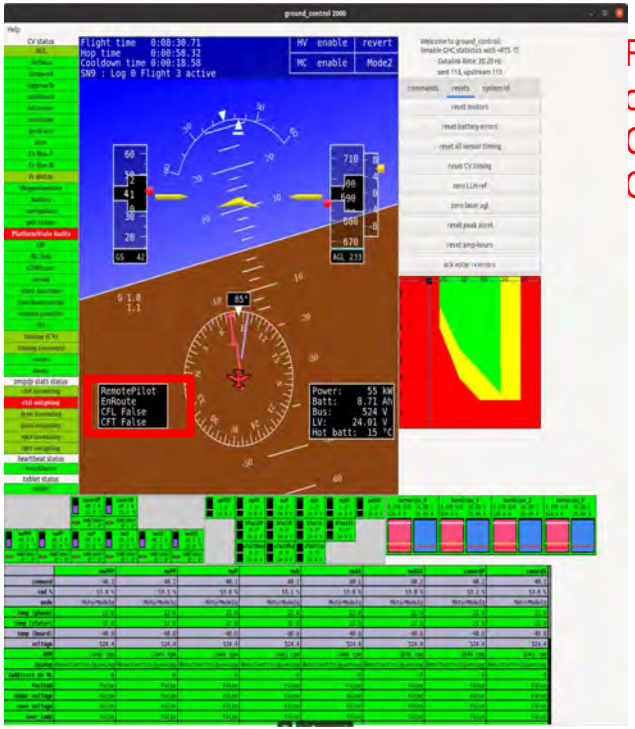
# ground_control 2000, clear for takeoff



Remote Pilot
CheckIdle → Takeoff
CFL False (clear for landing)
CLT False (clear for take off)
- Will go True when engaged and in CheckIdle, then will return to false as the aircraft departs on the departure path

# ground_control 2000, departure/enRoute




Remote Pilot
departure → enRoute
CFL False (clear for landing)
CLT False (clear for take off)

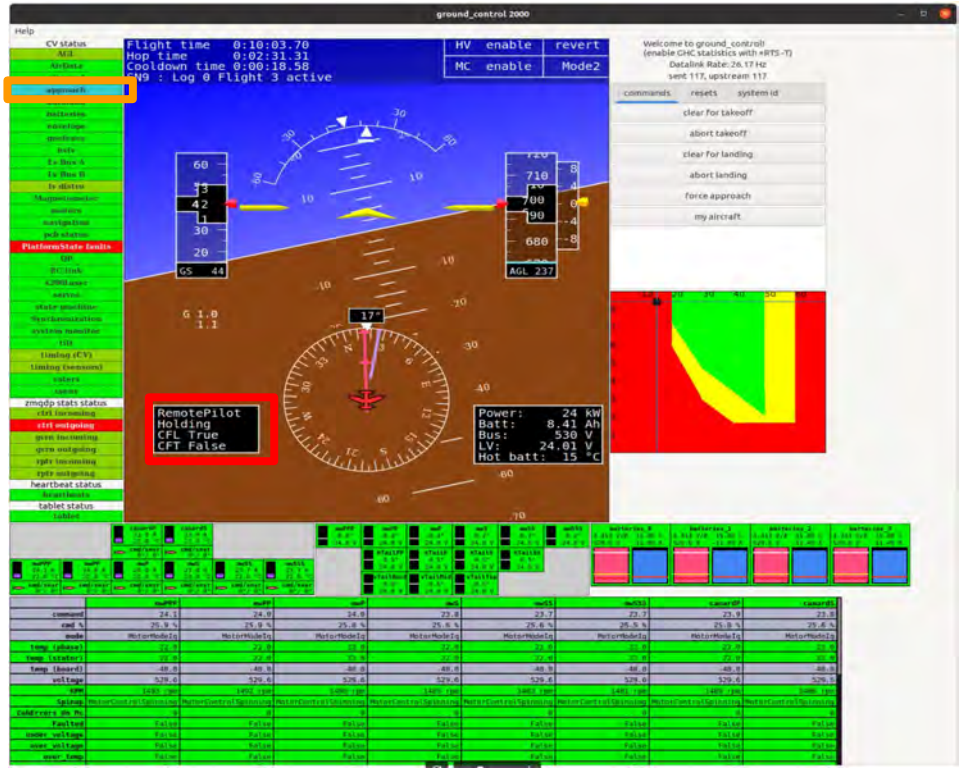
Aircraft will fly the departure path after takeoff until it intercepts the enRoute path.

# ground_control 2000, Holding


Autonomous
Holding
CFL False (clear for landing)
CFT False (clear for takeoff)

At the completion of the enRoute path, the aircraft enters the hodling path.

# ground_control 2000, clear for landing




Remote Pilot
Holding -> Approach
CFL true (clear for landing)
CFT False (clear for takeoff)

Approach turns blue and CFL flag goes to true.

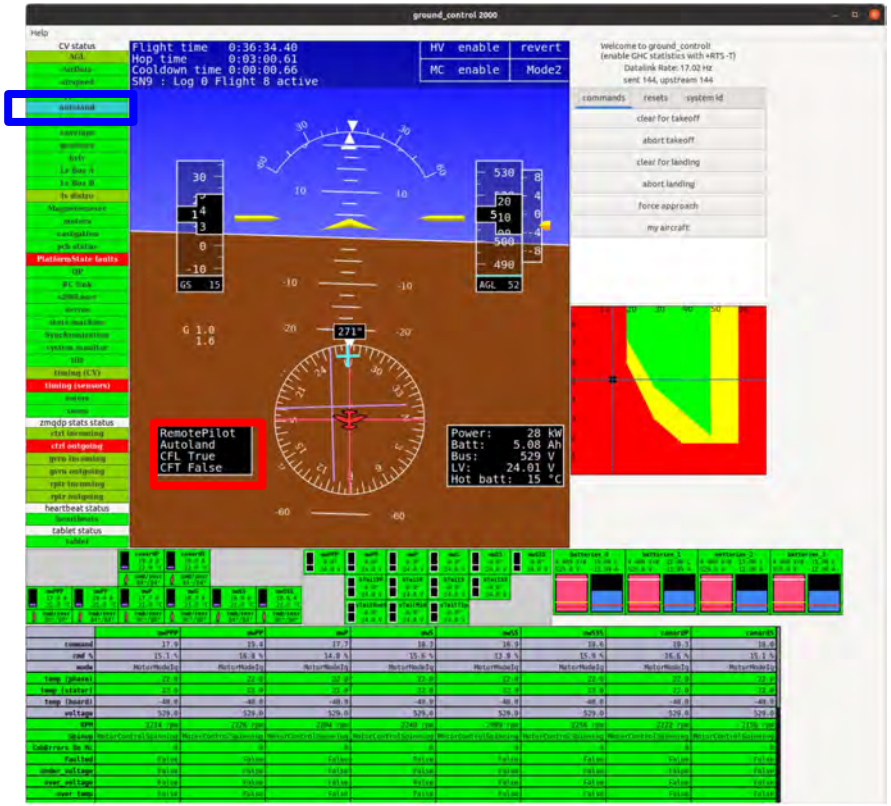
# ground_control 2000, approach


Remote Pilot
Approach (changes when the aircraft successfully breaks out)
CFL True (clear for landing)
CFT False (clear for takeoff)

approach is now green that the aircraft is on approach

autoland has turned blue as it is trying to meet certain conditions

# ground_control 2000, autoland




Autonomous
Autoland (changes when the aircraft successfully captures autoland)
CFL True (clear for landing)
CFT False (clear for takeoff)

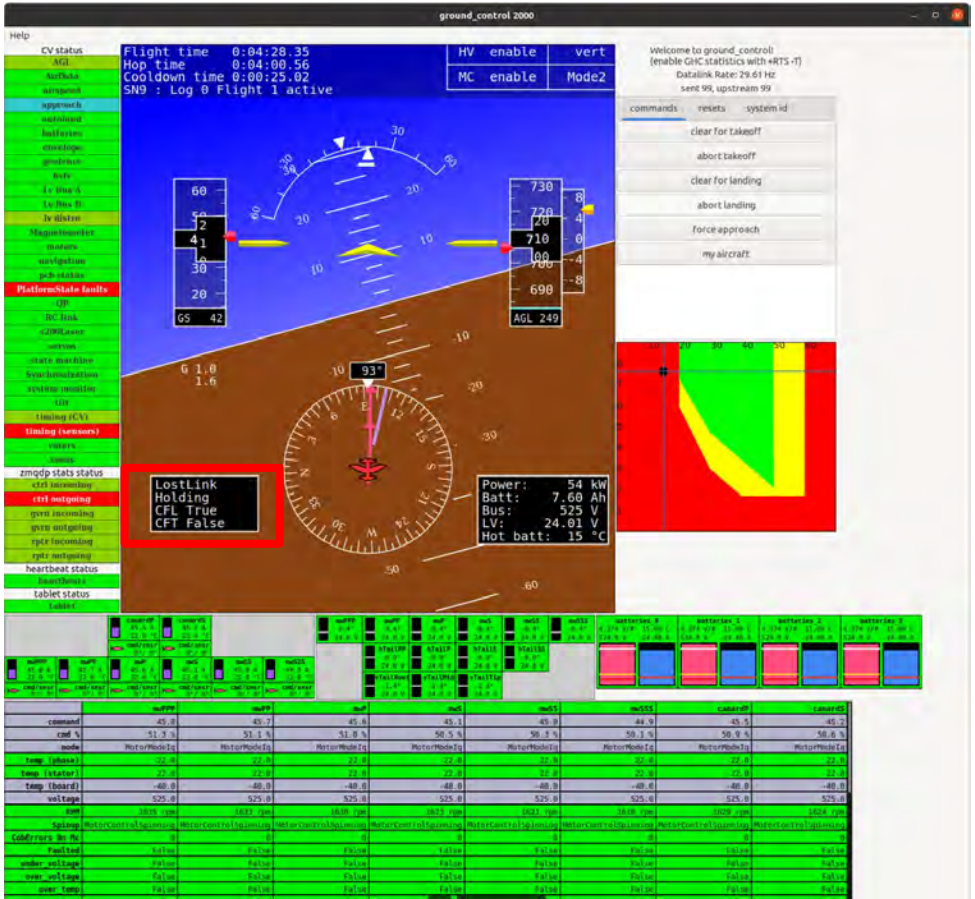
autoland remains blue

# ground_control 2000, GoAround


Autonomous
GoAround → On GoAround path
CFL False (clear for landing)
CLT False (clear for take off)

The aircraft will enter the go around path if the conditions are not met on the approach to enter autoland. If “abort landing” is pressed while the aircraft is on approach it will also enter the go around path.

# ground_control 2000, LostLink




Remote Pilot -> LostLink

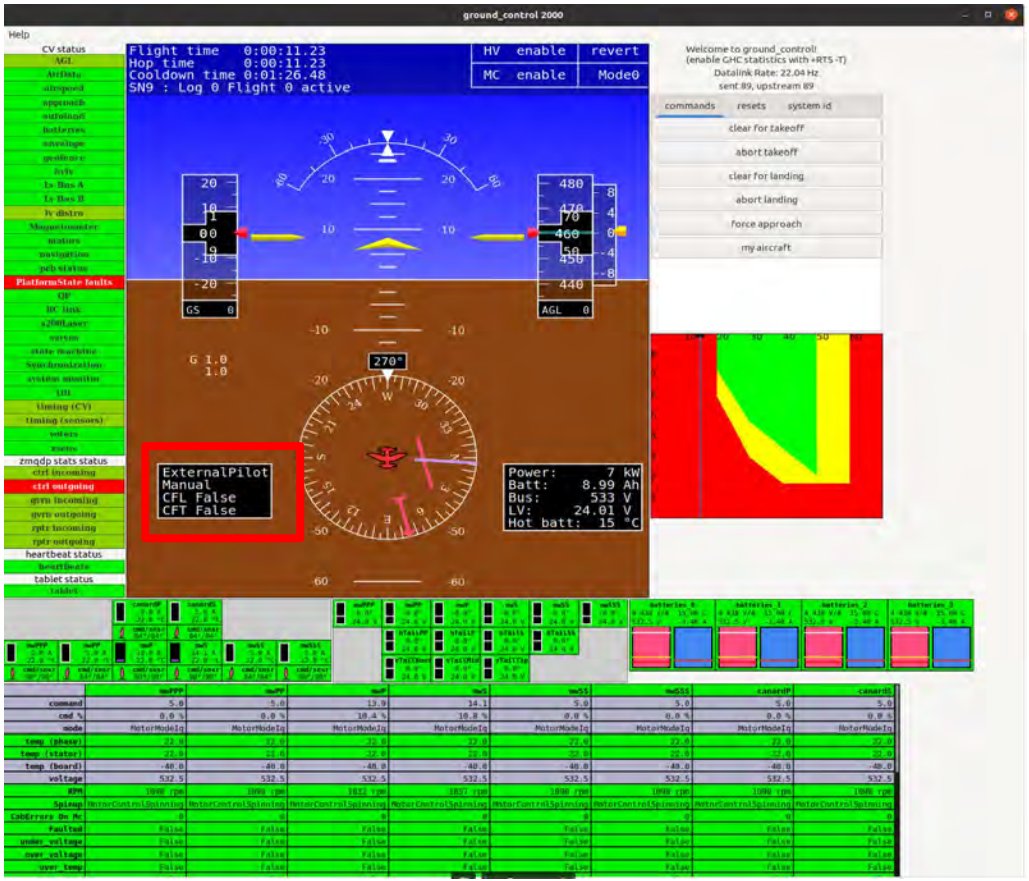
Holding -> LostLink FPL

CFL True

CFT False

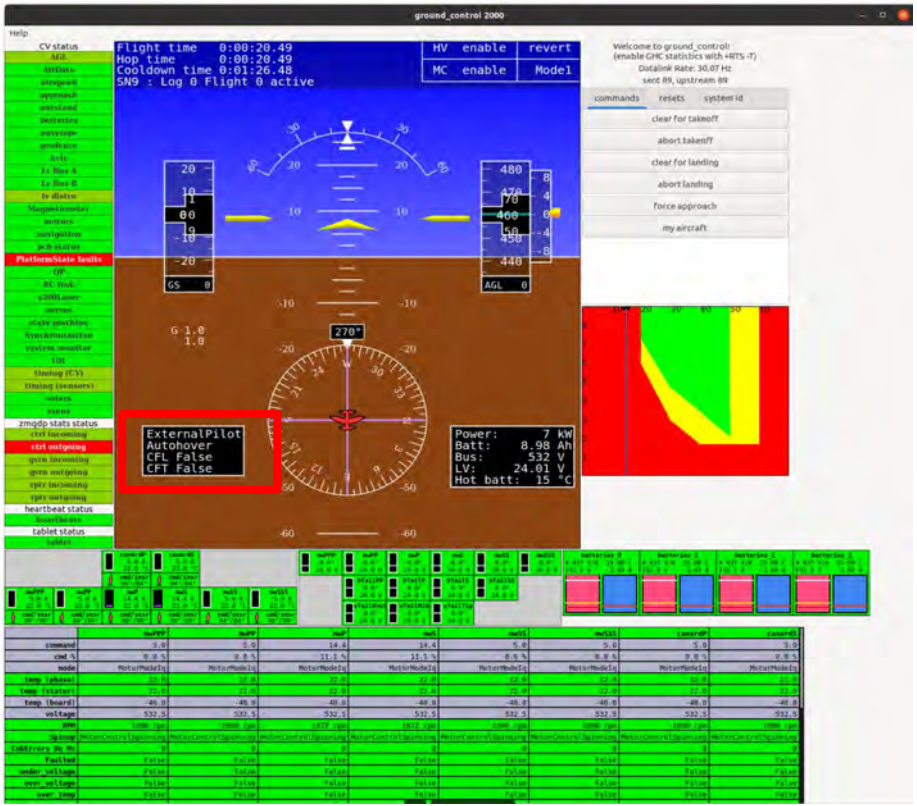
If the aircraft loses GCS link in Automated (RemotePilot) mode it will execute the LostLink flight plan and set CFL true.

# ground_control 2000, Manual




ExternalPilot
Manual
CFL False (clear for landing)
CFT False (clear for takeoff)

# ground_control 2000, AutoHover

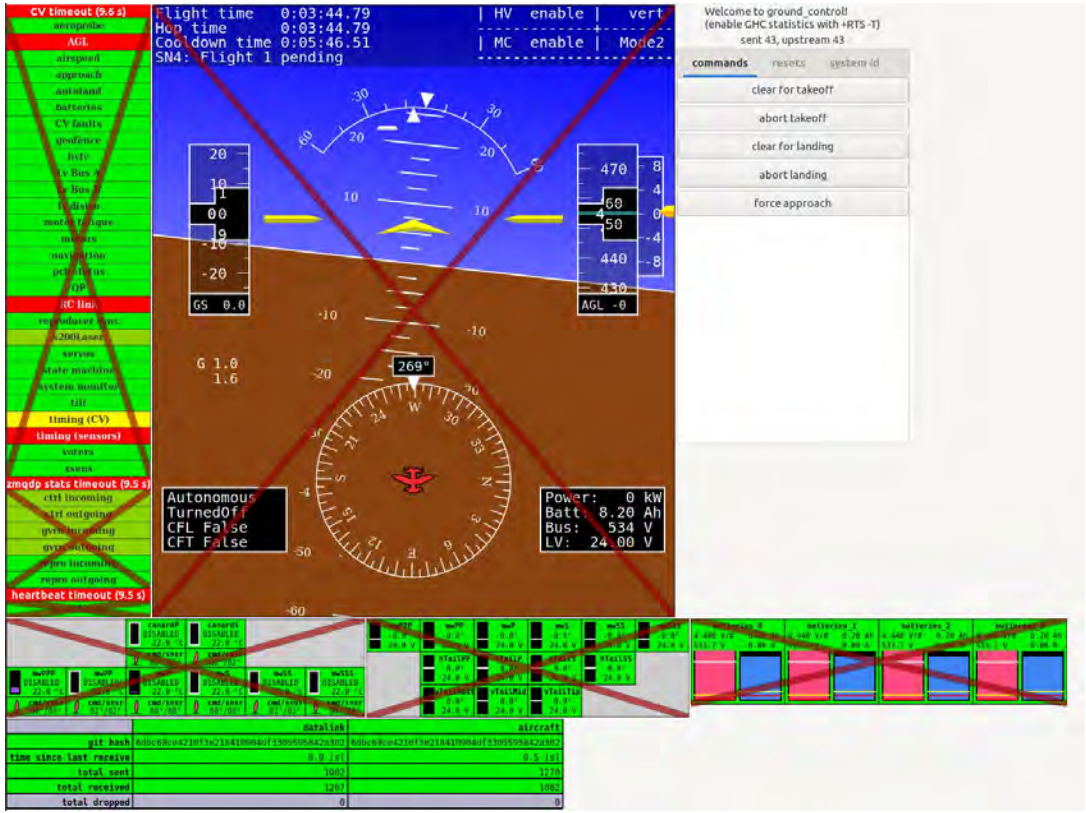



ExternalPilot
AutoHover
CFL False (clear for landing)
CFT False (clear for takeoff)

# ground_control 2000, Emergency Operations

Datalink dropout
Flap fault
Tilt fault
Motor fault
Motor overspeed
Missed breakout
RC Lost Link
Flight computer hang

# ground_control 2000, Emergency Operations, Datalink dropout (GCS Lost Link)




Indicators

- CV timeout counts up
- zmqdp stats timeout counts up
- heartbeat timeout counts up
- Red X's over all information including AHRS

Procedure

- **See** [Emergency Procedures]
- Communicate to pilot
  - "Microhard Dropout/GCS Lost Link"
- Aircraft will execute lost link flight plan

# GCS Event Log

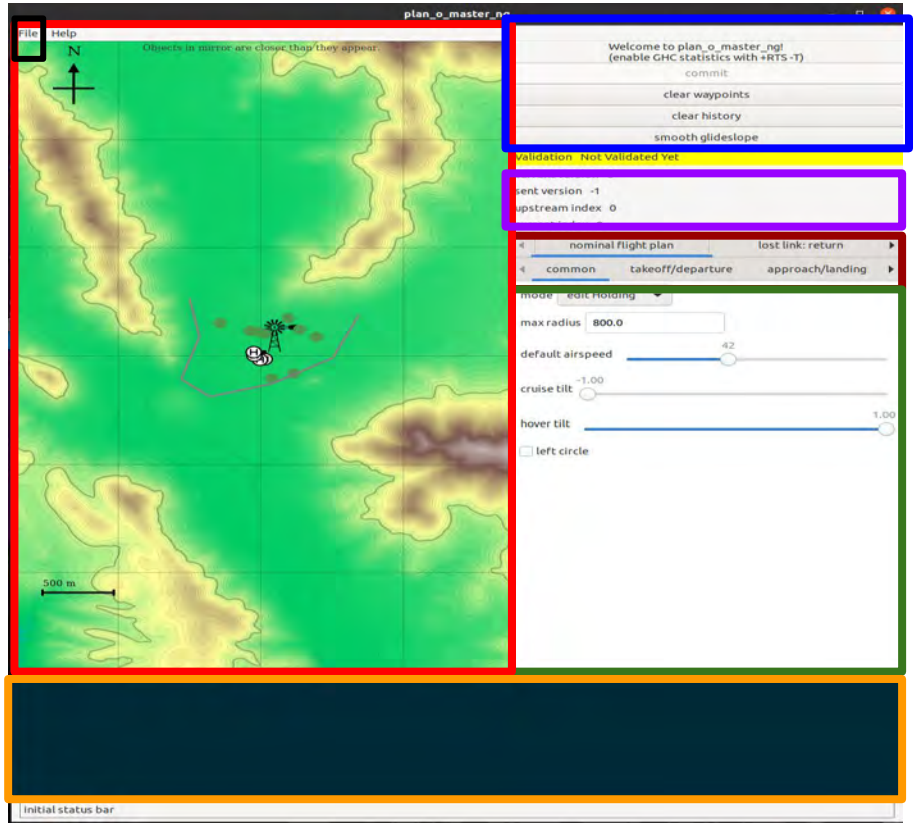
Main window w/ messages

Mutes “Grays Out” current messages

Deletes Muted/Grayed out messages

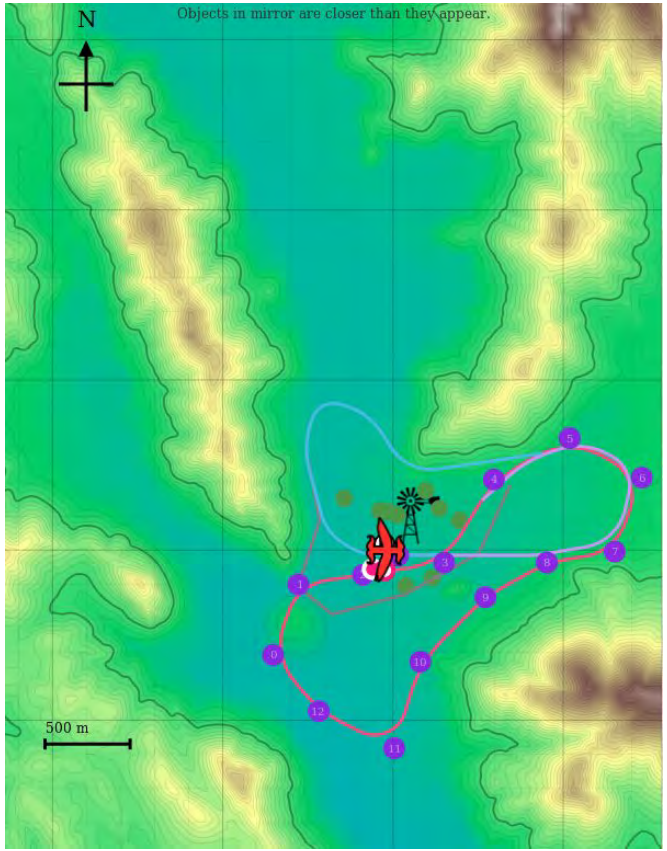
Clears all logged events

# plan-o-master 2000, Display




Lateral Path window
Atitude Path window
Major commands
GeoFence Validation
Plan indication
Flight path tabs
Flight path value settings
File Menu
- Load Path (pre-made flight plans)
- Save Path
- Export Mission Plan
- Quit

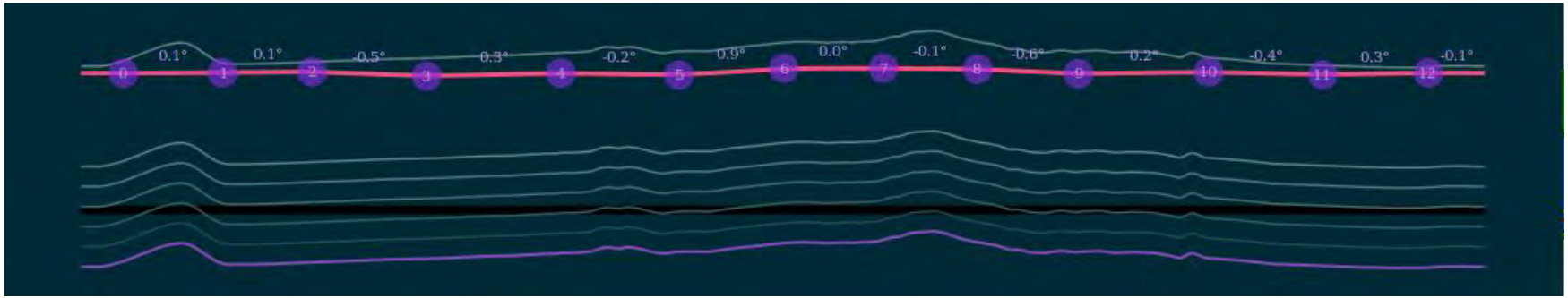
# plan-o-master 2000, Main window




This is the main window for the planning page. Aircraft is displayed with the heading read from the Xsens. Two red circles are the trackers which the aircraft will follow. Windmill is approximate location of the pilot stand. Terrain is shown for the local area.

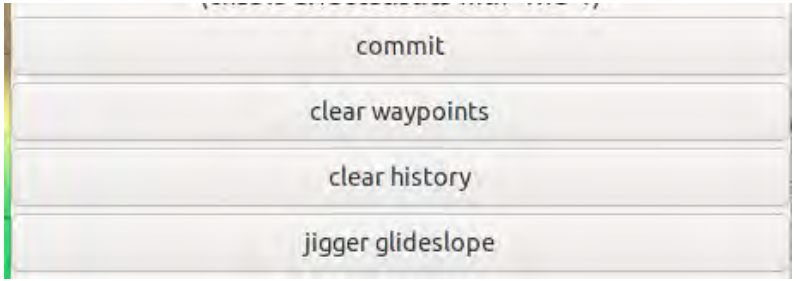
- You cannot click and drag on the map
- Left click adds a waypoint
- Right click removes the waypoint
- Mouse wheel zooms in and out which is how to move the map
- Light Blue path is the go-around path
- Dark Blue path is the Departure path
- Red path is the holding path
- Magenta is the approach path
- Purple circles with numbers are the way points
- TO=Take Off Point
- TE=Take Off End
- D= Departure End
- E= Entry Point (enRoute End)
- L=Landing Point
-
- Black line on terrain is based on the black line elevation in the Vertical window

# plan-o-master 2000, Vertical window




This is the vertical window for flight planning. Shown is the holding pattern. The red line shows the holding pattern altitude and the purple circles with numbers show each way point. The dark black line is movable and corresponds to the dark black line on the contour map. The purple line is the ground elevation. Each deviation is 20 m except for the large deviation which is ~ 100 m. Angles show the angle between waypoints. Climbs should be kept to < 6 degrees and descents should be kept to > -3 degrees. Helpful tips are to have the aircraft level at/between the waypoints where the approach breakout is.

# plan-o-master 2000, Major commands



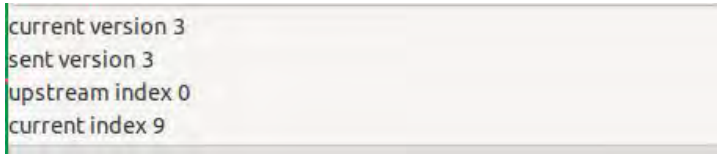

commit
: Sends the current flight plan to the aircraft. The aircraft will immediately go to the new flight plan.

clear waypoints
: Clears all the waypoints from the flight plan.

clear history
: Not sure what clear history does.

jigger glideslope
: Sets the glide slope for the approach base to linear.

# plan-o-master 2000, Plan indication




current version

The current flight plan being edited

sent version

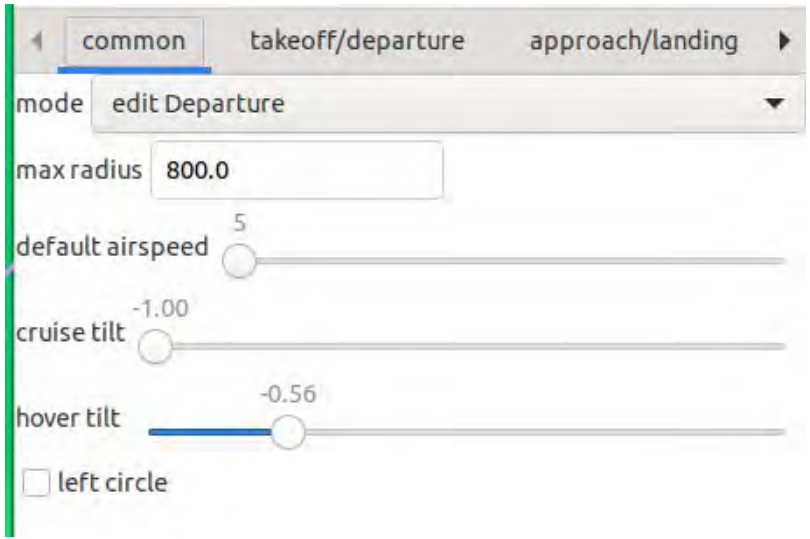
The current flight plan on the aircraft.

The current version and sent version is different during modifications and the same once committed. Current version only changes if it is different, not based on how many changes you make prior to committing the flight plan.

# plan-o-master 2000, Flight path tabs

Common
takeoff/departure
approach/landing

# plan-o-master 2000, Flight path tabs, common




mode
: edit Holding sets holding parameters

max radius
: maximum radius of the circle pattern if no way points are made

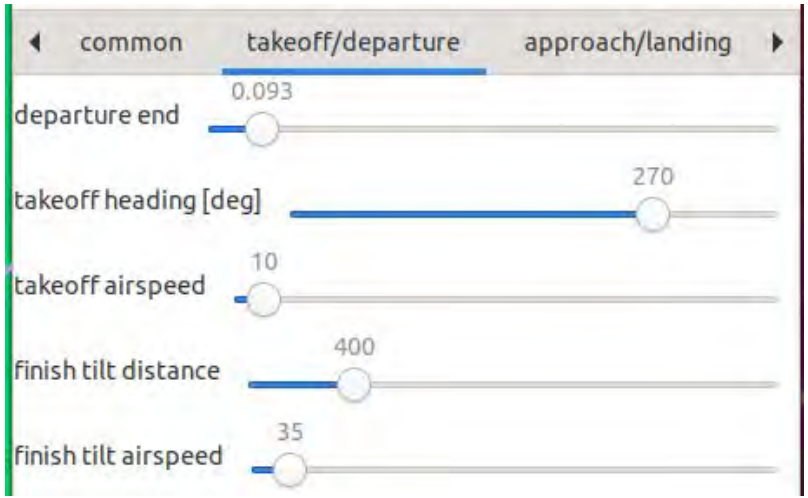
Default airspeed
: Default cruise speed for holding path and go around paths.

cruise tilt
: Should be set to -1.0

hover tilt
: Should be set to 1.0

left circle
: Needs to be engaged prior to setting any waypoints

plan-o-master 2000, Flight path tabs, takeoff/departure




Departure end

Where the go departure path will meet the holding path. Move this forward if a 6 degree climb is exceeded.

Takeoff heading [deg]

The heading of the aircraft on takeoff

Take off airspeed

The target airspeed that the aircraft will accelerate to after takeoff.

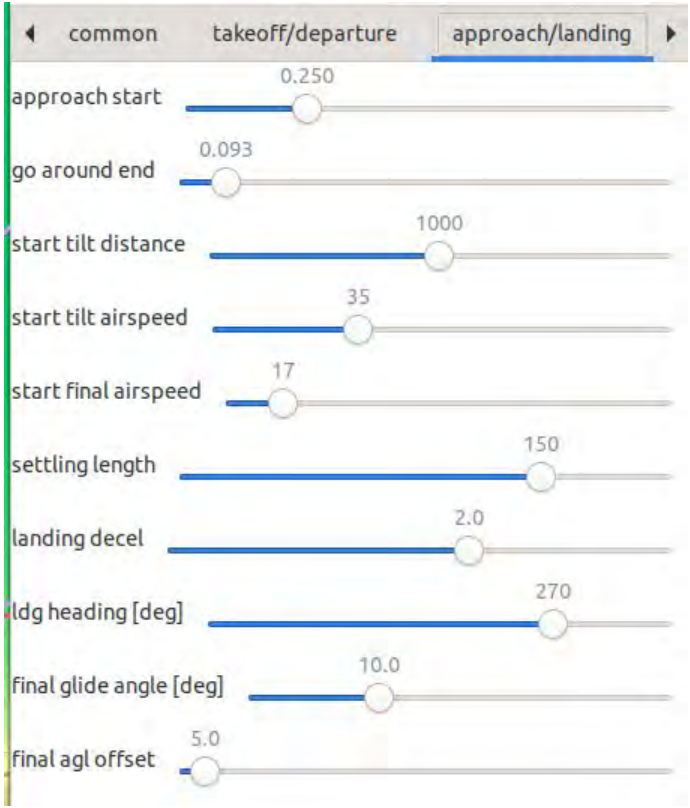
Finish tilt distance

The distance after take off the aircraft will be fully tilted to cruise configuration.

Finish tilt airspeed

The target airspeed that the aircraft will be at once all motors are tilted to cruise configuration.

# plan-o-master 2000, Flight path tabs, approach/landing




approach start
: Where on the approach path the approach will begin. Move this back if there is not enough distance to make a -3 degree descent to landing.

Go around end
: The point where the go around path intercepts the Holding path.

Start tilt distance
: The distance after take off that the aircraft begins tilting the motors to cruise config.

Start tilt airspeed
: The target airspeed that the aircraft will shoot for at the start of tilt.

Start final airspeed
: The target airspeed as the aircraft enters “autoland” on short final.

Settling Length
: The distance between the start of auto land and the landing point. (length of final descent path)

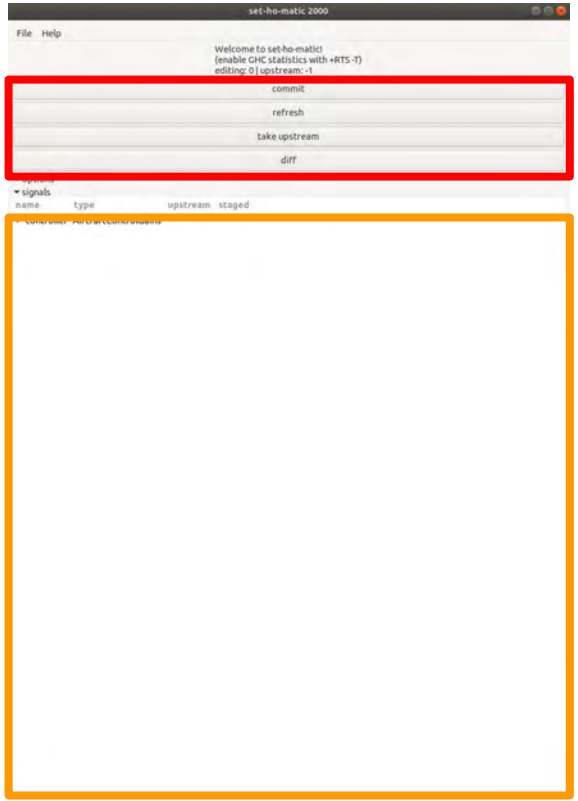
Landing decel
: The speed that the aircraft decelerates at on final in m/s^2.

Landing Heading
: The heading that the aircraft will be at on the landing.

Final Glide Angle
: The descent angle of the aircraft from the autoland point to touchdown.

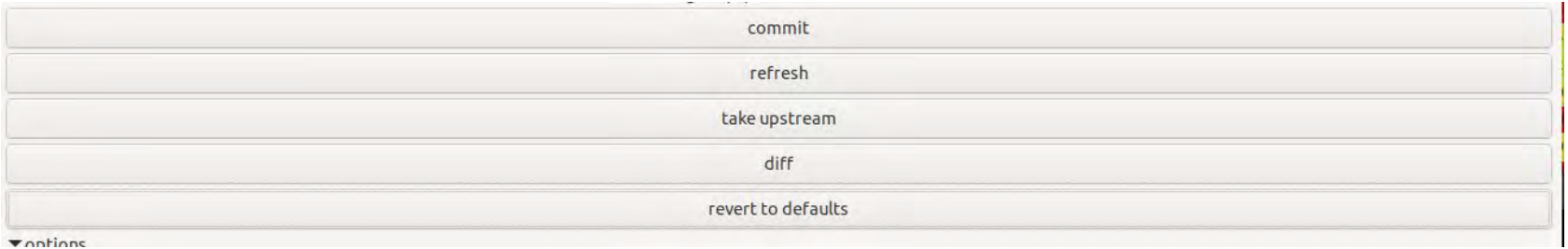
Final agl offset
: The vertical distance between the aircraft and landing point where the aircraft begins its vertical hover down to the pad.

# set-ho-matic 2000




Buttons
Controls

# set-ho-matic 2000, Buttons




commit
: Set the staged values to upstream. These will not take effect unless the radio transmitter is in Vert mode.

refresh
: Refresh the staged command values.

take upstream
: Pull down the current values on the aircraft and place them in the staged column.

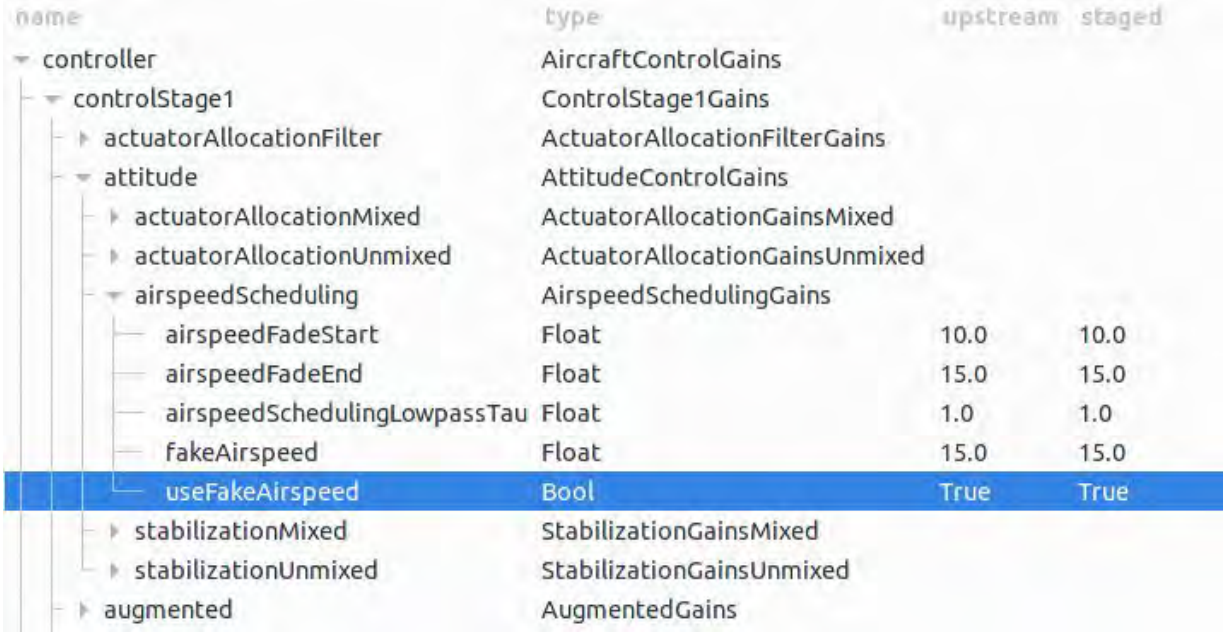
diff
: Shows the diff of staged and upstream values in the terminal that opened the set-ho-matic 2000.

Revert to defaults
: Automatically commits default values to the aircraft.

# set-ho-matic 2000, Controls

useFakeAirspeed
Disable motor (flight)
Adjust gains (test stand)
Sneaky disable motor (test stand)
Enable 75 amp spin (test stand)

# set-ho-matic 2000, Controls, useFakeAirspeed



| name | type | upstream | staged |
|---|---|---|---|
| controller | AircraftControlGains | | |
| controlStage1 | ControlStage1Gains | | |
| actuatorAllocationFilter | ActuatorAllocationFilterGains | | |
| attitude | AttitudeControlGains | | |
| actuatorAllocationMixed | ActuatorAllocationGainsMixed | | |
| actuatorAllocationUnmixed | ActuatorAllocationGainsUnmixed | | |
| airspeedScheduling | AirspeedSchedulingGains | | |
| airspeedFadeStart | Float | 10.0 | 10.0 |
| airspeedFadeEnd | Float | 15.0 | 15.0 |
| airspeedSchedulingLowpassTau | Float | 1.0 | 1.0 |
| fakeAirspeed | Float | 15.0 | 15.0 |
| useFakeAirspeed | Bool | True | True |
| stabilizationMixed | StabilizationGainsMixed | | |
| stabilizationUnmixed | StabilizationGainsUnmixed | | |
| augmented | AugmentedGains | | |

Commits useFakeAirspeed to the flight computer. Sets airspeed to 10 m/s which enables flaps for the RC control check performed on the ground. Takes effect when transmitter is placed in Vert.

controller.controlStage1.attitude.airspeedScheduling.useFakeAirspeed

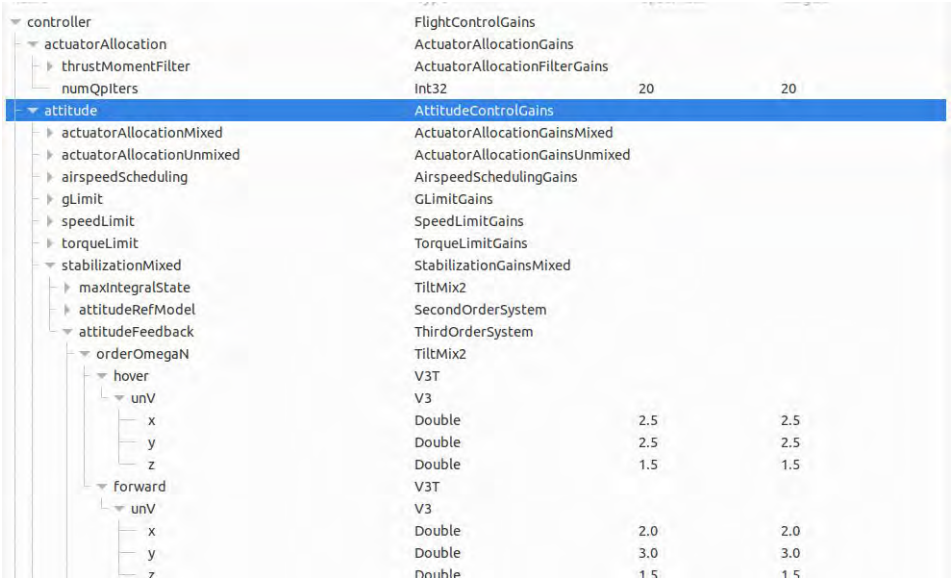
# set-ho-matic 2000, Controls, disable motor (flight)

| name | type | upstream | staged |
|---|---|---|---|
| mapping | MappingGains | | |
| motorControl | MotorControlGains | | |
| navigation | NavigationGains | | |
| outerOverride | OverrideGains | | |
| sensorProcessing | SensorsProcessGains | | |
| kProcesses | Sensors | | |
| yAirDataStatusMsg | SensorProcessGains | | |
| yEnergyStatusMsg | SensorProcessGains | | |
| yBatteryVoters | Batteries | | |
| ySystemMonitor | SensorProcessGains | | |
| yFlapSensors | Flaps | | |
| yInceptor | SensorProcessGains | | |
| yPilotSwitchPanel | SensorProcessGains | | |
| yFrsky | SensorProcessGains | | |
| yFrskyRssi | SensorProcessGains | | |
| yMotorStatusMsgs | Rotors | | |
| mwPPP | SensorProcessGains | | |
| kProcess | MotorGains | | |
| kInduceMotorOut | Bool | False | False |
| kTimeoutThreshold | Float | 0.15 | 0.15 |
| mwPP | SensorProcessGains | | |
| mwP | SensorProcessGains | | |
| mwS | SensorProcessGains | | |
| mwSS | SensorProcessGains | | |
| mwSSS | SensorProcessGains | | |
| canardP | SensorProcessGains | | |
| canardS | SensorProcessGains | | |

Controller>sensorprocessing>kProcesses>yMotorStatusMsgs>mwPPP(or desired motor)>kProcess>kInduceMotorOut

Disables each motor for flight, controlled by the vert switch on the RC transmitter.

# set-ho-matic 2000, Controls, Adjust gains (test stand)

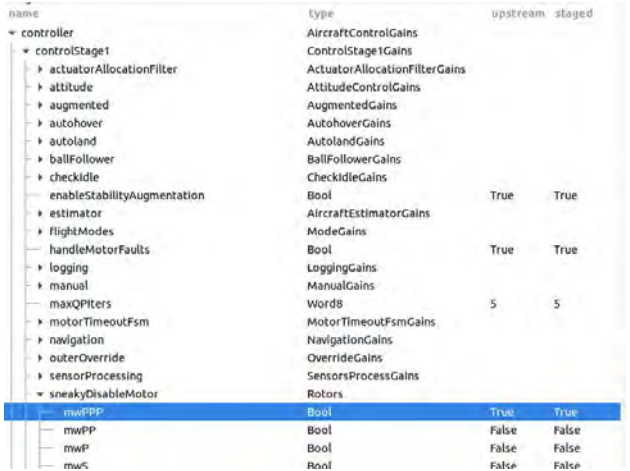


| | | | |
|---|---|---|---|
| controller | FlightControlGains | | |
| actuatorAllocation | ActuatorAllocationGains | | |
| thrustMomentFilter | ActuatorAllocationFilterGains | | |
| numQpIters | Int32 | 20 | 20 |
| attitude | AttitudeControlGains | | |
| actuatorAllocationMixed | ActuatorAllocationGainsMixed | | |
| actuatorAllocationUnmixed | ActuatorAllocationGainsUnmixed | | |
| airspeedScheduling | AirspeedSchedulingGains | | |
| gLimit | GLimitGains | | |
| speedLimit | SpeedLimitGains | | |
| torqueLimit | TorqueLimitGains | | |
| stabilizationMixed | StabilizationGainsMixed | | |
| maxIntegralState | TiltMix2 | | |
| attitudeRefModel | SecondOrderSystem | | |
| attitudeFeedback | ThirdOrderSystem | | |
| orderOmegaN | TiltMix2 | | |
| hover | V3T | | |
| unV | V3 | | |
| x | Double | 2.5 | 2.5 |
| y | Double | 2.5 | 2.5 |
| z | Double | 1.5 | 1.5 |
| forward | V3T | | |
| unV | V3 | | |
| x | Double | 2.0 | 2.0 |
| y | Double | 3.0 | 3.0 |
| z | Double | 1.5 | 1.5 |

Set feedback to a small, non-zero number. Do not set as zero as these are gains.

controller>attitude>stabilizationMixed>attitudeFeedback>orderOmegaN>hover/forward>unV>x/y/z

# set-ho-matic 2000, Controls, Sneaky disable motor (test stand)

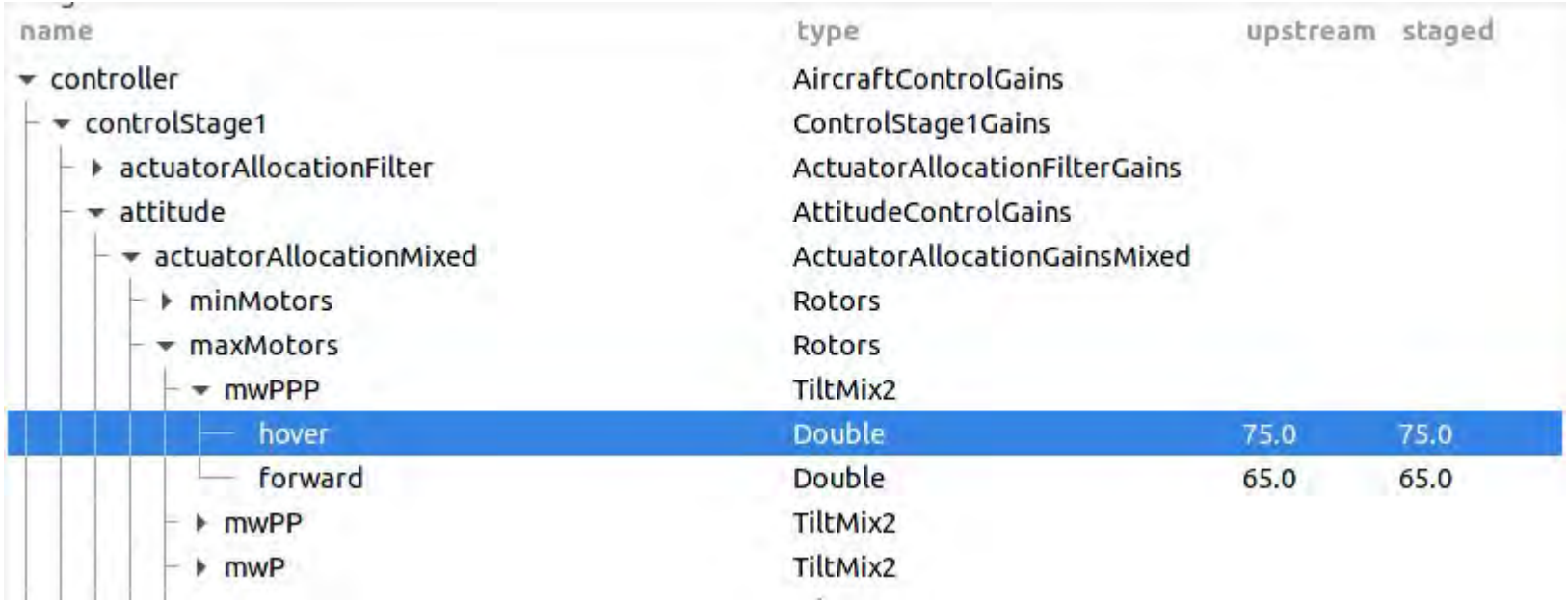


| name | type | upstream | staged |
|---|---|---|---|
| controller | AircraftControlGains | | |
| controlStage1 | ControlStage1Gains | | |
| actuatorAllocationFilter | ActuatorAllocationFilterGains | | |
| attitude | AttitudeControlGains | | |
| augmented | AugmentedGains | | |
| autohover | AutohoverGains | | |
| autoland | AutolandGains | | |
| ballFollower | BallFollowerGains | | |
| checkIdle | CheckIdleGains | | |
| enableStabilityAugmentation | Bool | True | True |
| estimator | AircraftEstimatorGains | | |
| flightModes | ModeGains | | |
| handleMotorFaults | Bool | True | True |
| logging | LoggingGains | | |
| manual | ManualGains | | |
| maxQPIters | Word8 | 5 | 5 |
| motorTimeoutFsm | MotorTimeoutFsmGains | | |
| navigation | NavigationGains | | |
| outerOverride | OverrideGains | | |
| sensorProcessing | SensorsProcessGains | | |
| sneakyDisableMotor | Rotors | | |
| mwPPP | Bool | True | True |
| mwPP | Bool | False | False |
| mwP | Bool | False | False |
| mwS | Bool | False | False |

This disables a motor without the flight computer knowing. This is not how we test motor outs in flight.

controller.controlStage1.sneakyDisableMotor.xxx

# set-ho-matic 2000, Controls, Enable 75 amp spin (test stand)

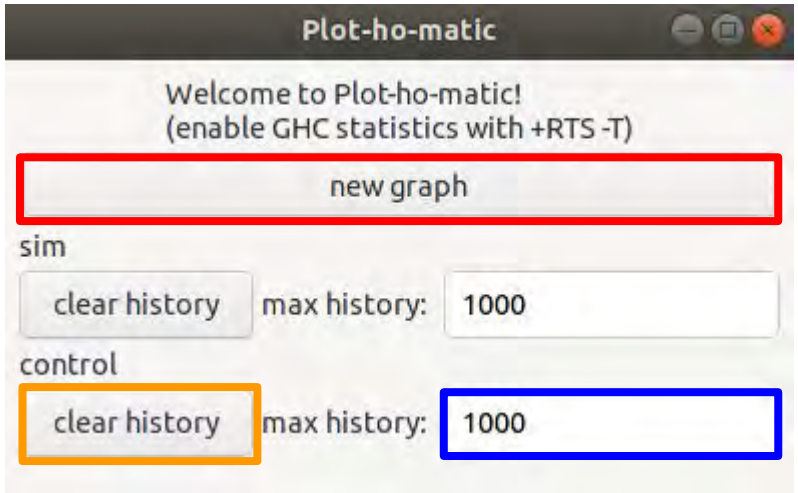


| name | type | upstream | staged |
|---|---|---|---|
| controller | AircraftControlGains | | |
| controlStage1 | ControlStage1Gains | | |
| actuatorAllocationFilter | ActuatorAllocationFilterGains | | |
| attitude | AttitudeControlGains | | |
| actuatorAllocationMixed | ActuatorAllocationGainsMixed | | |
| minMotors | Rotors | | |
| maxMotors | Rotors | | |
| mwPPP | TiltMix2 | | |
| hover | Double | 75.0 | 75.0 |
| forward | Double | 65.0 | 65.0 |
| mwPP | TiltMix2 | | |
| mwP | TiltMix2 | | |

Commits max motor to 75.0 amps instead of 65.0. Also need patch, see Cherry pick: https://gerrit.heavisoft.kittyhawk.aero/c/heavisoft/+/10005

controller.controlStage1.attitude.actuatorAllocationMix.maxMotors.xxx.hover

# plot-ho-matic




new graph
: Opens a new plot

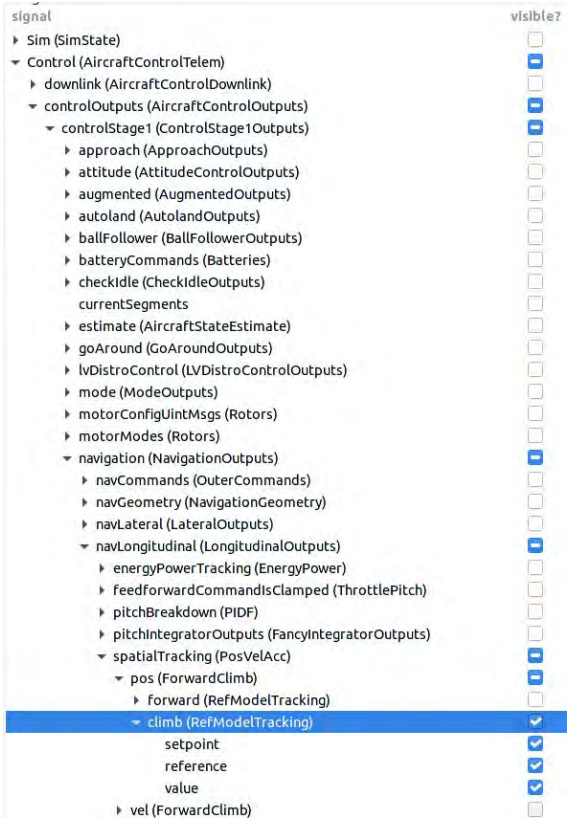
clear history
: Clears the current plot

max history
: How many points to display

# plot-ho-matic, new graph

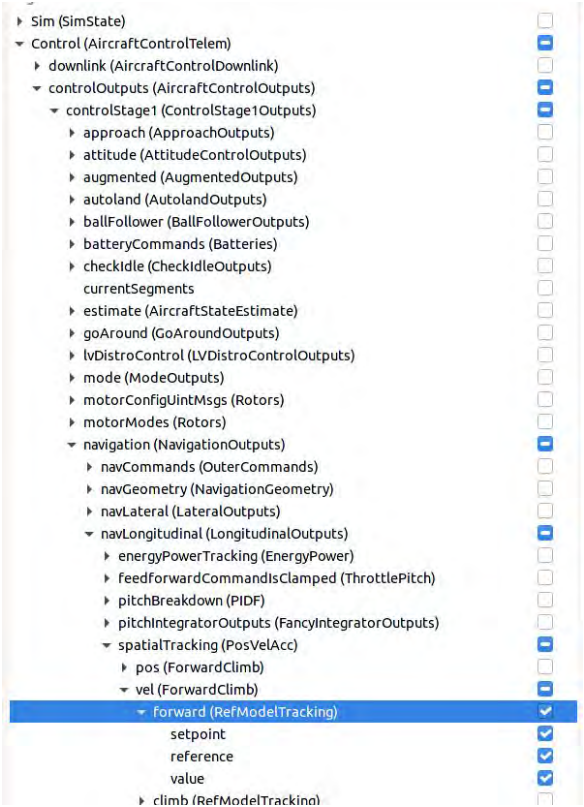
Altitude tracking
Airspeed tracking
Xsens vibration

# plot-ho-matic, new graph, Altitude tracking



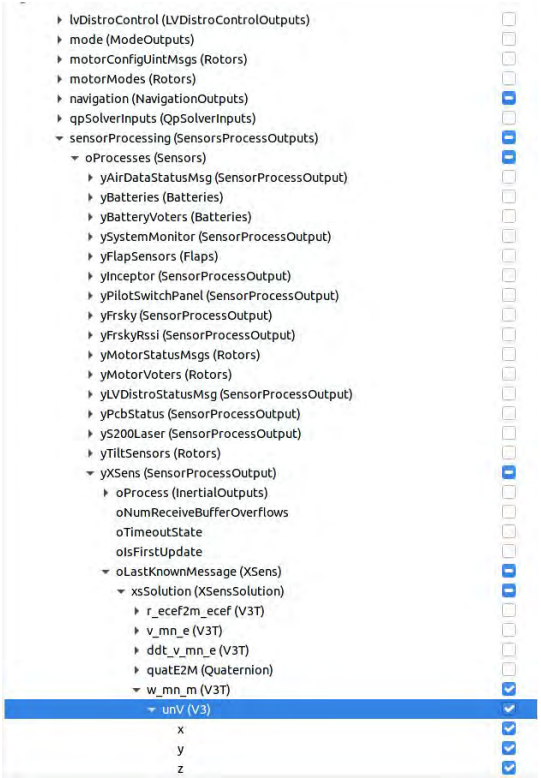

Control.controlOutputs.controlStage1.navigation.navLongitudinal.spatialTracking.pos.climb

# plot-ho-matic, new graph, Airspeed tracking




Control.controlOutputs.controlStage1.navigation.navLongitudinal.spatialTracking.vel.forward

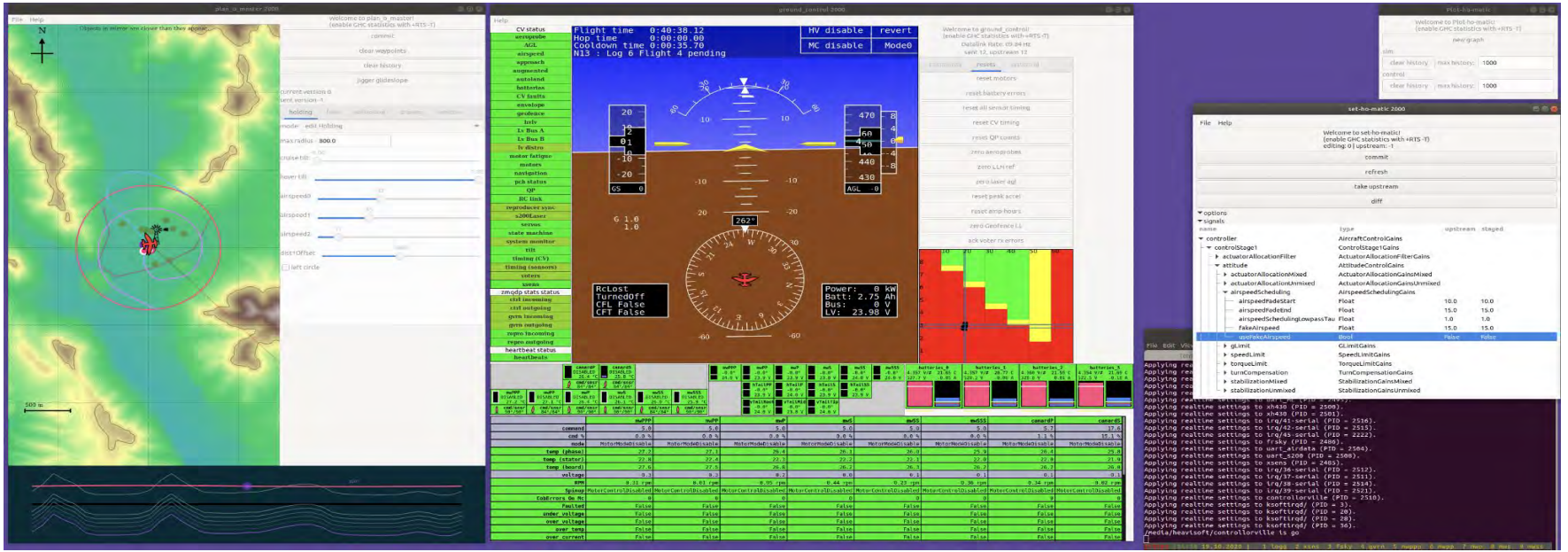
# plot-ho-matic, new graph, Xsens vibration




Control.controlOutputs.controlStage1.sensorProcessing.oProcesses.yXSenses.oLastKnownMessage.xsSolution.w_mn_m

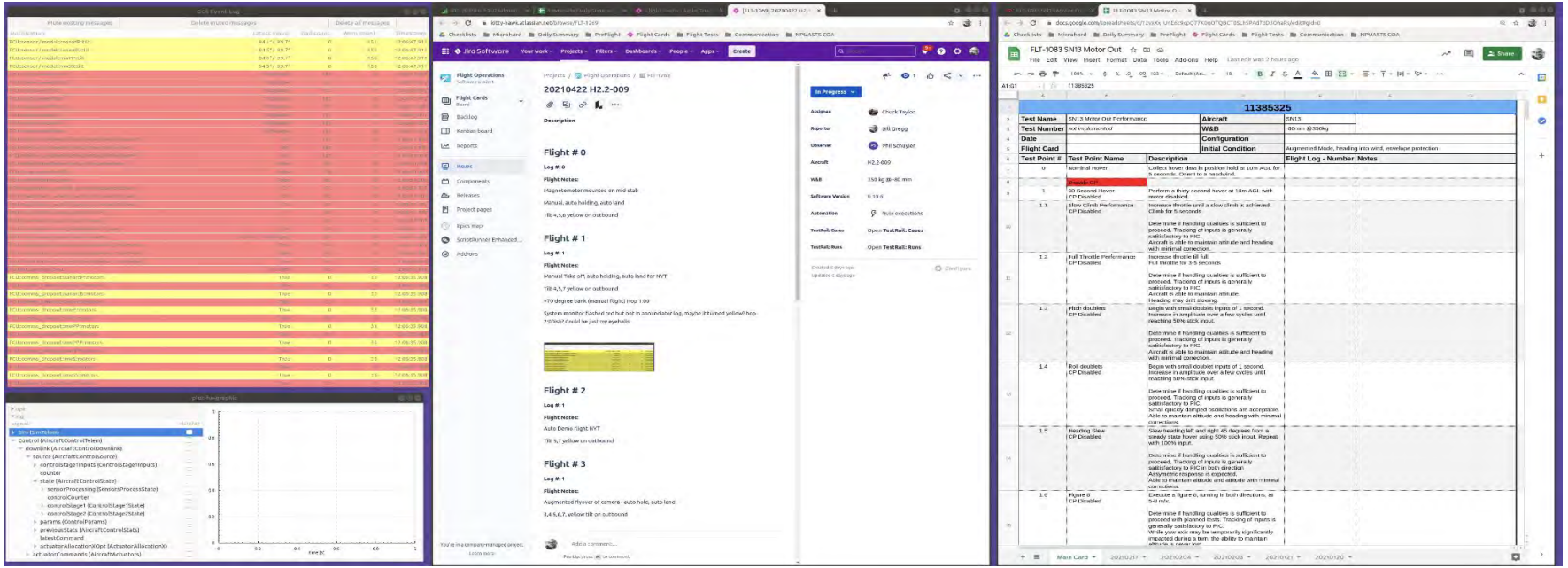
# GCS Screen Layout

## Screen 1



# GCS Screen Layout

## Screen 2



# Acronyms

| | |
|---|---|
| GCS | = ground control station |
| HUD | = heads up display |
| AHRS | = attitude heading and reference system |
| CV | = controllerville |
| zmqdp | = software messaging implementation |
| AGL | = above ground level |
| GS | = ground speed |
| lv distro | = low voltage distribution |
| pcb | = printed circuit board |
| QP | = quadratic programming |
| ctrl | = control |
| gvrn | = governorville |
| repro | = reproducerville |
| canardP | = canard port #1 |
| canardS | = canard starboard #2 |
| mwPPP | = motor port port port (outboard) #3 |
| mwPP | = motor port port (midspan) #4 |
| mwP | = motor port (inboard) #5 |

# Acronyms,cont.

| | |
|---|---|
| mwS | = motor starboard (inboard) #6 |
| mwSS | = motor starboard starboard (midspan) #7 |
| mwSSS | = motor starboard starboard starboard (outboard) #8 |
| mwPPP | = aileron port port port (outboard) #1 |
| mwPP | = aileron port port (midspan) #2 |
| mwP | = aileron port (inboard) #3 |
| mwS | = aileron starboard (inboard) #4 |
| mwSS | = aileron starboard starboard (midspan) #5 |
| mwSSS | = aileron starboard starboard starboard (outboard) #6 |
| hTailPP | = horizontal tail port port (outboard elevator) #1 |
| hTailP | = horizontal tail port (inboard elevator) #2 |
| hTailS | = horizontal tail starboard (inboard elevator) #3 |
| hTailSS | = horizontal tail starboard starboard (outboard elevator) #4 |
| vTailRoot | = vertical tail root (bottom rudder) #1 |
| vTailMid | = vertical tail mid (mid-rudder) #2 |
| vTailTip | = vertical tail tip (top rudder) #3 |

# Acronyms, cont.

V/# = voltage per cell
V = voltage
Ah = amp-hour
A = amp
SN = serial number
HV = high voltage
MC = motor controller
Batt = battery
RC = radio control
TX = transmitter
RX = receiver

# Automated Flight Planning

| Revision | Date | Changes |
|---|---|---|
| 0.17.0-0 | 20210919 | 0.17.0 initial release |
| | | |

For an overview of all the buttons and functionality of the Plan_O_Master please reference the GCS Operators Handbook . This page is designed to be a tutorial of how to effectively and safely plan an automated flight.

---



## Flight Plan Segments

**Take off:** This is a very short segment of the flight, the time from when the aircraft lifts off the pad to where it meets the take off end point. From the TO (take off) dot, to the TE (take off end) dot.

**Departure:** The departure path is the path the aircraft will fly following completion of the take off segment. The departure path will intercept the holding path.

**EnRoute:** The enRoute section of the flight plan is the “cruise” section of the flight plan that the aircraft will fly to traverse from A to B BVLOS flight plan. At French Ranch the enRoute portion of flight is very short and intercepts the holding path to keep the aircraft within line of sight.

**Holding:** The holding paths will be the hold that the aircraft intercepts at each of the TO and/or landing locations on an A to B BVLOS flight plan. The holding path is currently used as the “cruise”section of the auto path at French Ranch where the aircraft will cruise and continue flying the same holding path until it is given another command.

**Approach:** The approach path is what the aircraft will break out of the holding path and intercept once it is cleared for a landing. The approach path will bring the aircraft from the holding path down to the autoland section of flight.

**Go Around:** The go around path is a separate path from the departure path that the aircraft will follow when it has a missed approach OR when the GCS operator commands it to go around. The go around path will bring the aircraft back to to holding pattern altitude and intercept the holding path.

**Lost Link Return:** The lost link return flight path will be the path that the aircraft follows in the event of a GCS lost link scenario when the aircraft is on the automated flight plan. This path will take the aircraft back to its origin location if it is closer to the take off point than its destination point. ***currently this is the only functional lost link path.*

**Lost Link Continue:** The lost link continue flight path will be the path that the aircraft follows in the event of a GCS lost link scenario when the aircraft is on the automated flight plan. This path will take the aircraft to its destination if it is closer to the destination than its take off point.

**Auto Land:** Auto land is the phase of flight on short final where the aircraft begins its final decent to the pad. The aircraft will be in the hover configuration and being a steeper decent with less forward velocity once it enters the auto land phase.

---

## Flight Plan Limitations

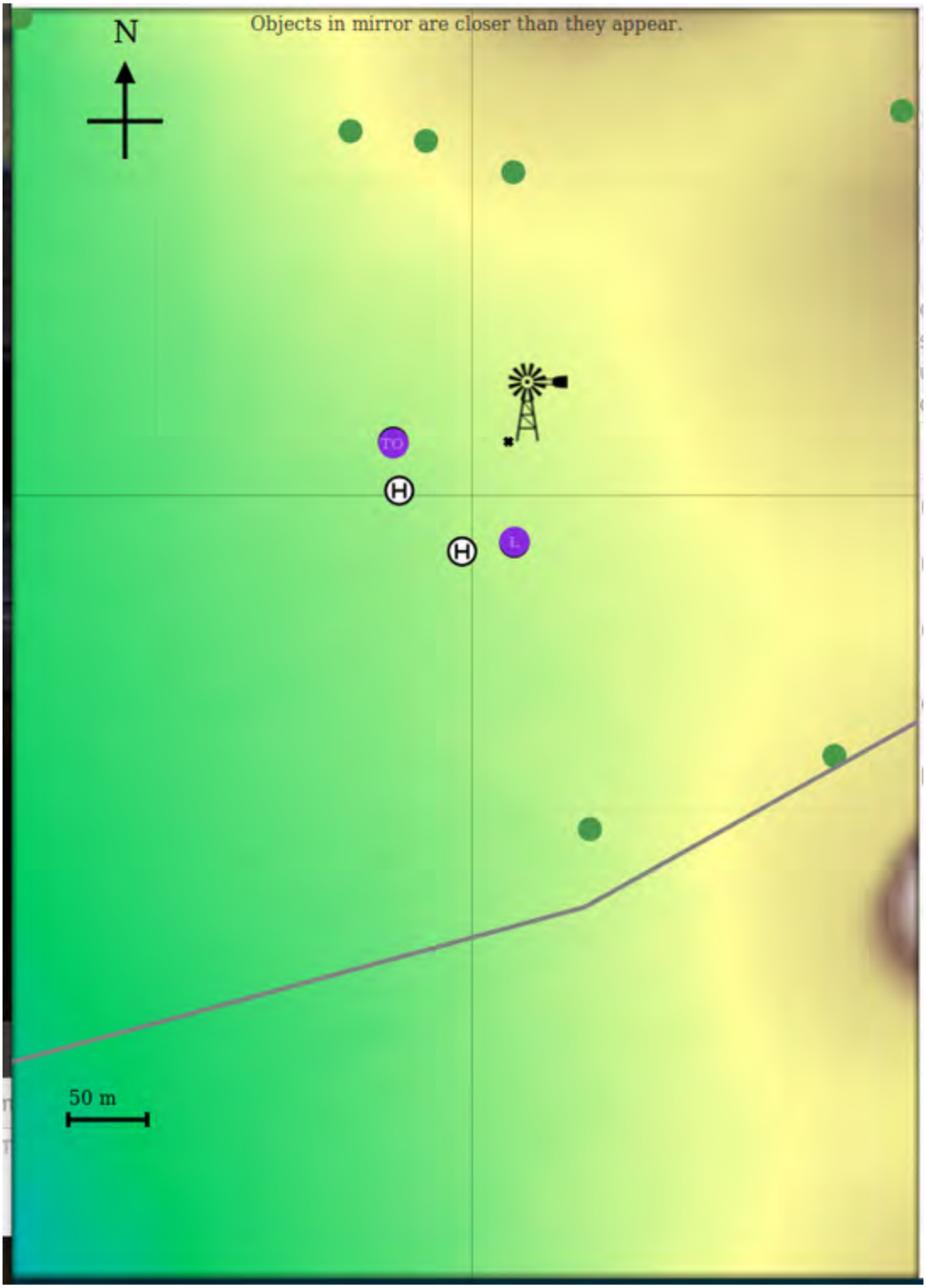
| | Lower Bound | Typical | Upper Bound |
|---|---|---|---|
| **Takeoff/Departure Tab** | | | |
| **Take off airspeed** | | 10 m/s | |
| **Finish Tilt Distance** | | 350 m | |
| **Finish Tilt Airspeed** | | 37 m/s | |
| **Climb Angle** | | ~6 degrees | |
| **Approach/Landing Tab** | | | |
| **Approach angle** | | ~3 degrees | |
| **Start Tilt Airspeed** | | 35 m/s | |
| **Start Final Airspeed** | | 17 m/s | |
| **Settling Length** | | 150 m | |

| | | | |
|---|---|---|---|
| **Landing decel** | | ~1 m/s^2 | |
| **Final Glide Angle** | | ~10 degrees | |
| **Final AGL offset** | | ~7 m | |

---

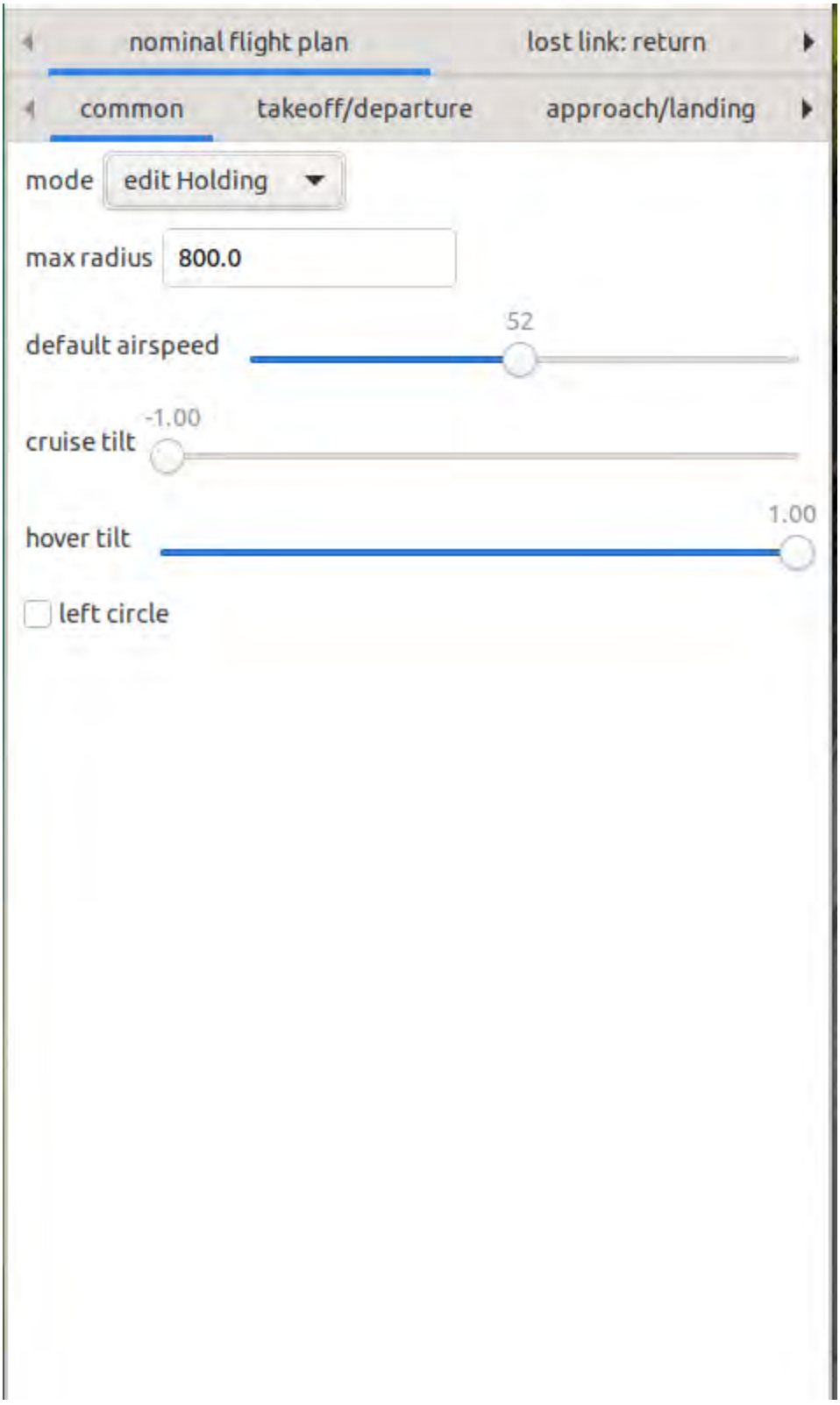
## Creating a Flight Plan

1. **Setting the Take Off and Landing Points**
    a. *Left Click* on the map screen where you want the aircraft to takeoff. This will drop **both** the take off and landing point in the same spot. They are labeled **TO** for take off, and **L** for landing.
    b. If you are going to take off and land from different pads, you can *left click* and drag the **TO** and **L** points to their respective pads. In the example below I have set the **TO** point on Pad 9 and **L** point on pad 5.




2. **Creating a Holding Path**

a. Under the *nominal flight plan>common tab* in the right hand column of the plan_o_master; click on the *mode* drop down and select **edit holding.**



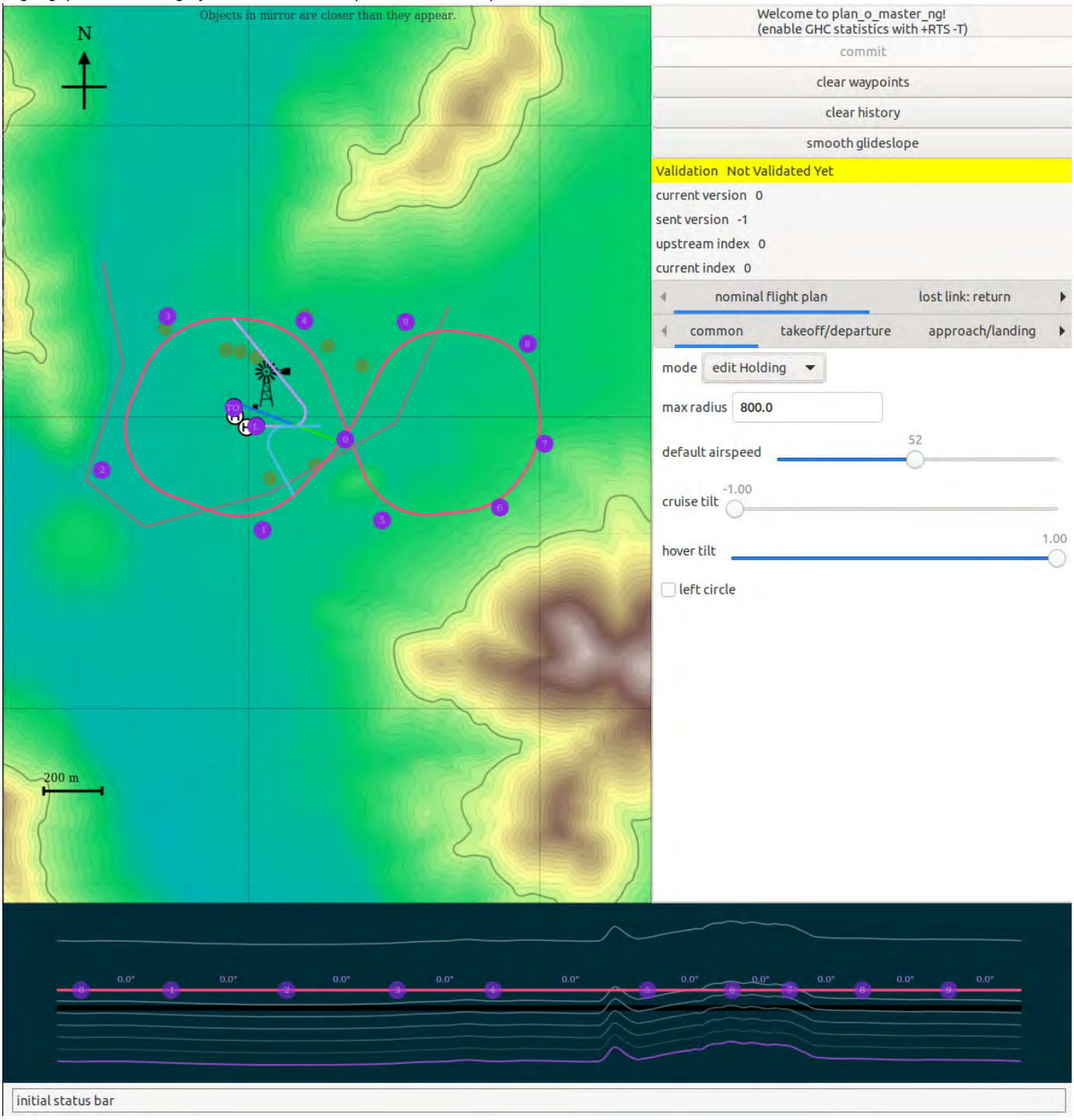

b. Left click on the map display and this will drop your 0 point (first waypoint). By deafault this will create a circle path around the 0 point radius equal to the *"max radius"* set above. If you want a circle path, your life just got a lot easier. Set your desired radius in the *"max radius"* box above and you have a circle path.

c. In this example we are going to make a figure 8 holding path so we are manually going to add more way points. To do this; continue *left clicking* on the map and with each click you will drop the proceeding way point in the holding path i.e. point 1,2,3,4,5,6, etc.

d. If you drop an unwanted way point you can delete it by *right clicking* on top of it. Alternatively you can left click and hold on any existing way points to drag and move them around.

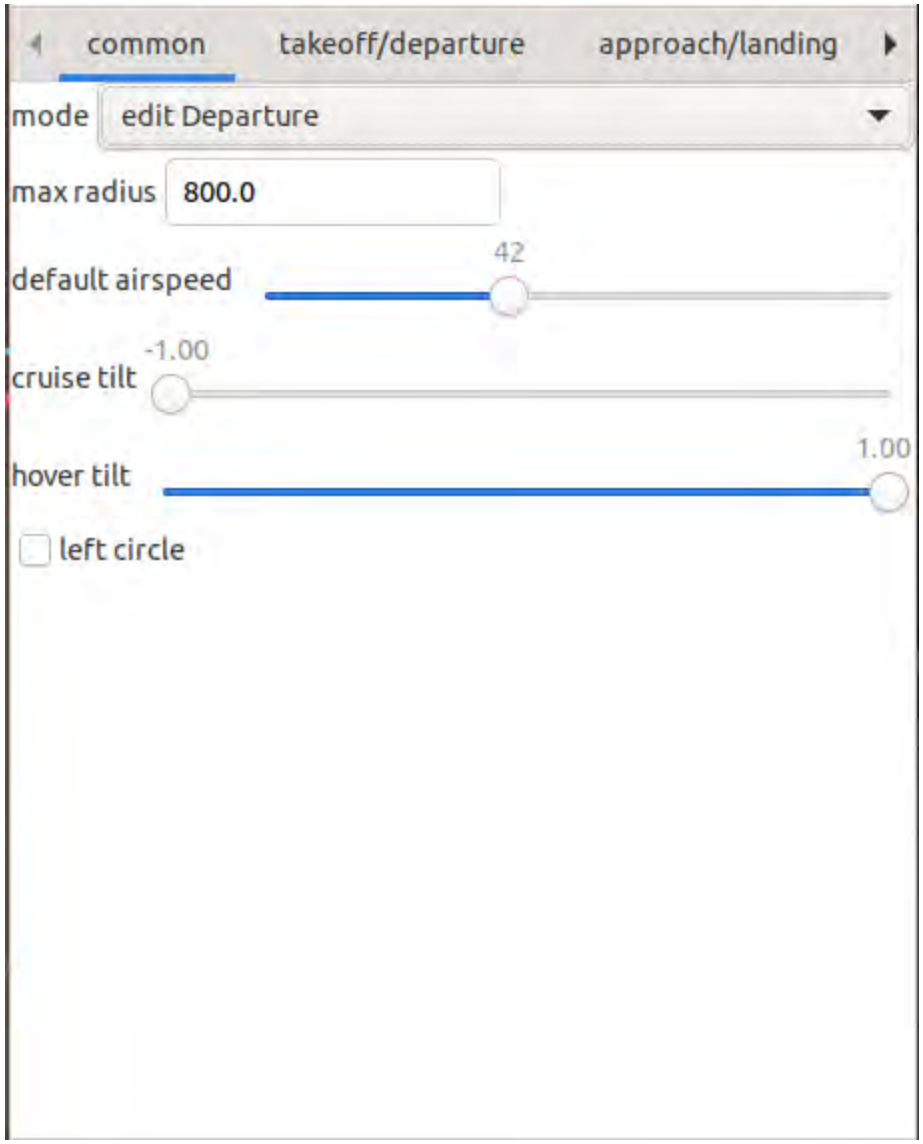
e. Setting the altitude of the holding path is done in the grey window in the bottom of the screen which is giving us a profile view of the holding path. By default all of the points are set at the same altitude of ~120m AGL. It is possible to change the altitude of the points individually by *left clicking* and dragging any of the way points up/down in this window. Alternatively you can change the altitude of all of the way points in the holding path at the same time (to maintain a level holding path) by holding *shift* and left clicking anywhere along the holding path within this window and moving it vertically up/down.

For reference; the purple line across the bottom is the ground. The grey lines that are closely spaced are vertically separated by 20m and the larger gap between the grey lines towards the top of the window represents 100m.

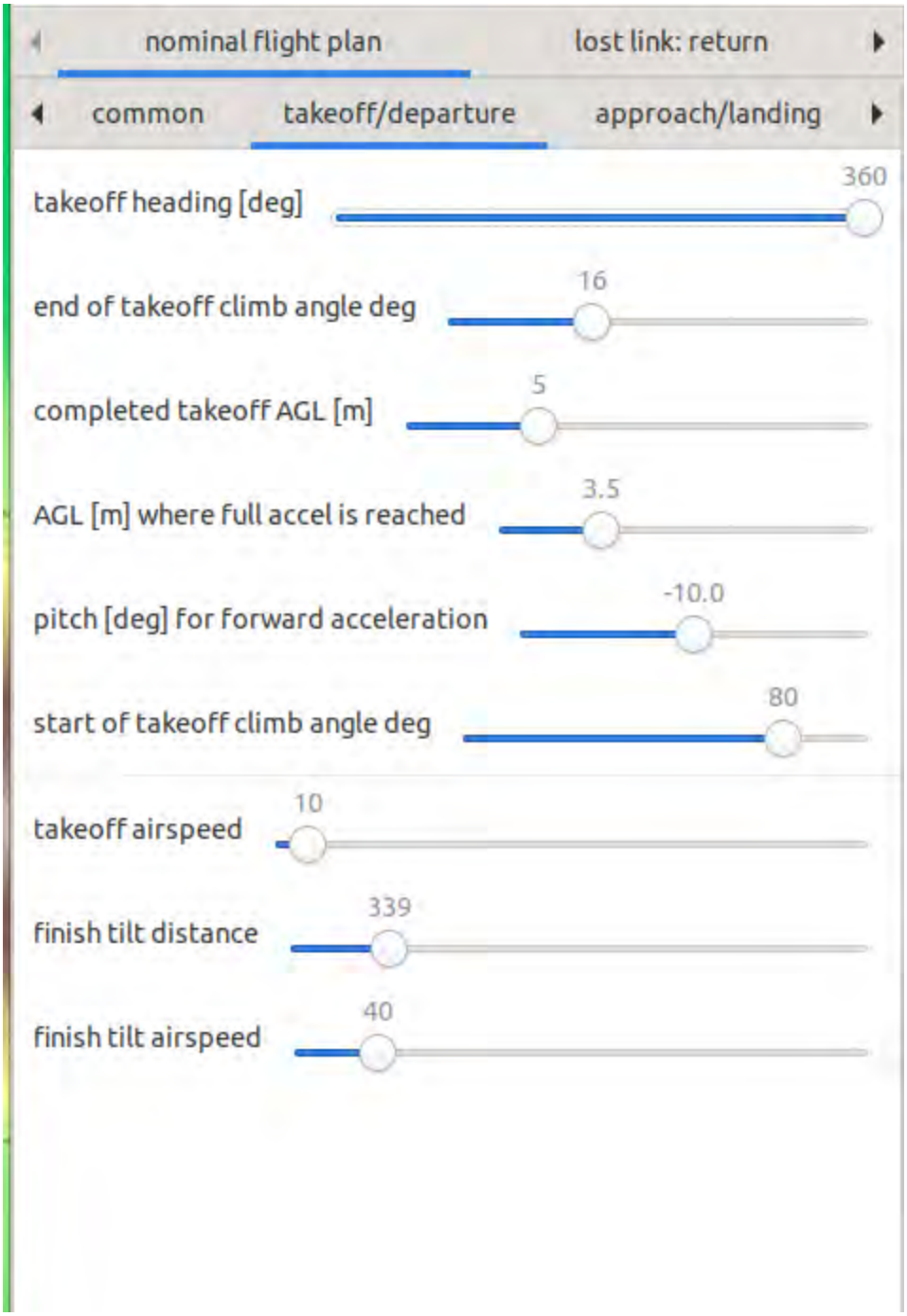



3. **Creating the Departure Path**

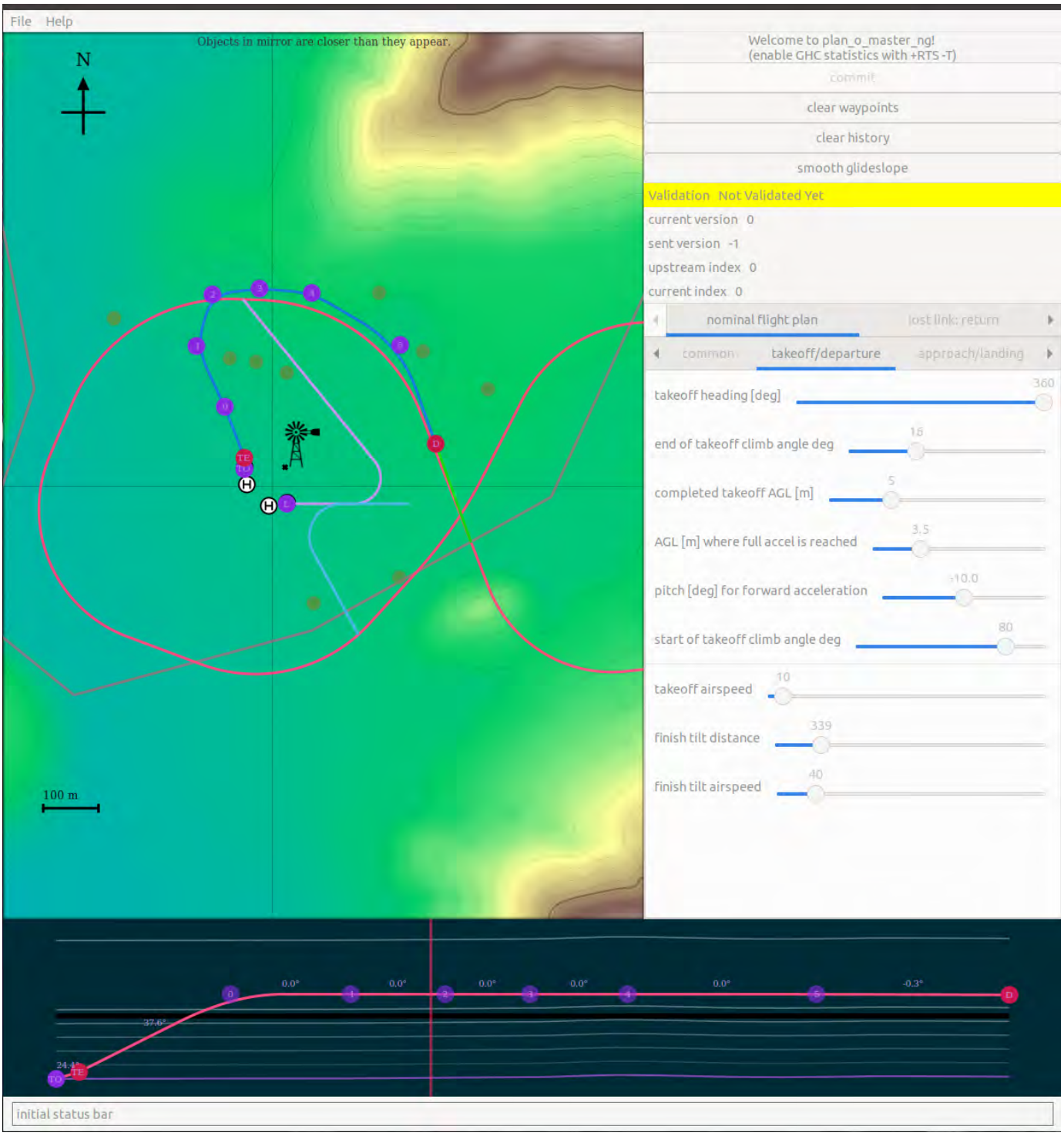
a. Under the *nominal flight plan>common tab* in the right hand column of the plan_o_master; click on the *mode* drop down and select **edit departure.**




b. Next; select the *takeoff/departure* tab. In this tab we are going to specify the **takeoff heading** to the direction that we want the aircraft to fly the departure. This will also need to align with the heading of the aircraft as it sits on the pad. If the delta between the aircraft's heading and the take off heading is greater than 15 degrees the aircraft will not take off.

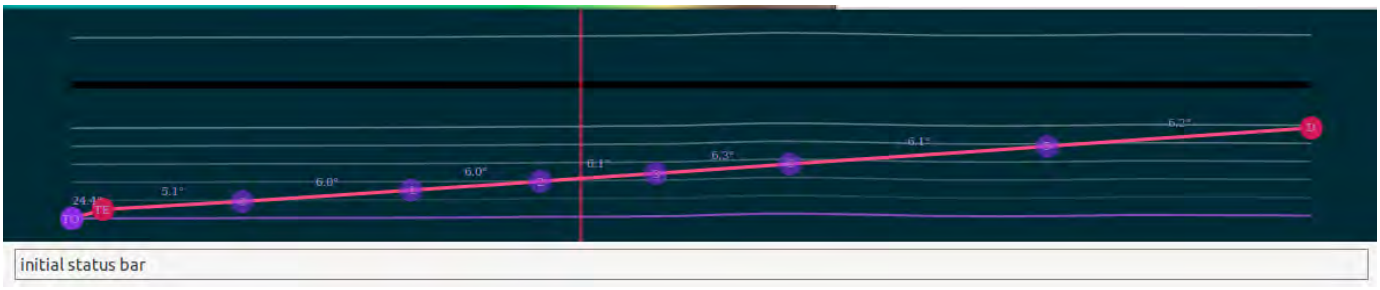



c. In the example below I set the **takeoff heading** to 360 or north. The end of the departure path is indicated by the red D waypoint. This intercepts the enRoute path which is the lime green colored path. At French Ranch it isn't necessary to build an elaborate enRoute path since our landing pads are all relatively close and can all utilize the same holding path.




d. As shown above in the bottom portion of the screen; you can see a side profile view of the departure path. It has a very sharp climb out between the first 3 points and it is level the rest of the path. This needs to be manually adjusted point by point in that window. Starting with the first point after the TE point, we want to shoot for a climb angle of less than or equal to 6 degrees between points. This is done by *left clicking* and dragging the points vertically to set the altitude target of each point. The manually adjusted departure path is shown below.

For reference; the purple line across the bottom is the ground. The grey lines that are closely spaced are vertically separated by 20m and the larger gap between the grey lines towards the top of the window represents 100m.




e. **Takeoff/Departure** settings overview.

The **takeoff heading** slider will change the vector of the TE point in relation to the TO point. Essentially it is the heading that the aircraft will assume immediately after take off from the pad. This heading should always align with the heading of the aircraft on the pad, and be relatively in-line with the departure path.

The **end of takeoff climb angle** adjusts the angle the aircraft will be climbing at when it reaches the TE point of the end of the take off portion of flight.

The **completed takeoff AGL** is the altitude above the ground that the aircraft meets the TE or take off end and begins tracking the departure path.

The **AGL where full accel is reached** adjusts the height above ground at which the aircraft reaches full acceleration.

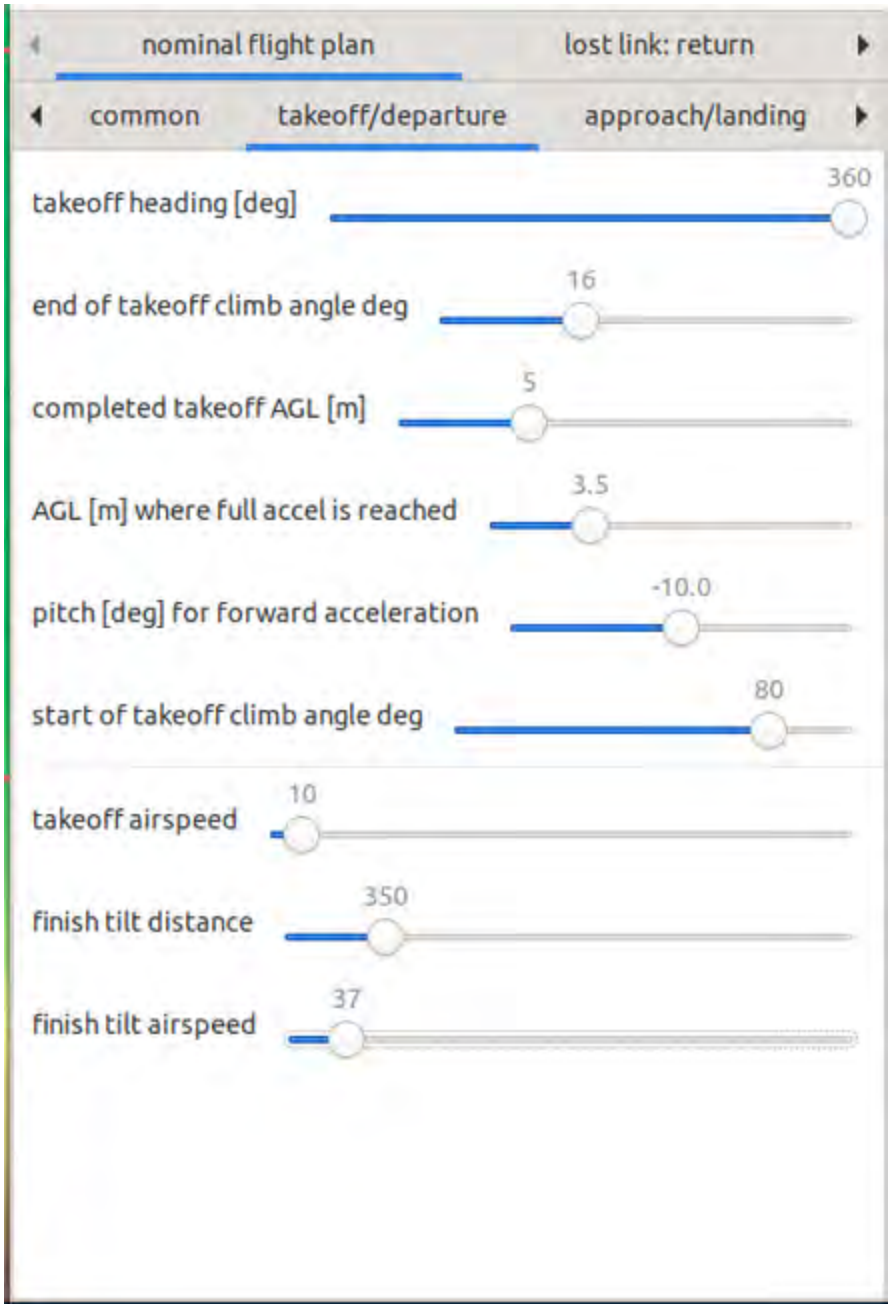
The **pitch for forward acceleration** slider adjusts the amount that the aircraft will pitch in order to achieve forward acceleration.

The **start of takeoff climb angle** adjusts the launch angle at which the aircraft leaves the ground.

The **take off airspeed** is the speed that the aircraft will acclerate to during the take off phase of flight (between the TO and TE points).

The **finish tilt distance** is the distance (meters) from the TO point that the aircraft will be fully tilted into the cruise configuration.

The **finish tilt airspeed** is the airspeed (m/s) that the aircraft will target at the point when it reaches full cruise tilt.



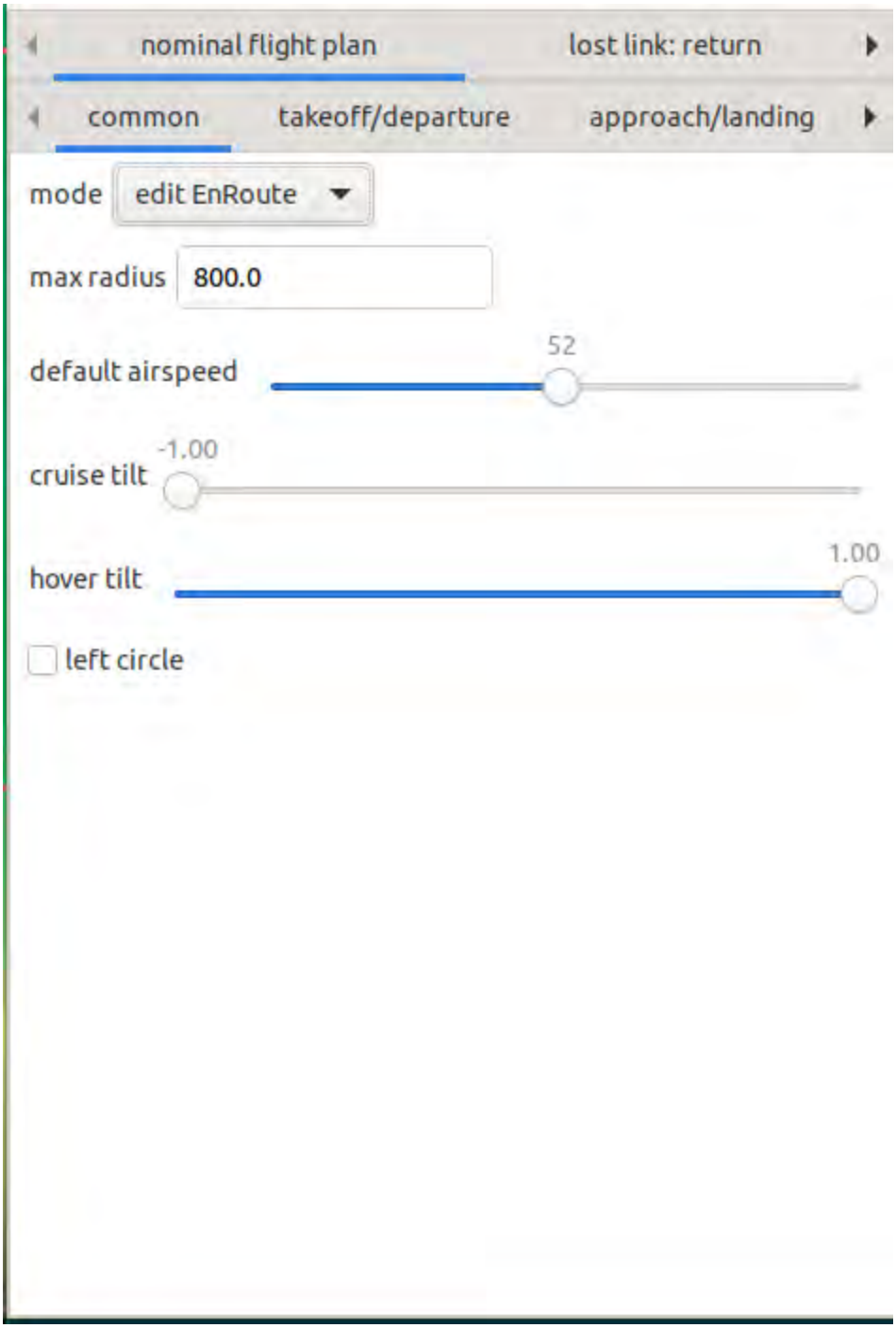

It is important to set the **finish tilt distance** to 350 m, and the **finish tilt airspeed** to 37 m/s. These are default/recommended values that have been proven to work well. The "*finish tilt*" point is depicted above by the vertical red line.

⚠ **All other values aside from the **Takeoff Heading, Takeoff airspeed, Finish tilt distance, and Finish tilt airspeed**, should be left at default values until further testing is completed.

---

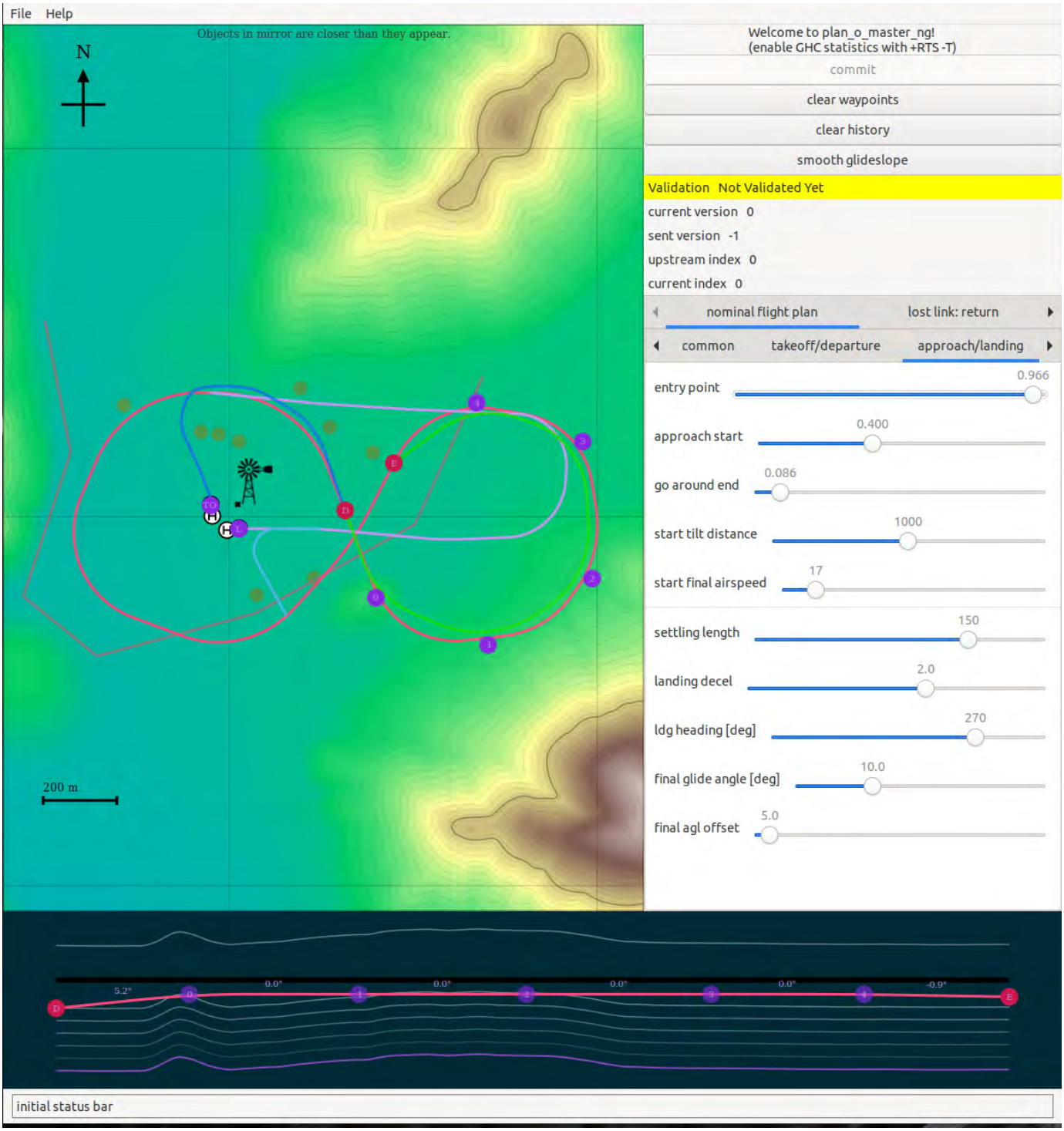
4. **Creating an enRoute Path:**

a. Under the *nominal flight plan>common tab* in the right hand column of the plan_o_master; click on the *mode* drop down and select **edit enRoute.**



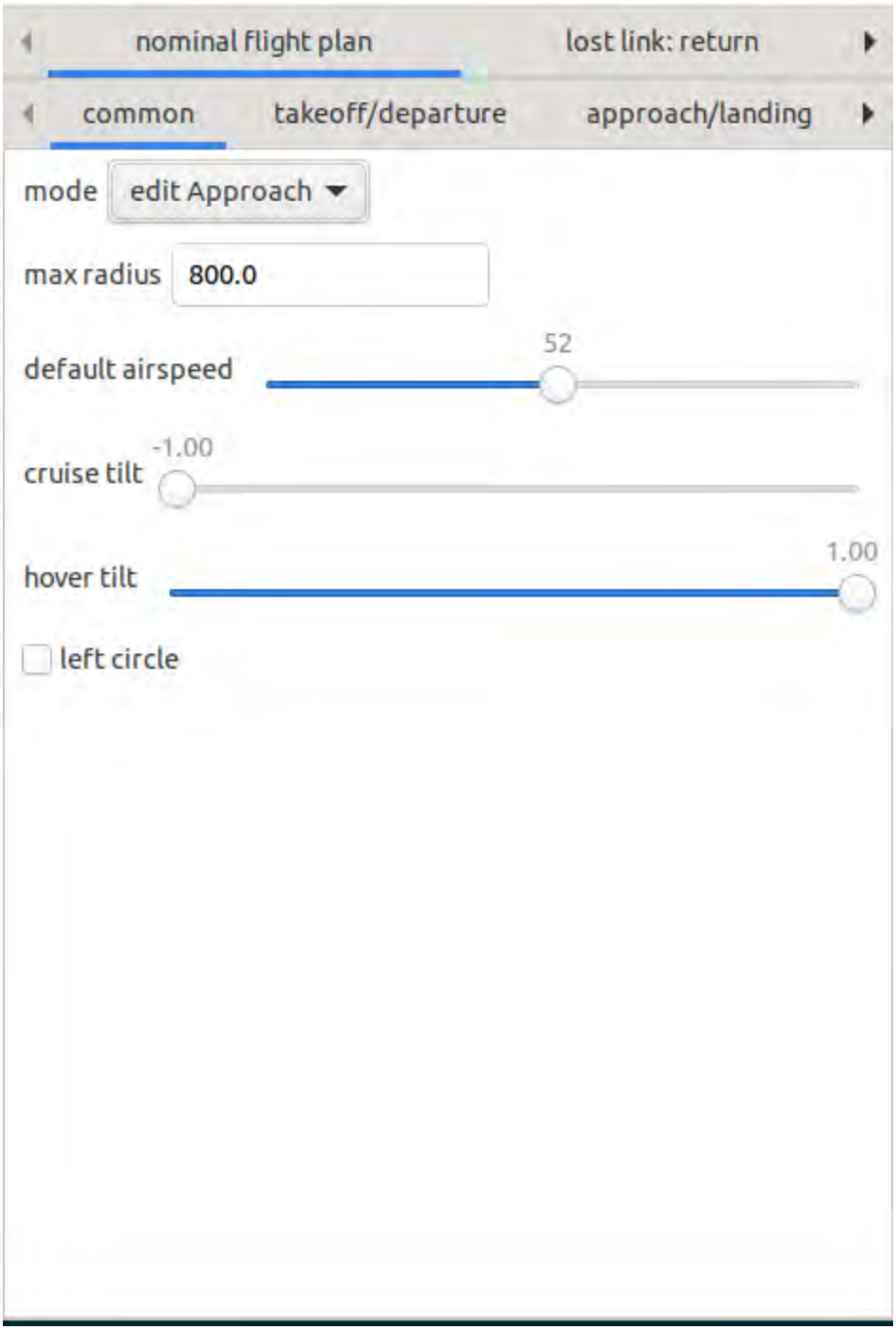

b. You should now see the lime green line on the main map display highlighted. This path will only have two points on it at this point, which are the red D (departure end) and the E (entry/holding intercept) points. The E point can be moved to the desired intercept along the holding path by navigating to the *nominal flight plan>approach/landing* tab and moving the entry point slider. You can use the same method as above to drop more way points and finishing building the enRoute path. Left click to add way points, left click and hold to drag, and right click to delete way points.

The enRoute path is really designed to take the aircraft from point A to B and fly BVLOS. At French Ranch this isn't necessary and can be left unedited most of the time, but for the purpose of this demonstration i have created a short enRoute path.

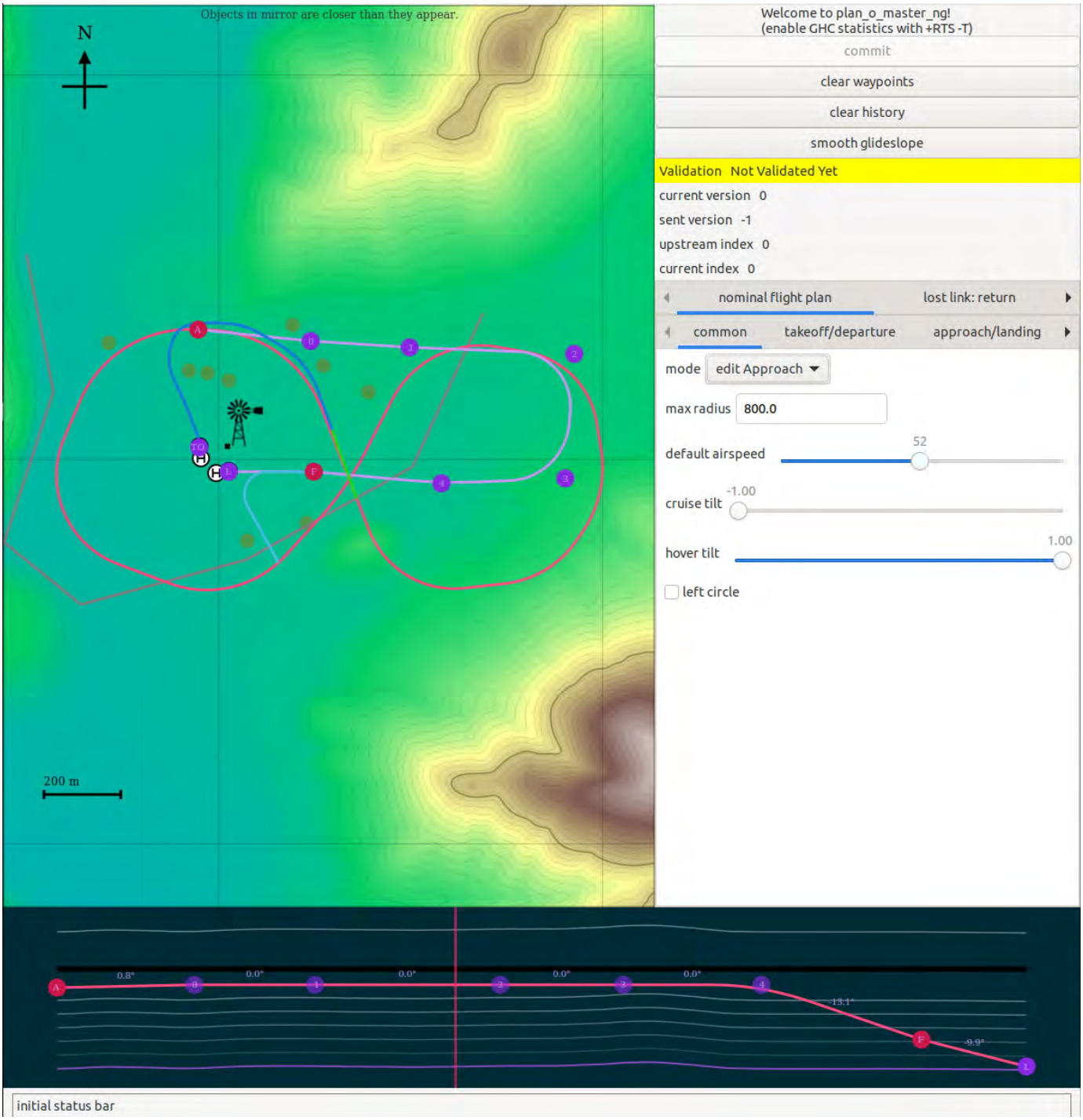



5. **Creating an Approach Path:**

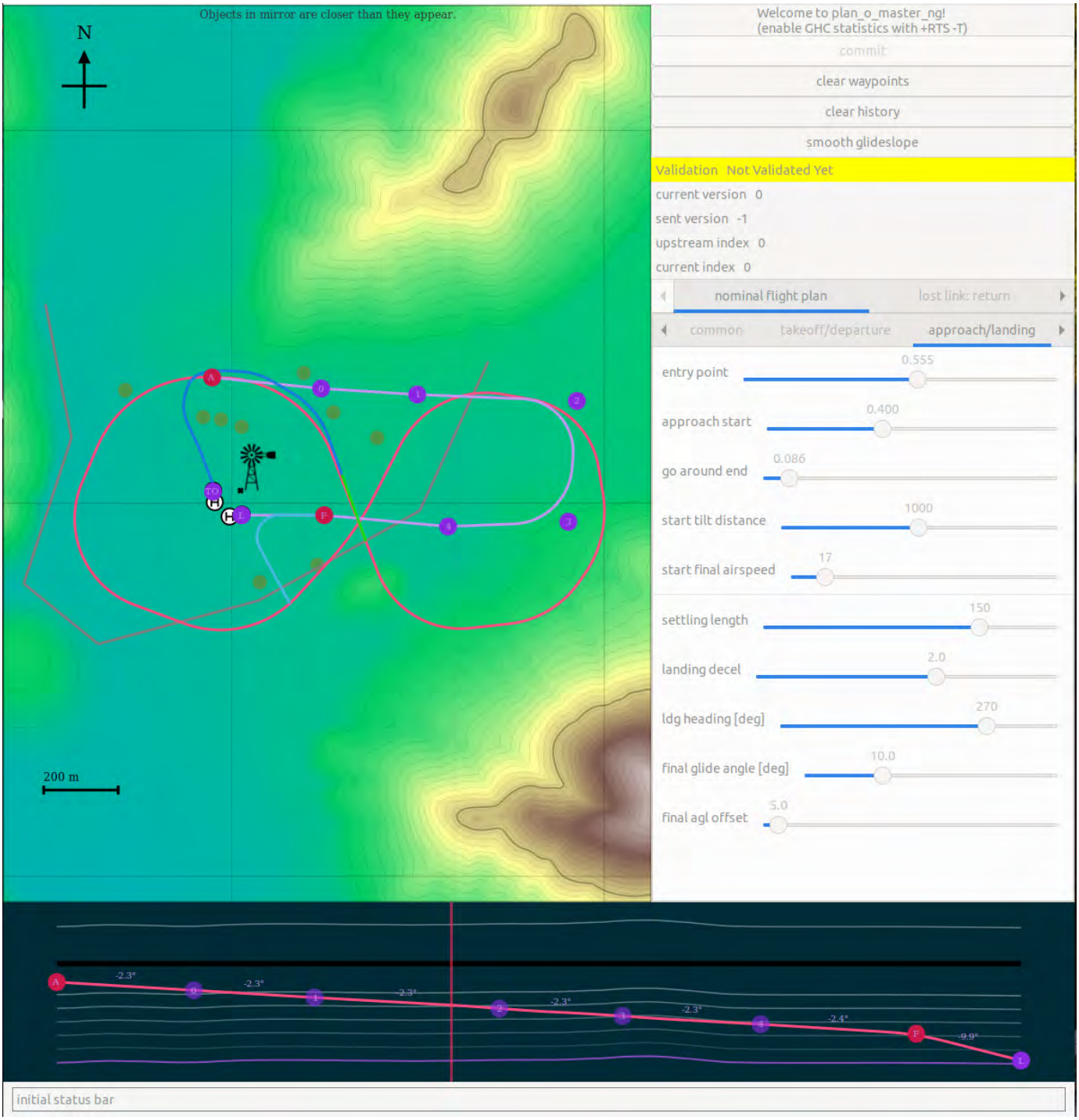
a. Under the *nominal flight plan>common tab* in the right hand column of the plan_o_master; click on the *mode* drop down and select **edit approach.**




b. You should now see the magenta line on the main map display highlighted. This path will only have two points on it at this point, which are the red A (approach start/breakout point) and the F (final) dot. You can use the same method as above to drop more way points and finishing building the approach path. Left click to add way points, left click and hold to drag, and right click to delete way points. After your waypoints are placed to create your desired track, use the **smooth glideslope** button to smooth out the descent angle as shown below; the aircraft will descent at a constant 5 degree slope until it gets to the F dot. To change the overall angle of the approach path you can move the approach start slider under the **approach/landing** tab. (see the next section below for detailed settings on the approach path) See the screenshots below:

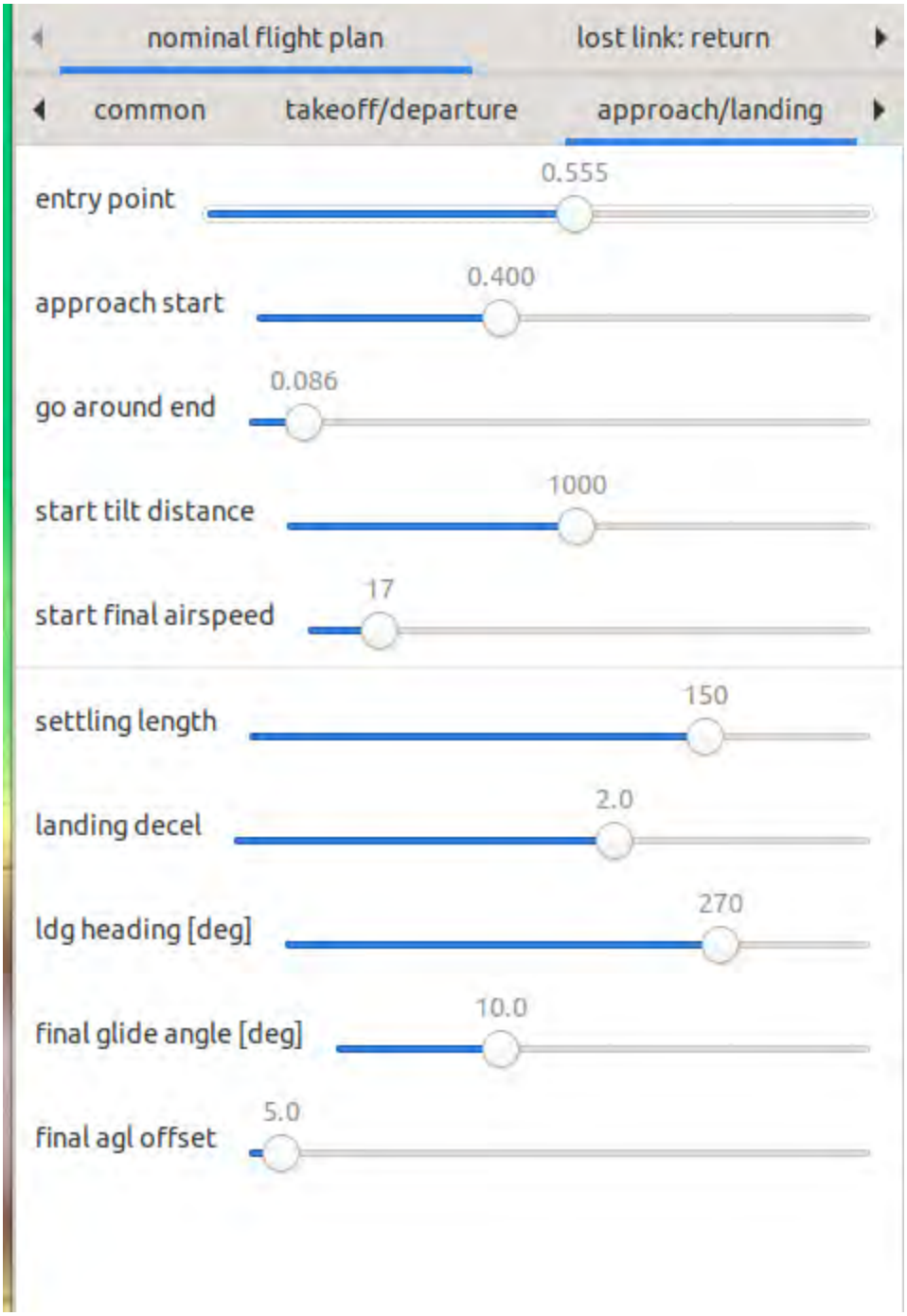



**Un-smoothed Glideslope:**




**Smoothed Glideslope:**

c. Next select the *approach/landing* tab to adjust your settings.




The **approach start** slider will move the A point (start of the approach/breakout point) along the holding path.

The **start tilt distance** slider will change the distance in meters that the aircraft begins tilting on the approach path.

The **start tilt airspeed** is the airspeed at which the aircraft will target to begin tilting the motors to the hover configuration.

The **start final airspeed** is the airspeed the aircraft will target to begin its final descent to the pad. This happens at the red F dot on the approach path, and is the point where the aircraft changed flight modes from *"approach"* to *"autoland"*.

The **settling length** changes the distance in meters between the F dot (start of autoland) and the Landing point.

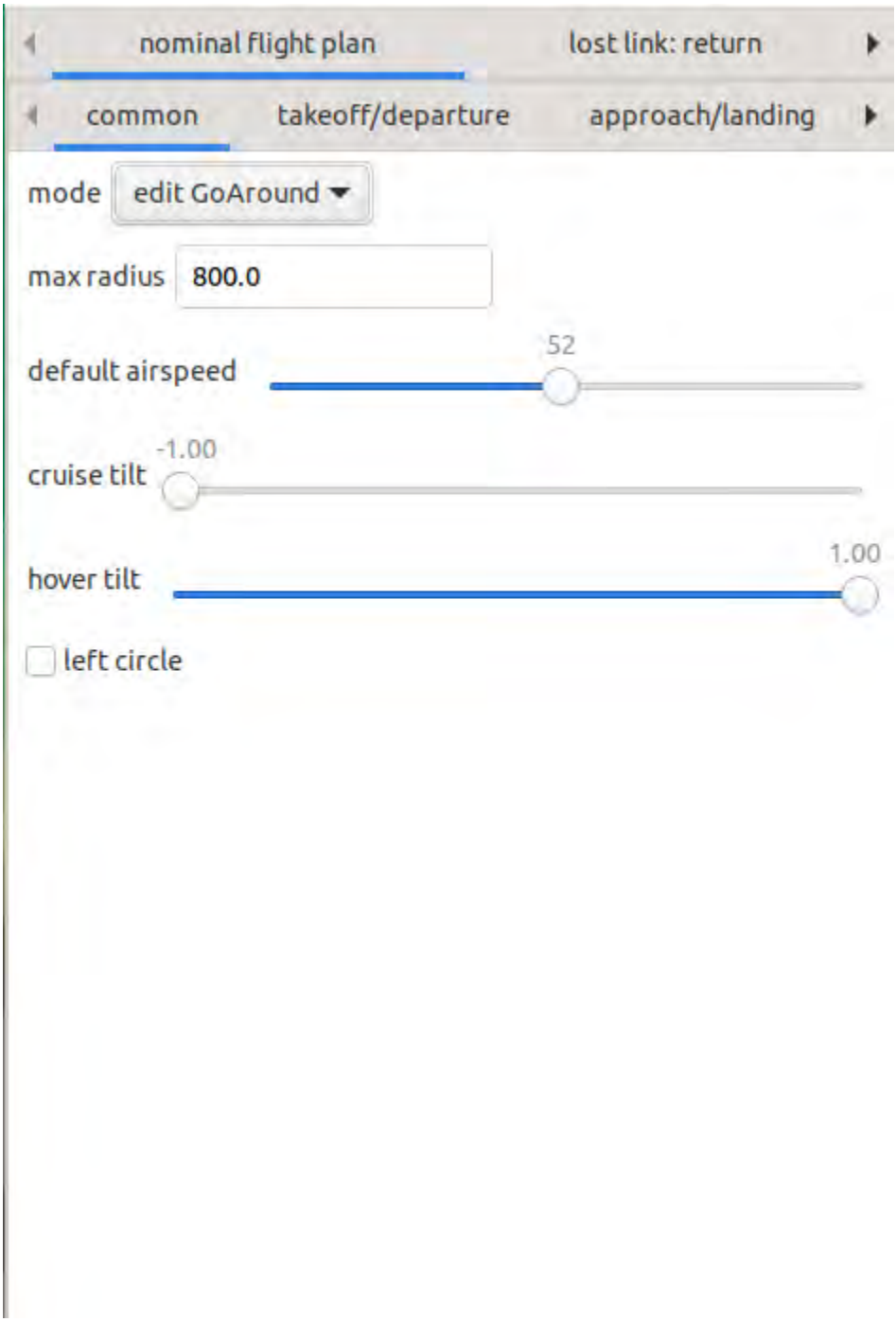
The **landing decel** will change the speed that the aircraft decelerates in m/s^2 after it enters the *autoland* phase.

The **final glide angle** will change the angle of descent during the autoland phase from the F dot, the the **final agl offset** height. The final agl offset is the height above the ground that the aircraft will begin a straight vertical hover descent to its landing point.

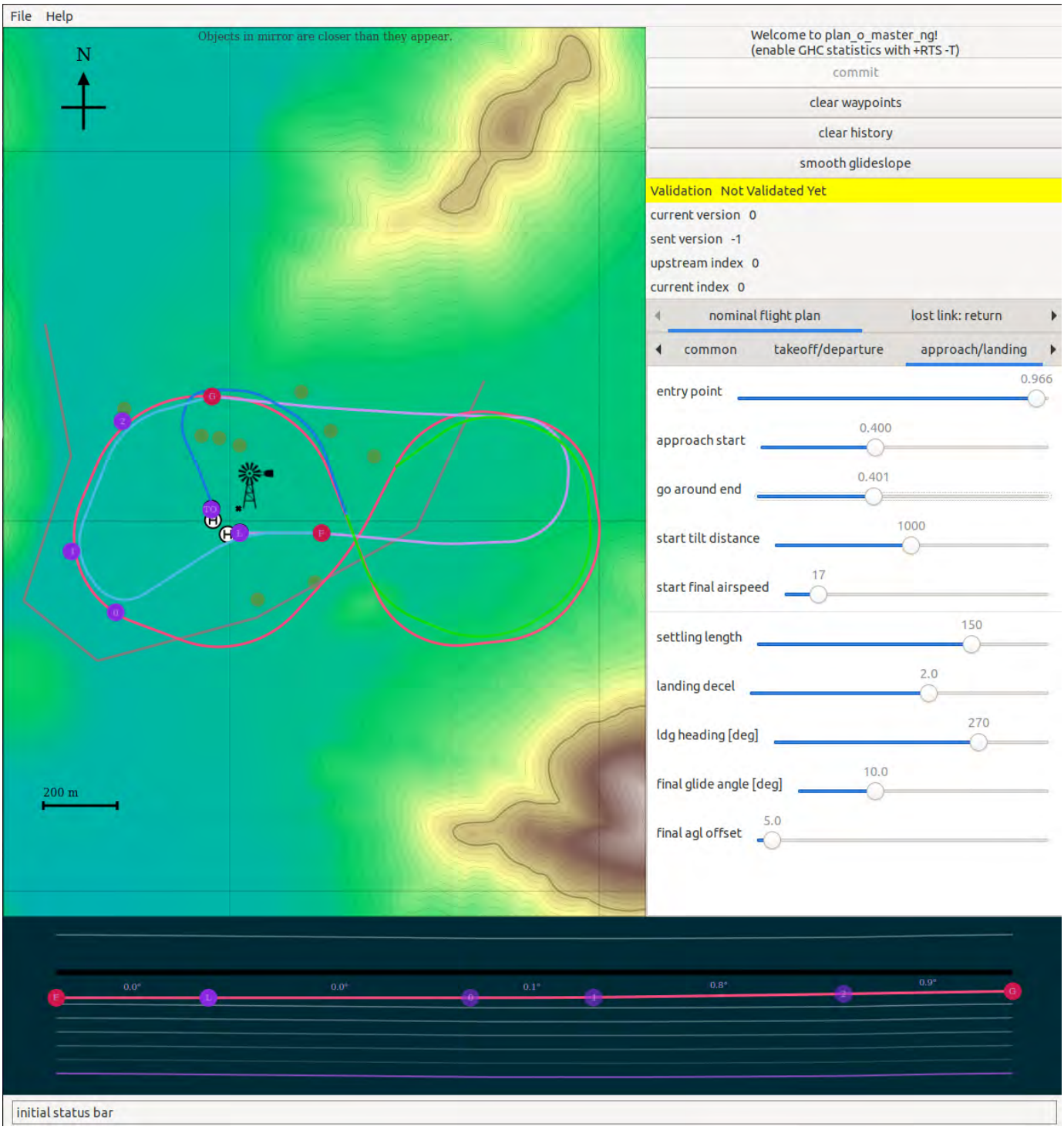
⚠ If any of the above settings are adjusted the **SMOOTH GLIDESLOPE** button will need to be used again.

6. **Creating a Go Around Path**

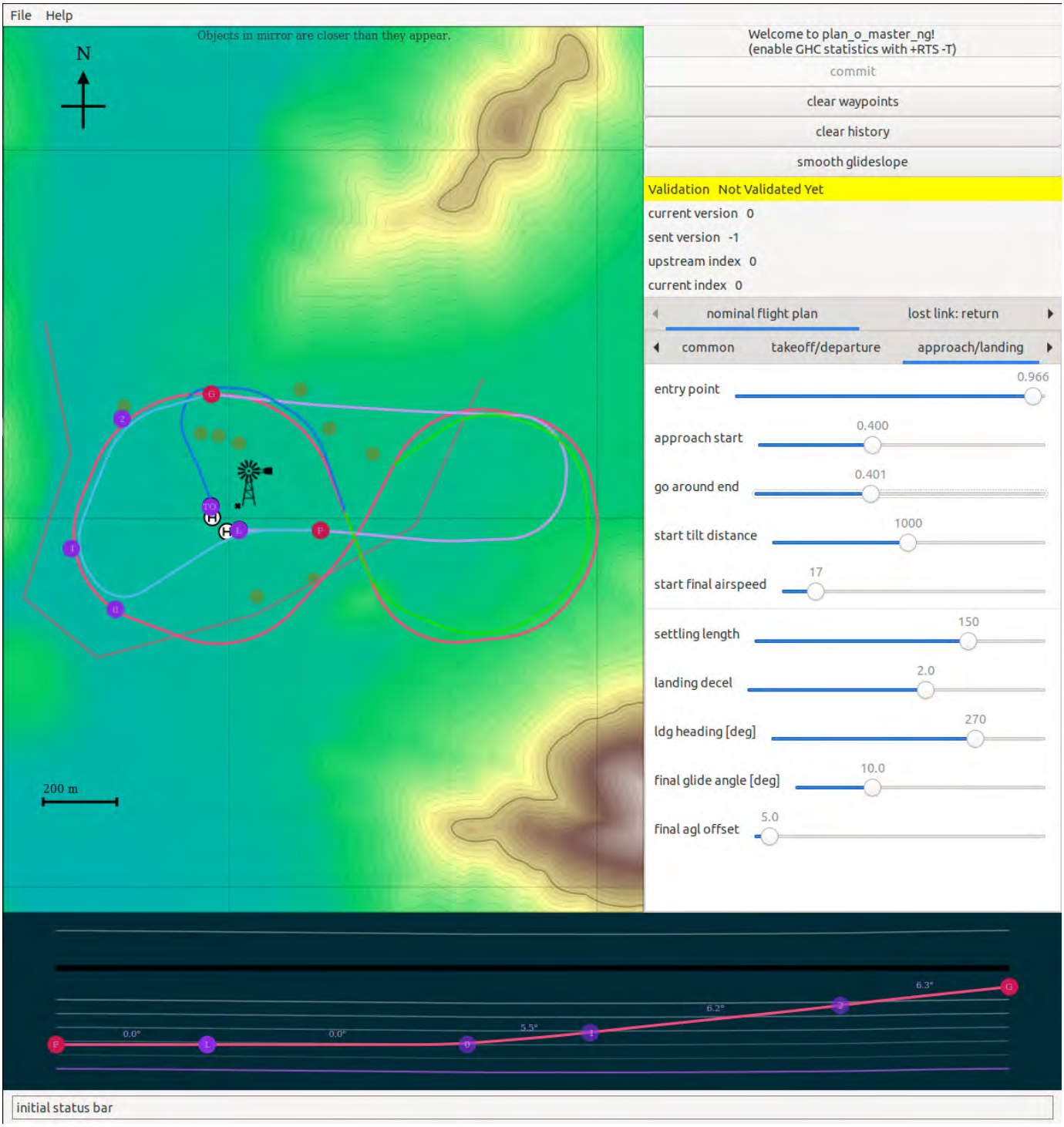
a. Under the *nominal flight plan>common tab* in the right hand column of the plan_o_master; click on the *mode* drop down and select **edit go around.**




b. You should now see the light blue line on the main map display highlighted. This path will only have two points on it at this point, which are the red F (final) dot and the G dot (go around end/holding intercept). You can use the same method as above to drop more way points and finishing building the GoAround path. Left click to add way points, left click and hold to drag, and right click to delete way points. Your path should look something like the screenshot below after you use the **go around end** slider in the *nominal flight plan>approach/landing tab* to move the intercept point along the holding path to your desired intercept point on the holding path.



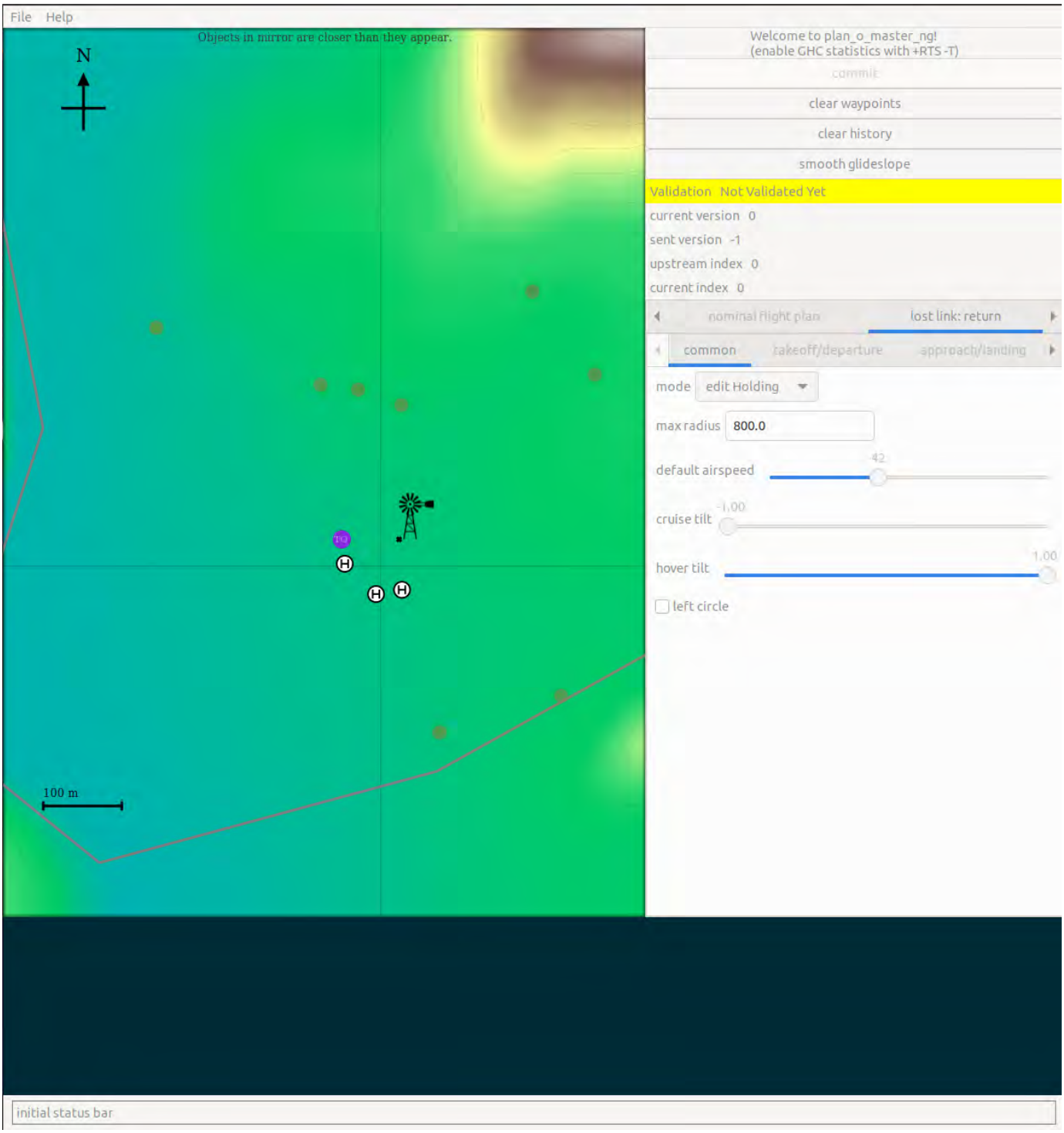

c. By default all of the holding path points will be at the holding path altitude. These points will need to be adjusted to create a climbing outbound path similar to the departure. Start by moving the **0** point to ~40m AGL, this will cause the **F** & **L** to follow. Then adjust the following way points on the gr around path accordingly targeting a ~6 degree climb angle all the way to the holding path intercept point. As shown below.




7. **Creating a Lost Link Return Path**

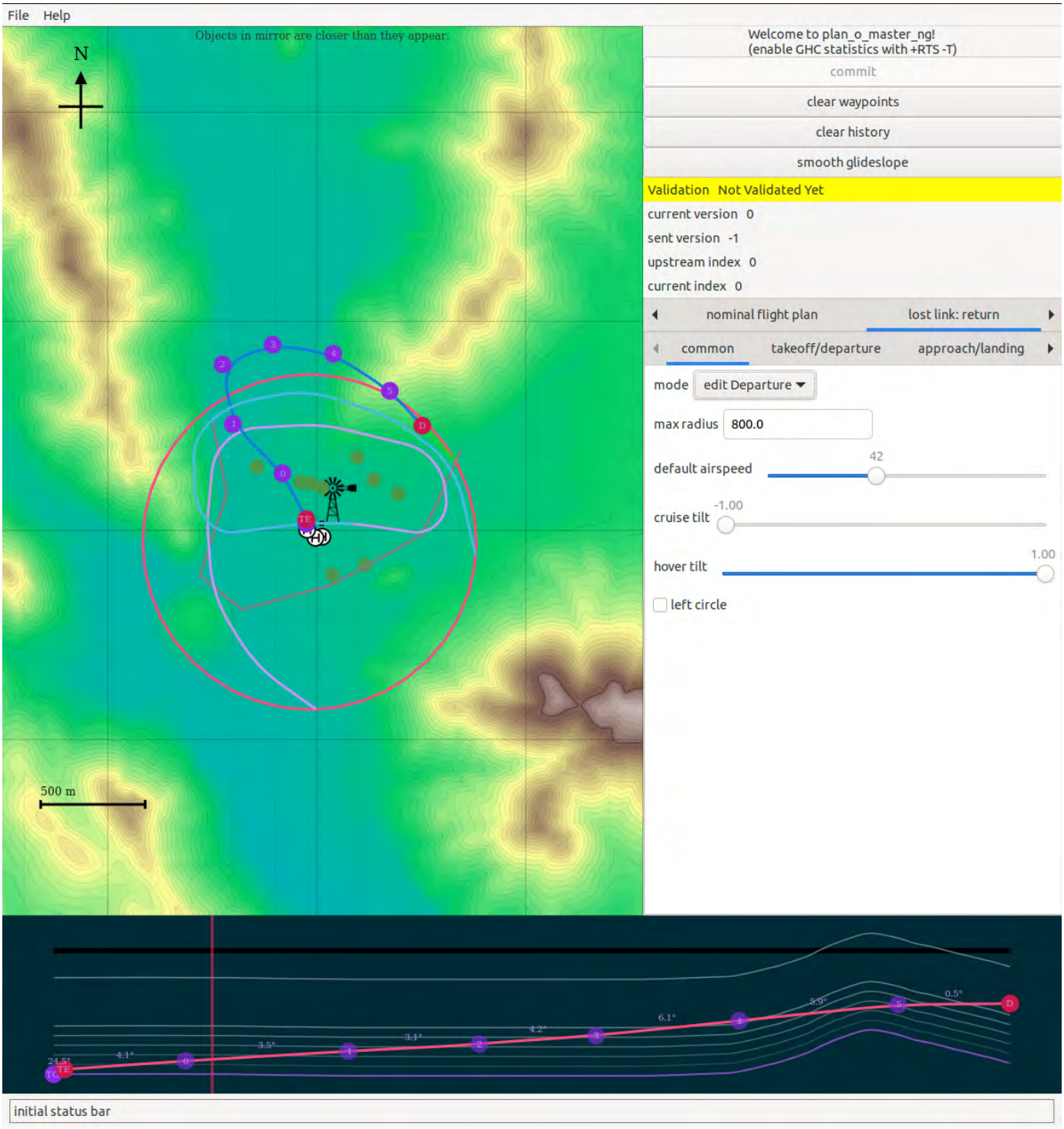
a. Under the *lost link:return>common tab* in the right hand column of the plan_o_master; click on the *mode* drop down and select **edit holding.**

b. Set the takeoff and landing points on the same pad that the aircraft is taking off on the nominal flight plan above. This will ensure that the aircraft returns to the pad of origin on the lost link return path. As of right now; the lost link return path is the only active lost link path.




c. Drop only one point, the 0 point in the center of the pads and the plan_o_master will create an orbit circle path around that single way point; this is perfect for the lost link path.

d. Now edit the rest of the flight path segments following the same steps showed above for **departure, en route, approach, & go-around.**



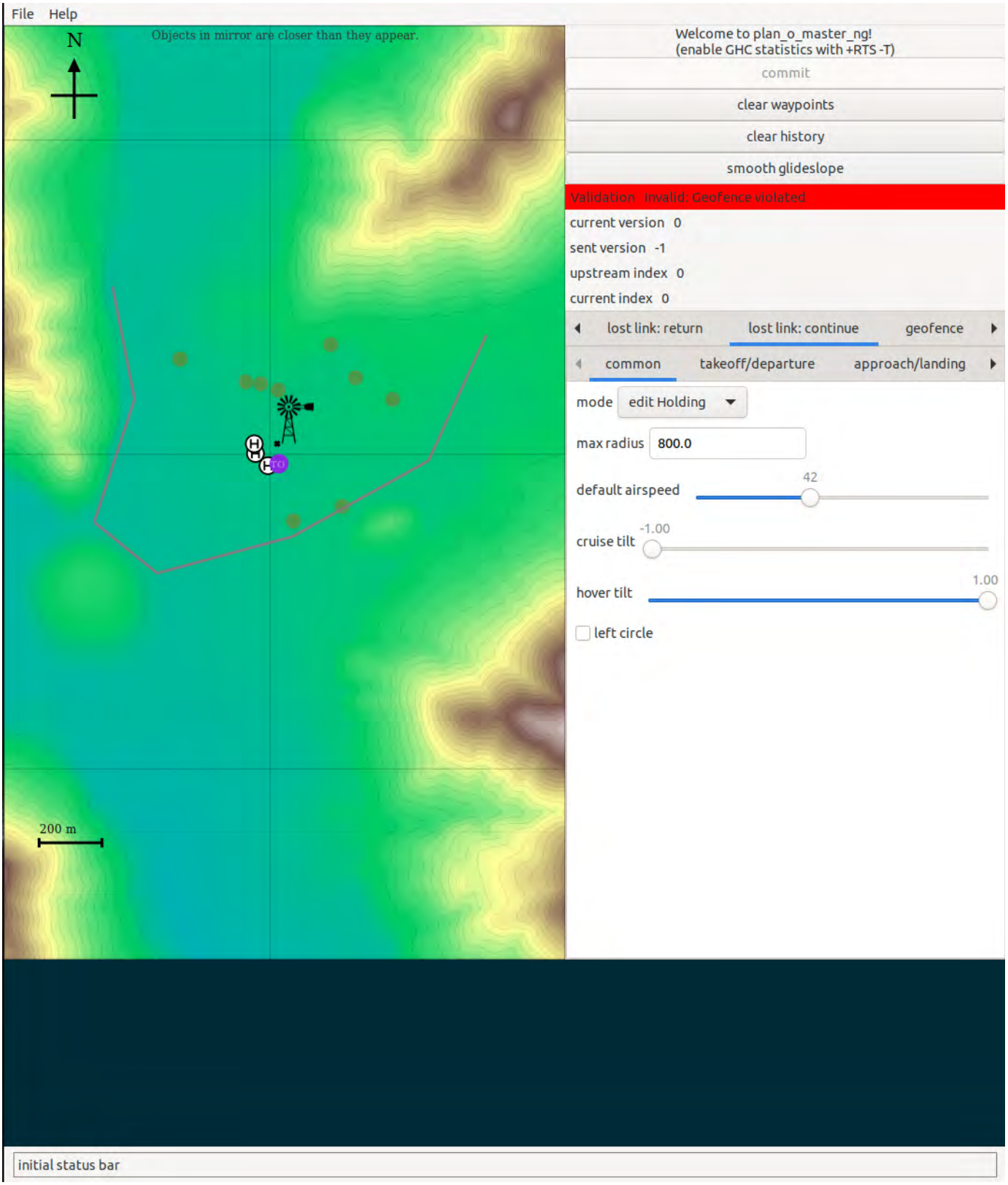

Above is the example of the lost link return path that I created for this flight plan.

---

8. **Creating a Lost Link Continue Path**

a. Under the *lost link:continue>common tab* (you'll need to use the right arrow to tab over the continue path tab) in the right hand column of the plan_o_master; click on the *mode* drop down and select **edit holding.**

b. Set the takeoff and landing points on the same pad that the aircraft is landing at on the nominal flight plan above. This will ensure that the aircraft continues to the destination pad on the lost link continue path. As of right now; the lost link return path is the only active lost link path; however you have to create a lost link continue path for the plan_o_master to validate the flight path.




c. Drop only one point, the 0 point in the center of the pads and the plan_o_master will create an orbit circle path around that single way point; this is perfect for the lost link path.

d. Now edit the rest of the flight path segments following the same steps showed above for **departure, en route, approach, & go-around.**

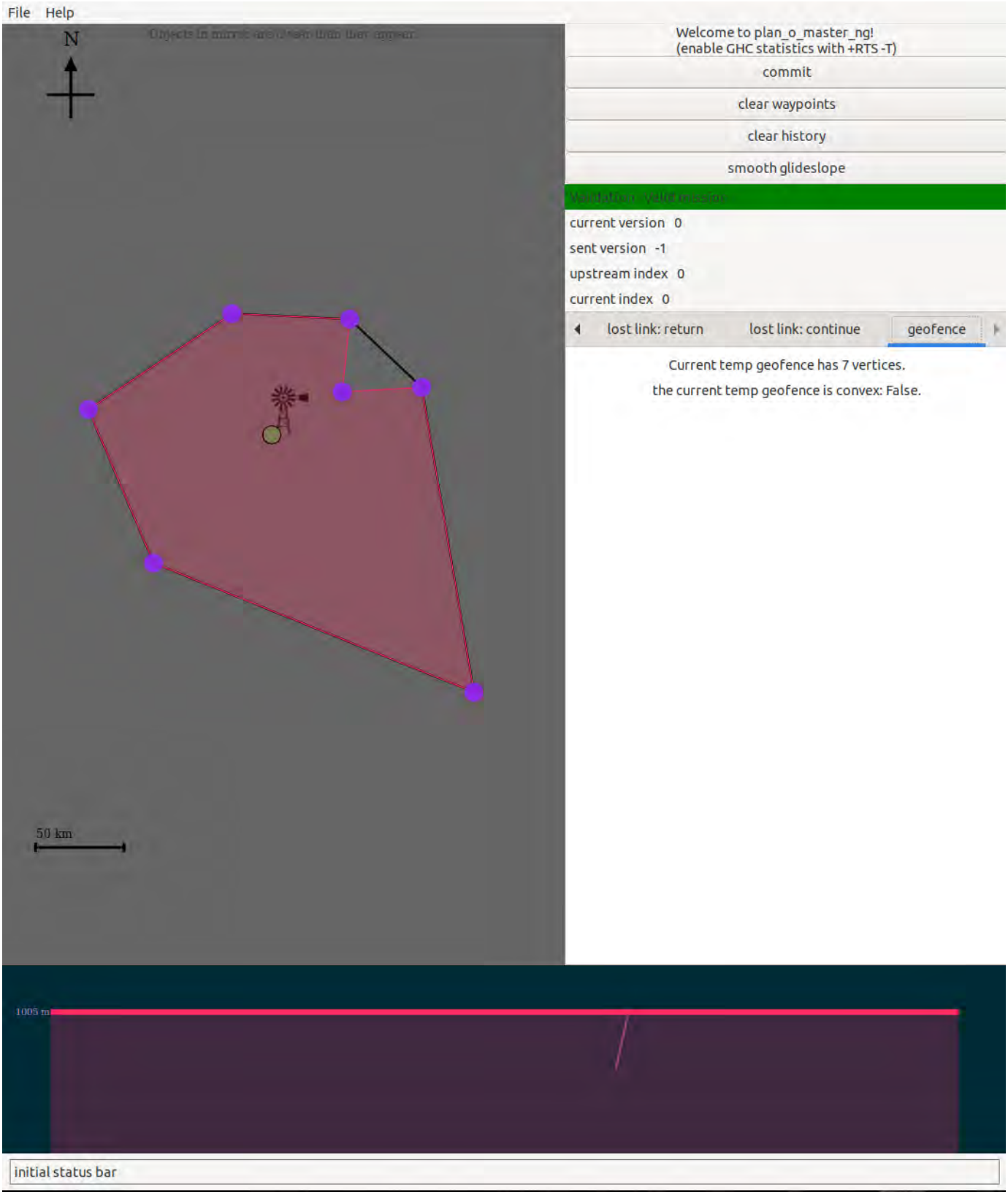
e. This path can be the same as the one above, a simple orbit around the landing area.

---

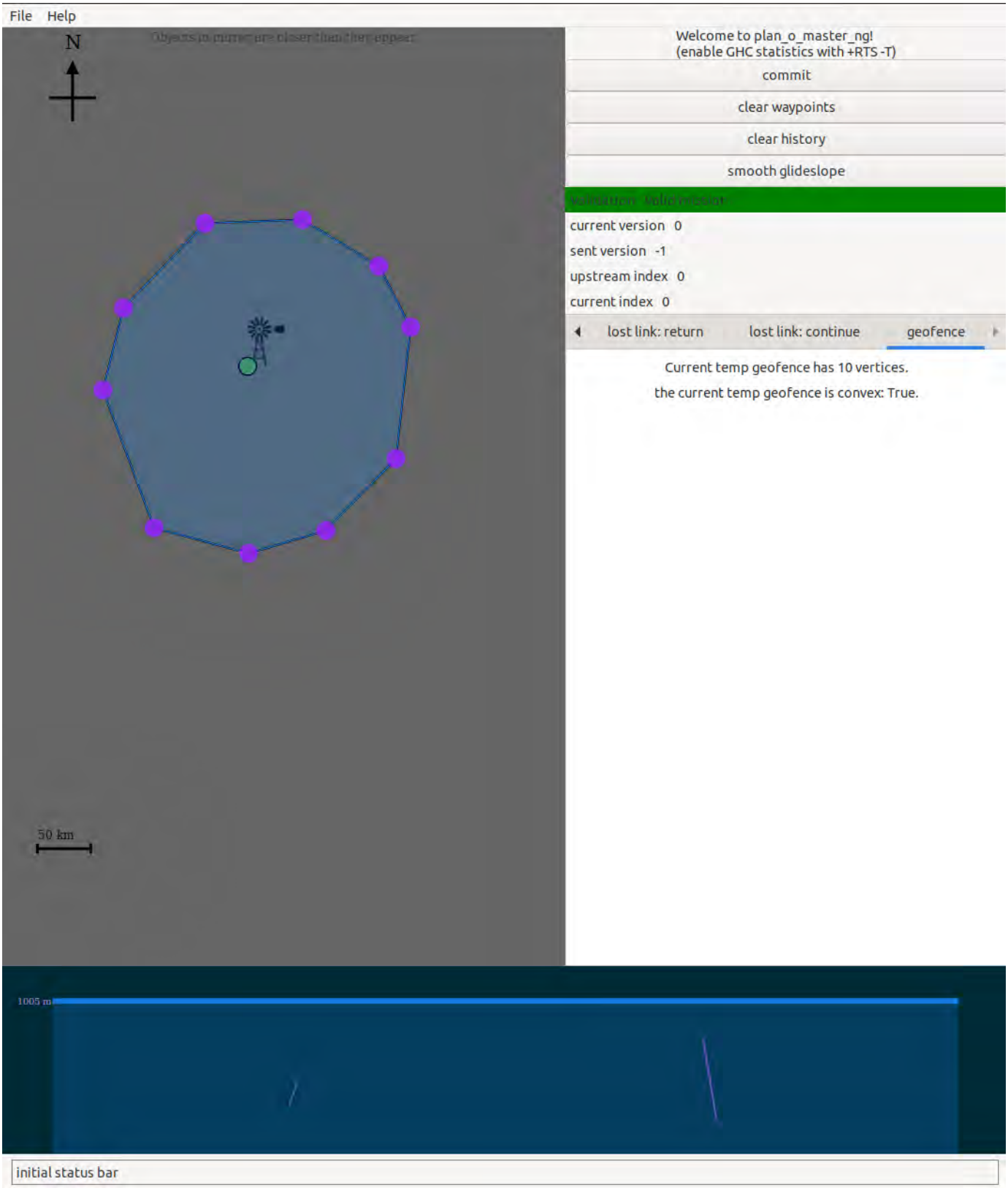
9. **Creating A GeoFence**

a. Select the **geofence tab** to the right of the lost link continue path. This will allow you to edit the geofence vertices on the map. It is important to consider the fact that the aircraft will enter autohover down mode if it exits the geofence in manual mode. For this reason, make the geofence a large polygon to adeqautely cover all of the VLOS area at French Ranch…and then some.

b. To place geofence vertices on the map, left click. To move a vertices left click and drag on the point. To delete a vertices right click on the point.




In the example above, the red geofence indicates it is invalid due to concavity. The geofence must be convex.




Above is an example of a valid geofence.

c. To adjust the altitude or ceiling of the geofence, and blue bar in the bottom window can be grabbed by left clicking and dragging up or down. In this example it is sitting at 1005m high (annotated on the left hand side). This value will change as it is moved up down so you know what your ceiling is set to.

---

10. **Saving the Path**

Under the file menu, click “Save path”. In the left panel click on “Desktop” to save the path to the desktop.

## Flight Plan Naming Convention

Site_TakeOffLocation&Direction-LandingLocation&Direction_PathShape/Use

Example: FR_P9N-P5W_Circle (FrenchRanch_TakeOffPad9North-to-LandingPad5West_CirclePath)

Add “Draft” to the beginning of the file name until the path has been flown and validated.

Once the path has been validated, remove the “Draft” from the filename and submit the file to the software team as a Jira ticket task to include in the next release if desired.

## Battery Required Calculator

The Battery Required Calculator is a simple calculator to approximate the amount of energy used in any given flight plan along with the battery temperature increase over that flight plan. To use the Battery Required Calculator change the blue input boxes to match your mission and the green outputs will display the amount of energy required for the flight both in KWh and Ah. To do this the length of the cruise portion of the flight plan must be estimated. This includes the enroute portion of the flight path along with the holding path.  This will mostly be used for flight plans extending beyond line of sight thus external tools will be used to estimate the length of the flight plan.

As a note the Battery Required Calculator is based off of approximations thus should not be treated as the exact answer, but rather as a ballpark number for planning purposes and to make sure flight plans are feasible, always monitor battery margins while in flight and act accordingly

# Manuevers



In addition to the guidance below, all limitations must be followed except for the explicit execution of a test plan supporting the expansion of that limit. Limitations

## Flight Path

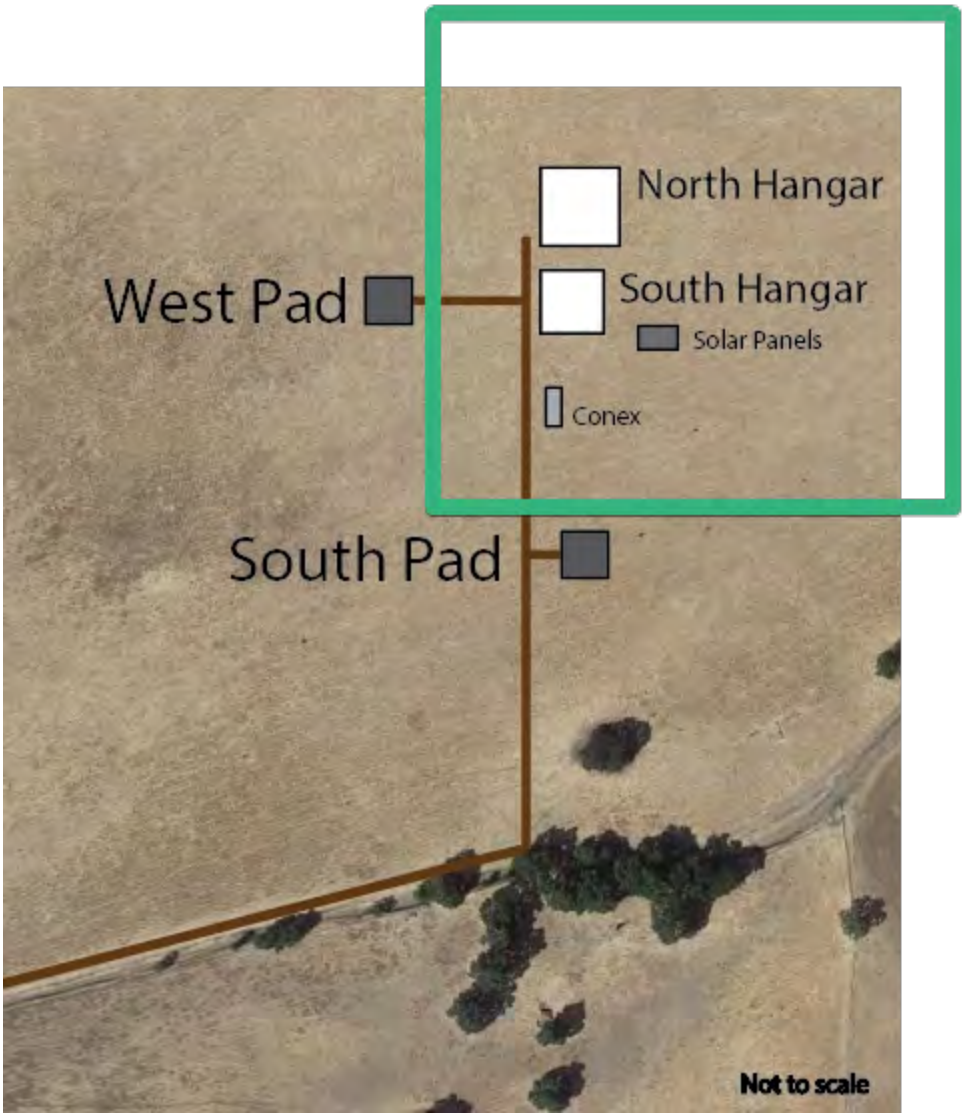
The vehicle will make turns away from the ground station whenever practical. On departure and approach the vehicle will not come “within the pads”. If a vehicle is coming within the pads the response should be to immediately go around or land the vehicle based on aborted transitions guidance.

Automated and manual flight paths will never overfly the area “within the pads”.

All flight demos shall maintain a minimum of 500' separation with all personnel during maneuvers.

Flight envelope maneuvers (stalls/spins) will allow for recovery no lower than 500 ft AGL, preferbly 1000 ft AGL.
https://docs.google.com/presentation/d/1tp5-PgmjYdaGRzqXAqa3LXxtQ4wfQuDZ5x6ifnNSNbU/edit#slide=id.p

### “Within the pads”




## Transition

### Block 2 Vehicles Outbound

- Hover
- Pitch forward to build up forward speed
- Full tilt
- Pitch back to maintain altitude
- Increase power once RPMs change to climb out, minimum 35 m/s
- Pitch deck angle ~10-15 degree
- Climb out at 42 m/s

### Block 2 Vehicles Inbound

- From pattern altitude, power to idle, 42 m/s
- Initiate no more than 45 degree banked descending turn
- Half way through turn tilt to hover
- Maintain ~30-35 m/s through approach
- Begin pitch back without gaining altitude to lose airspeed
- Around 25 m/s begin anticipating power input when the wing stalls ~20 m/s
- Use power to control descent to pad
- Maintain nose of aircraft with direction of travel
    - Slip in crosswinds, do not crab

## Aborted Outbound Transition

- If there has not been an audible RPM change, tilt back to hover
    - Depending on terrain tilt back to hover
- Return to pad in hover configuration ~20 m/s

## Aborted Inbound Transition

### Above 20 m/s

- Increase power and pitch up to maintain 42 m/s and climb away from personnel

### Under 20 m/s

- Continue to hover configuration and land where safe

## Multi Axis Maneuvers

- Figure 8 maneuvers at speeds from 5-10 m/s exercise motor demands and control authority limits well in hover.

## Motor Out Hover Handling Qualities

As an approved mitigation for variable motor out performance, all aircraft until further notice must complete the following prior to completing motor out based test plans. Each pylon position called out in the test plan shall complete this testing prior to executing the test plan.
https://docs.google.com/spreadsheets/d/1WZKwy042uhgu8oJNrCeggjMZdc-cfY8HNnMzr5qERpY/edit#gid=0

# French Ranch
# Glide Consideration

# Notes

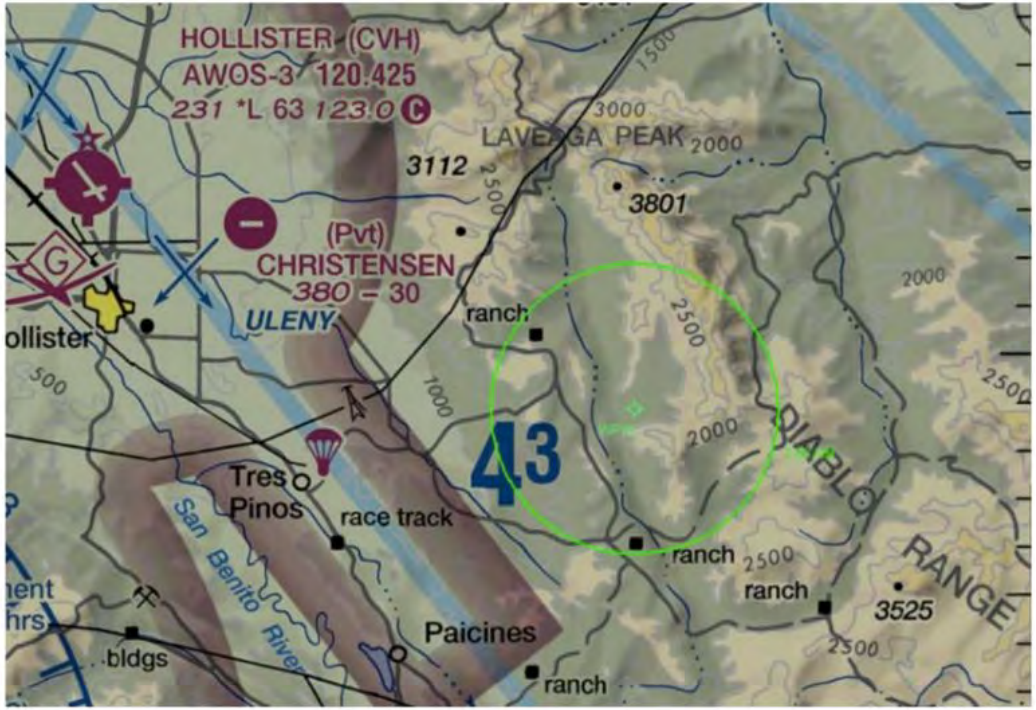
Heaviside Glide Ratio

- 12.5 (worst case glide)  over estimation since we can only reduce throttle to 1.0 amps in cruise, not allow a freewheel
- More likely estimation is 6.6 miles straight line distance due to spiral mode: https://docs.google.com/document/d/1r0tTvHPcwJu13QjpbuRjIZAD3wd9G674DAEnh9rSwPY/edit#heading=h.g71x2n2ee7pw

COA

- 3 nm radius of of 36 48’ 52.00” N 121 10’ 23.00” W
- 5000 ft MSL and below

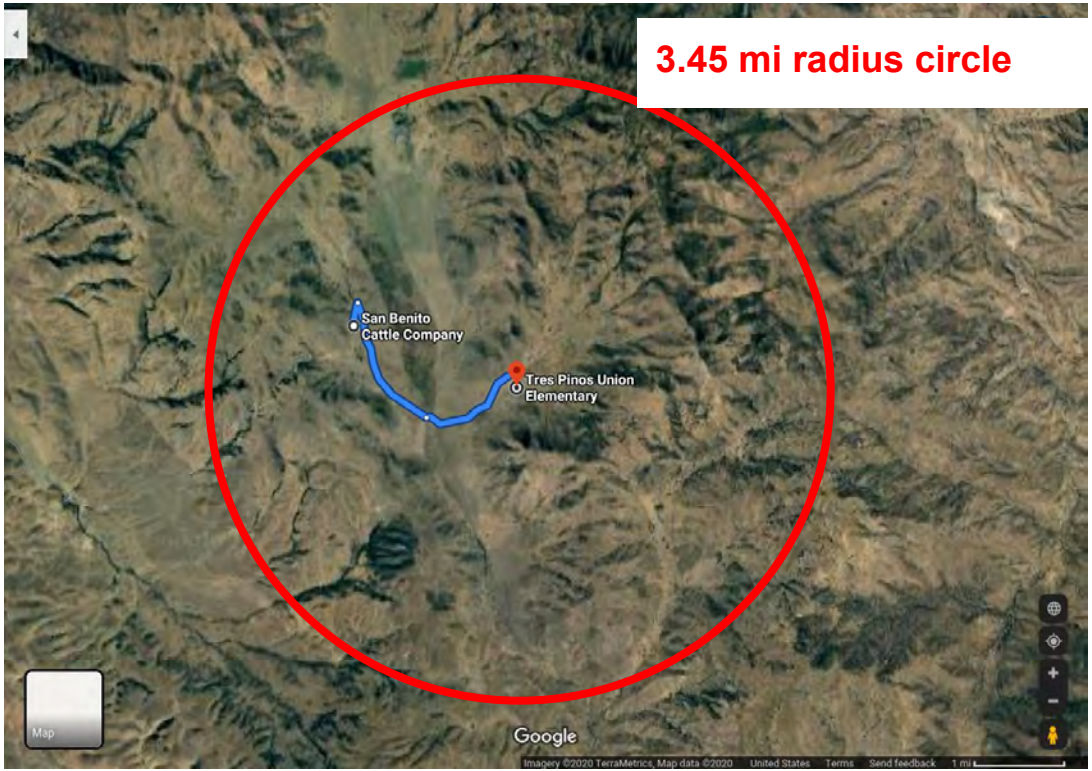
# VFR Chart


HOLLISTER (CVH)
AWOS-3 120.425
231 *L 63 123.0 C
3112
(Pvt)
CHRISTENSEN
380 – 30
ULENY
ollister
LAVERGA PEAK
3801
ranch
43
Tres
Pinos
race track
San Benito River
Paicines
bldgs
ranch
ranch
ranch
3525
DIABLO
RANGE
1500
3000
2000
2500
1000
500

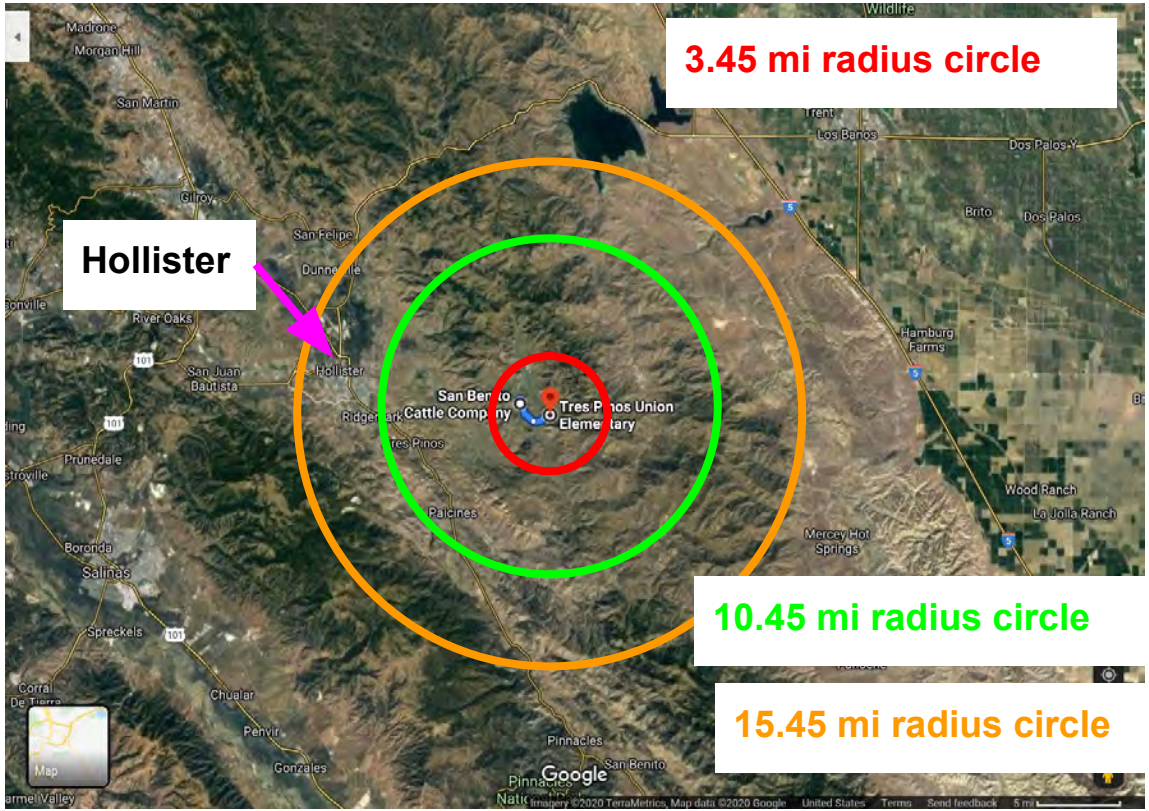
# Google Maps

3 nm

3.45 mi



# Worst Case 5000 ft MSL 12.5 L/D, spiral mode




## Assumptions

- No wind
- Does not take terrain into account. Assumes flat and at sea level.
- Best glide does not take into account spiral mode or drag from windmilling propellers.
- Spiral mode is shown as time to 90 degree heading change.

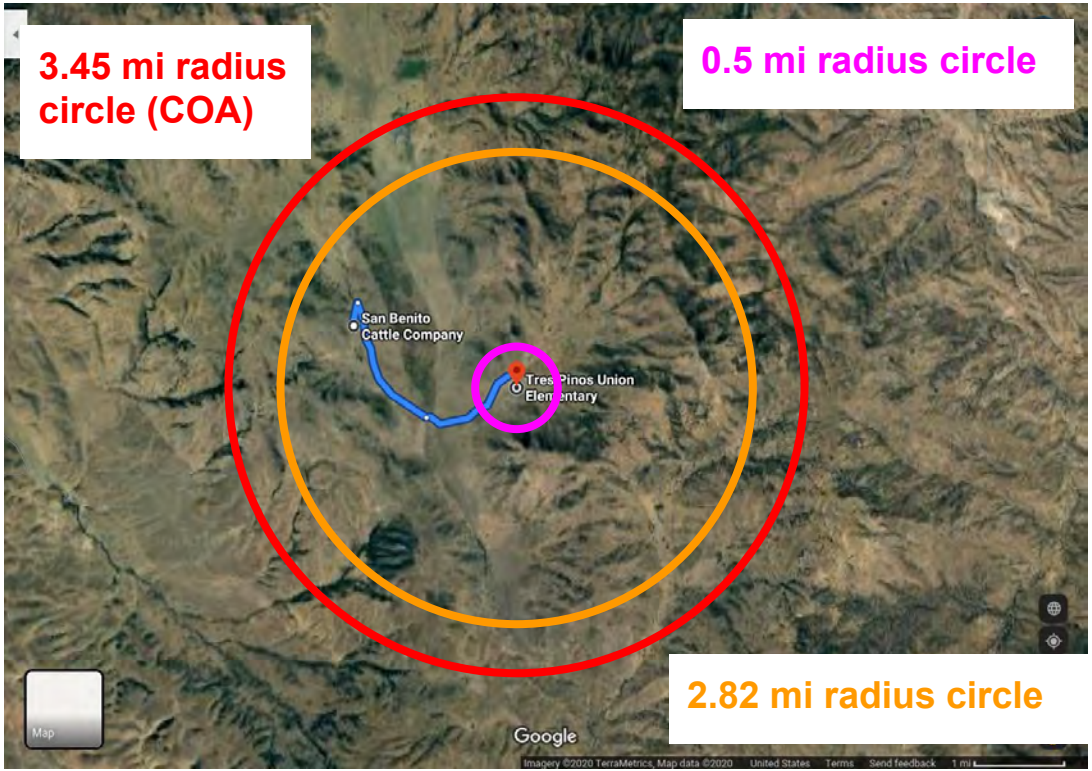
# Notes

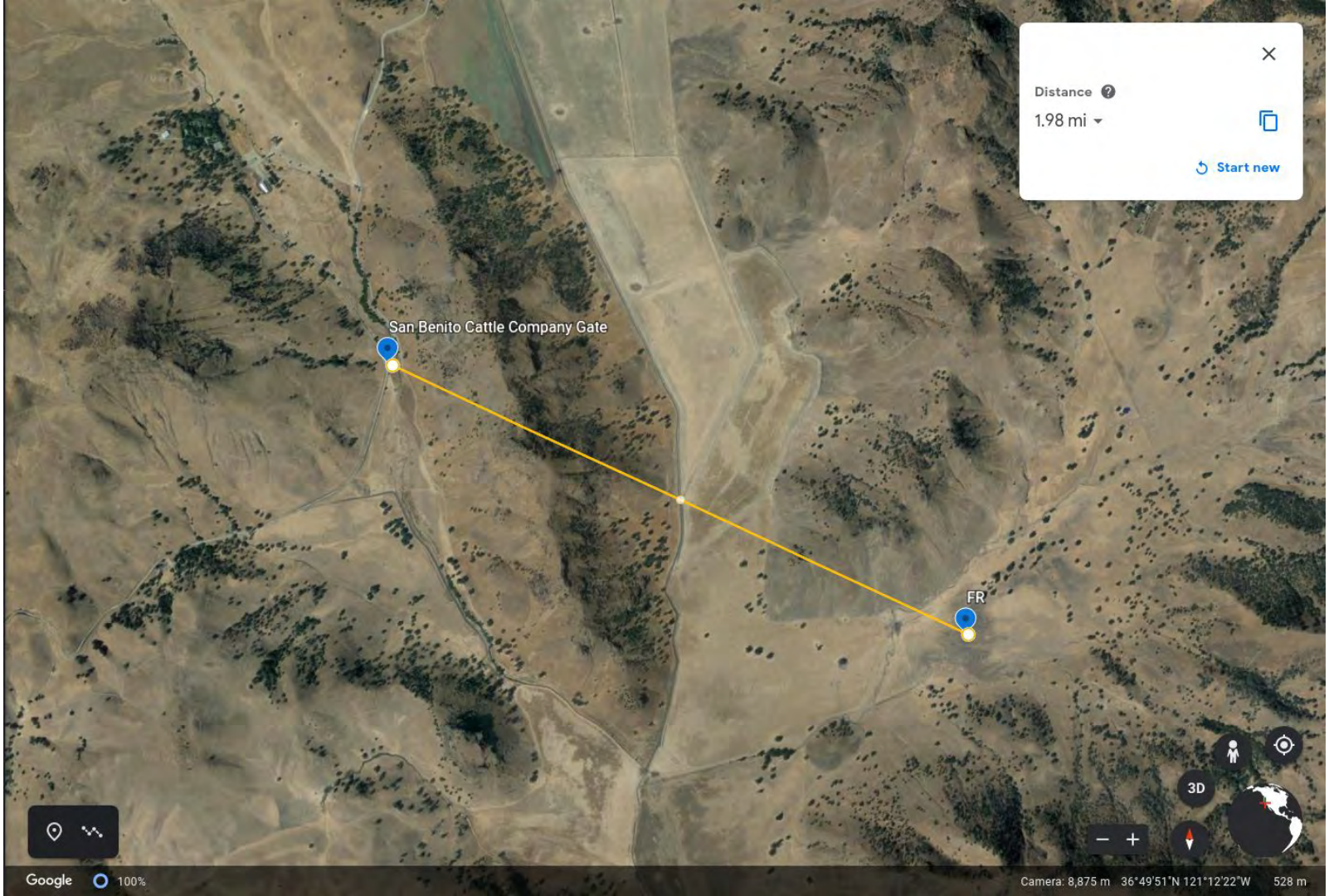
- Flying in a valley, most terrain is higher than takeoff point
- West has very high terrain (more populated areas)
- East has Interstate-5
- Farm to the north under COA
- San Benito Cattle Company Gate is under COA (public road)

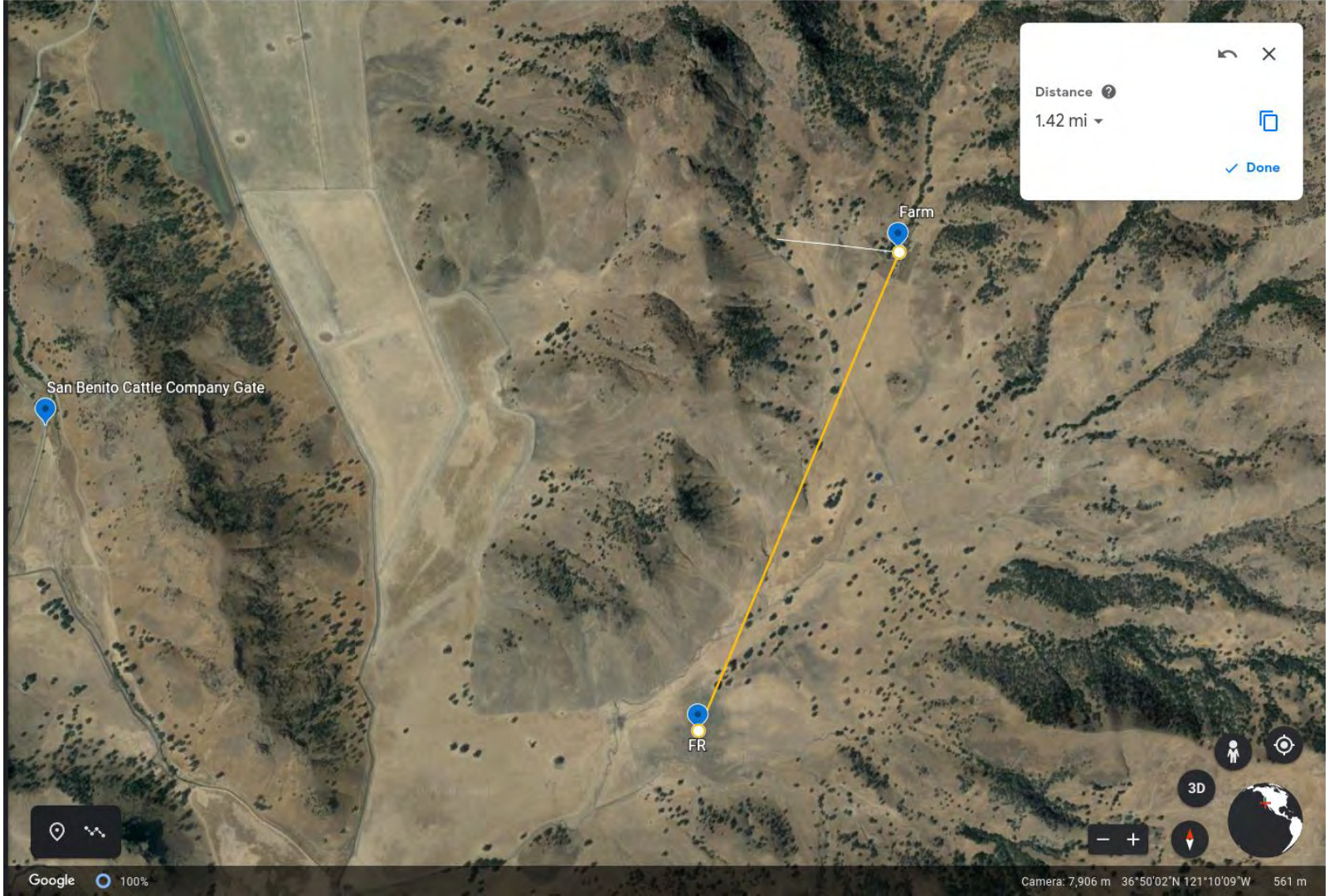
# Typical Circle (1000 ft MSL, 0.5 mile radius)

- Still a 2.36 mile glide
- Public road and Farm is accessible via glide

# Typical, 1000 ft AGL, 0.5 mile radius, 12.5 L/D

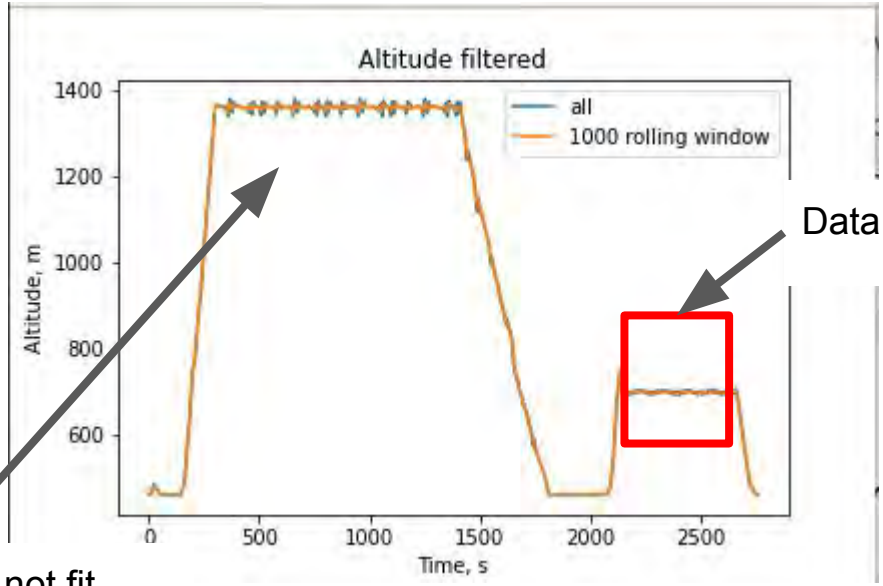



Distance
1.98 mi
Start new
San Benito Cattle Company Gate
FR
3D
Google
100%
Camera: 8,875 m 36°49'51"N 121°12'22"W 528 m


Distance
1.42 mi
Done
Farm
San Benito Cattle Company Gate
FR
3D
Google
100%
Camera: 7,906 m 36°50'02"N 121°10'09"W 561 m

# Old Slides

# Rolling mean, full data set



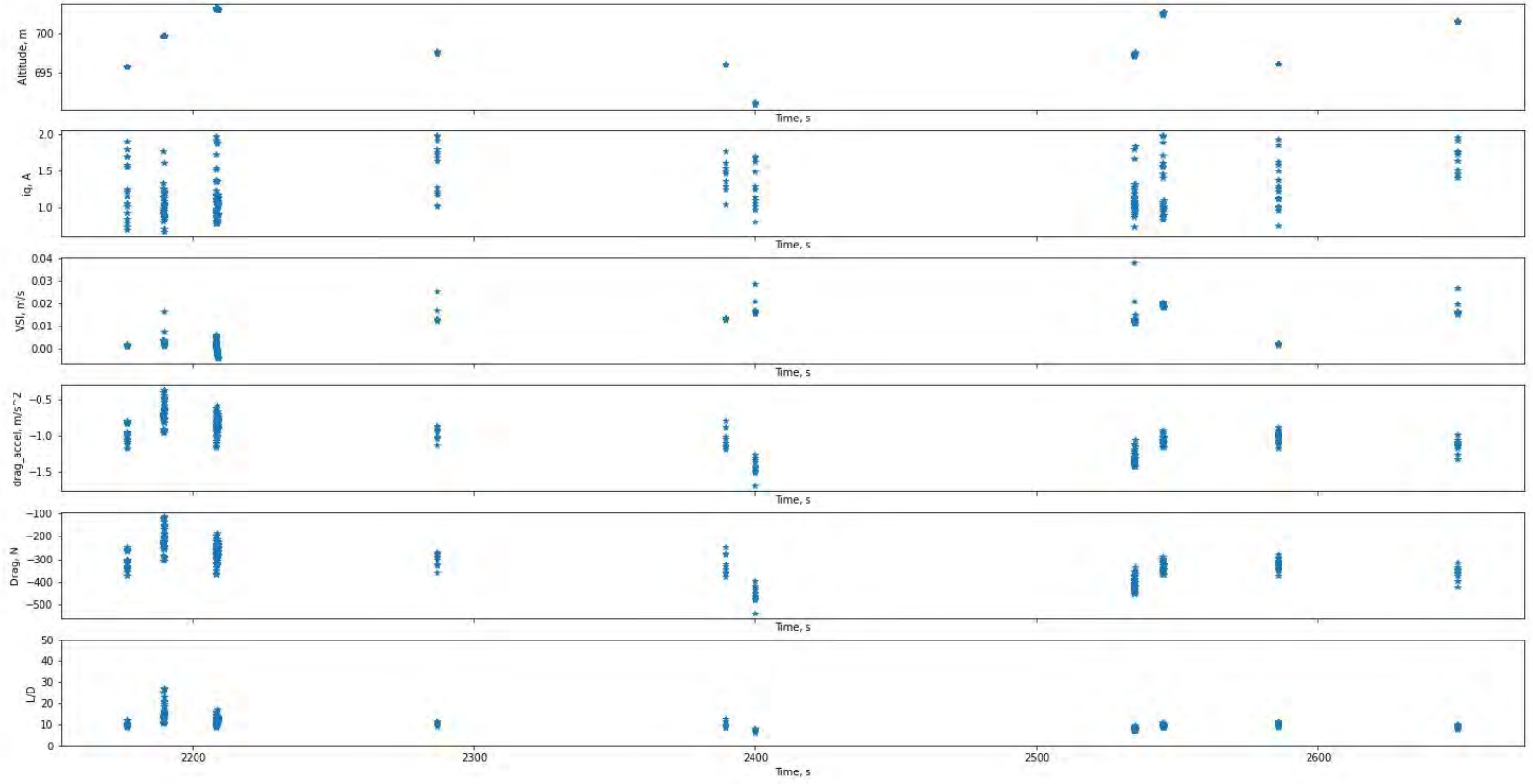

Data used for glide ratio calc

Data ignored, did not fit filter

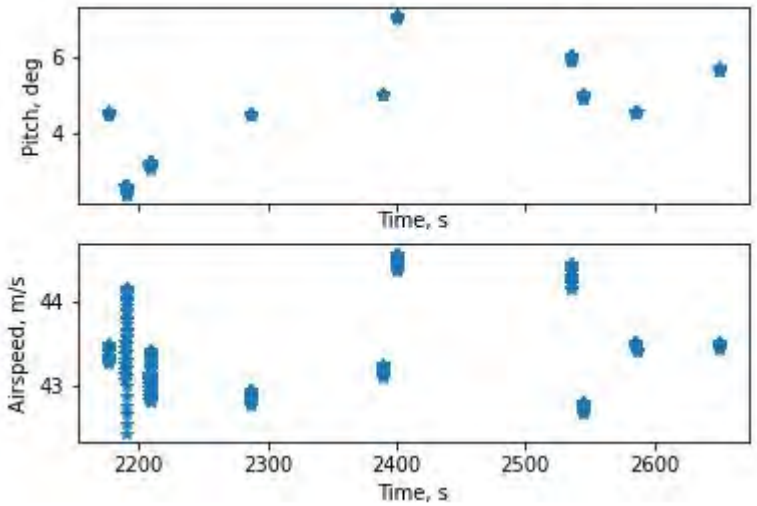
# Notes notes

- Using an example flight with a circle (data will be banked)
- Filtering based on
  - Rolling mean of 1000 samples (10 seconds of data at 100 Hz)
  - -0.005 < Vertical speed < 0.005 (m/s)
  - Drag acceleration < 0.0 m/s^2
  - Airspeed > 35.0 m/s (cruise tilt)
  - Average Motor iq < 2.0 amps
- https://drive.google.com/drive/folders/12B3Rewjk8ykL-Whjx-JSBumWinTDFeLV
  - clover_drag.py

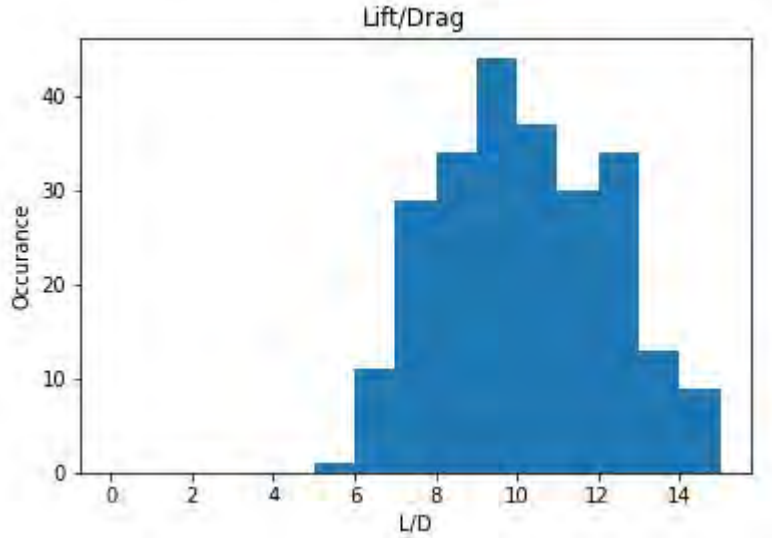
# Data


Altitude, m
700
695
Time, s
iq, A
2.0
1.5
1.0
Time, s
VSI, m/s
0.04
0.03
0.02
0.01
0.00
Time, s
drag_accel, m/s^2
−0.5
−1.0
−1.5
Time, s
Drag, N
−100
−200
−300
−400
−500
Time, s
L/D
50
40
30
20
10
0
2200
2300
2400
2500
2600
Time, s

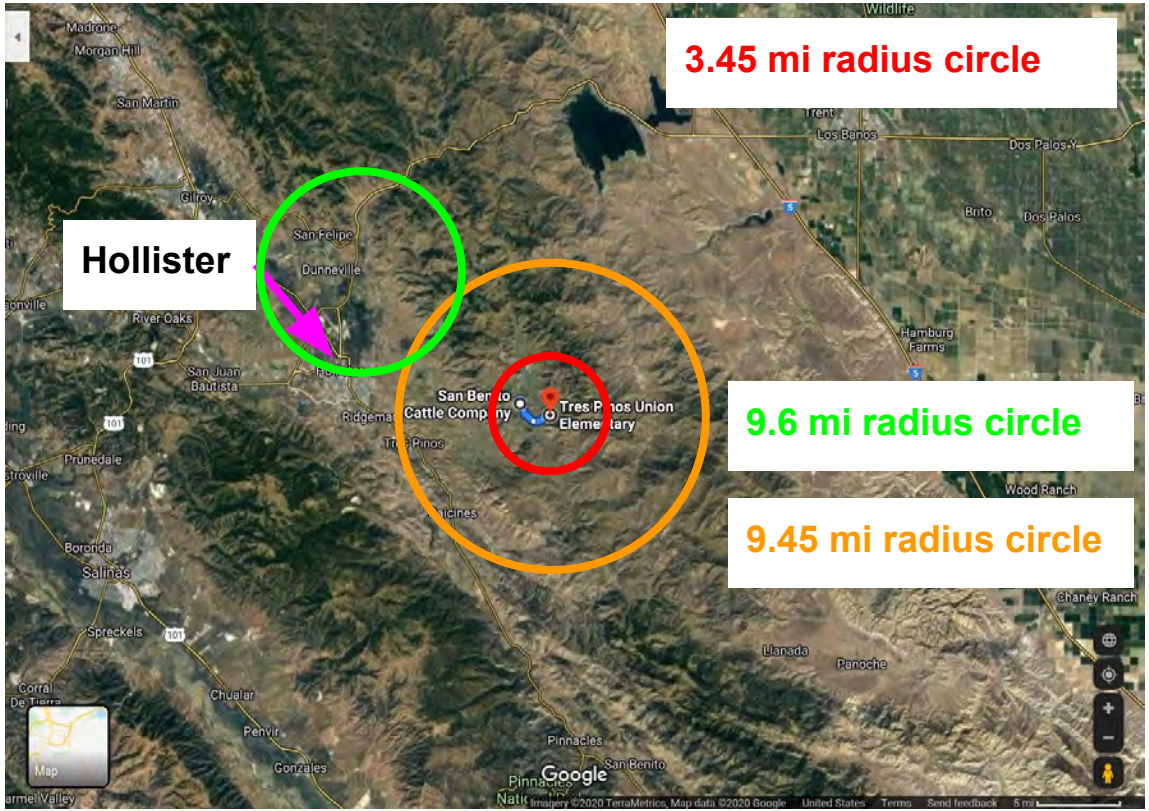
# Pitch and Airspeed



# Lift/Drag



# Assume 2500 ft MSL 12.5 L/D, spiral mode




## Assumptions

- No wind
- Does not take terrain into account. Assumes flat and at sea level.
- Does not take into account spiral mode or drag from windmilling propellers.
- Half the altitude since terrain is high around test site (in a valley)
- Half the altitude because it is unlikely the vehicle maintains trimmed best glide speed

# Heaviside Test Card

| | | | | |
|---|---|---|---|---|
| **Test Name** | MOTOR OUT HOVER HANDLING QUALITIES | **Aircraft** | ALL | |
| **Test Number** | *not implemented* | **W&B** | CHECK LIMITATIONS | |
| **Date** | AS REQUIRED | **Configuration** | ALL | |
| **Flight Card** | --- | **Initial Condition** | Acquire heading and enter a position hold in Augmented at >10m. Orient to a headwind if >5kts | |

| Test Point # | Test Point Name | Description | Flight Log - Number | Notes |
|---|---|---|---|---|
| | **Complete the following on a per pylon basis to support planned testing of the day.** | | | |
| 1 | Slow Climb Performance | Increase throttle until a slow climb is achieved.<br><br>Determine if handling qualities is sufficient to proceed. | | Tracking of inputs is generally satitisfactory to PIC.<br>Aircraft is able to maintain attitude and heading with minimal correction. |
| 2 | Full Throttle Performance | Increase throttle till full.<br><br>Determine if handling qualities is sufficient to proceed. | | Tracking of inputs is generally satitisfactory to PIC.<br>Aircraft is able to maintain attitude.<br>Heading may drift slowing. |
| 3 | Pitch doublets | Begin with small doublet inputs of 1 second. Increase in amplitude over a few cycles until reaching 50% stick input.<br><br>Determine if handling qualities is sufficient to proceed. | | Tracking of inputs is generally satitisfactory to PIC.<br>Small quickly damped oscillations are acceptable.<br>Able to maintain altitude and heading with minimal corrections. |
| 4 | Roll doublets | Begin with small doublet inputs of 1 second. Increase in amplitude over a few cycles until reaching 50% stick input.<br><br>Determine if handling qualities is sufficient to proceed. | | Tracking of inputs is generally satitisfactory to PIC.<br>Small quickly damped oscillations are acceptable.<br>Able to maintain altitude and heading with minimal corrections. |
| 5 | Heading Slew | Slew heading left and right 45 degrees from a steady state hover using 50% stick input. Repeat with 100% input.<br><br>Determine if handling qualities is sufficient to proceed. | | Tracking of inputs is generally satitisfactory to PIC in both direction<br>Assymetric response is expected.<br>Able to maintain altitude and attitude with minimal corrections. |
| 6 | Figure 8 | Execute a figure 8, turning in both directions, at 5-8 m/s.<br><br>Determine if handling qualities is sufficient to proceed with planned tests | | Tracking of inputs is generally satisfactory to PIC.<br>While yaw axis may be temporarily significantly impacted during a turn, the ability to maintain altitude is never lost.<br>No adverse handling qualities in straight flight. |

# Limitations

| Revision | Date | Changes |
|---|---|---|
| 0.17.0-0 | 20210919 | 0.17.0 initial release |
| | | |

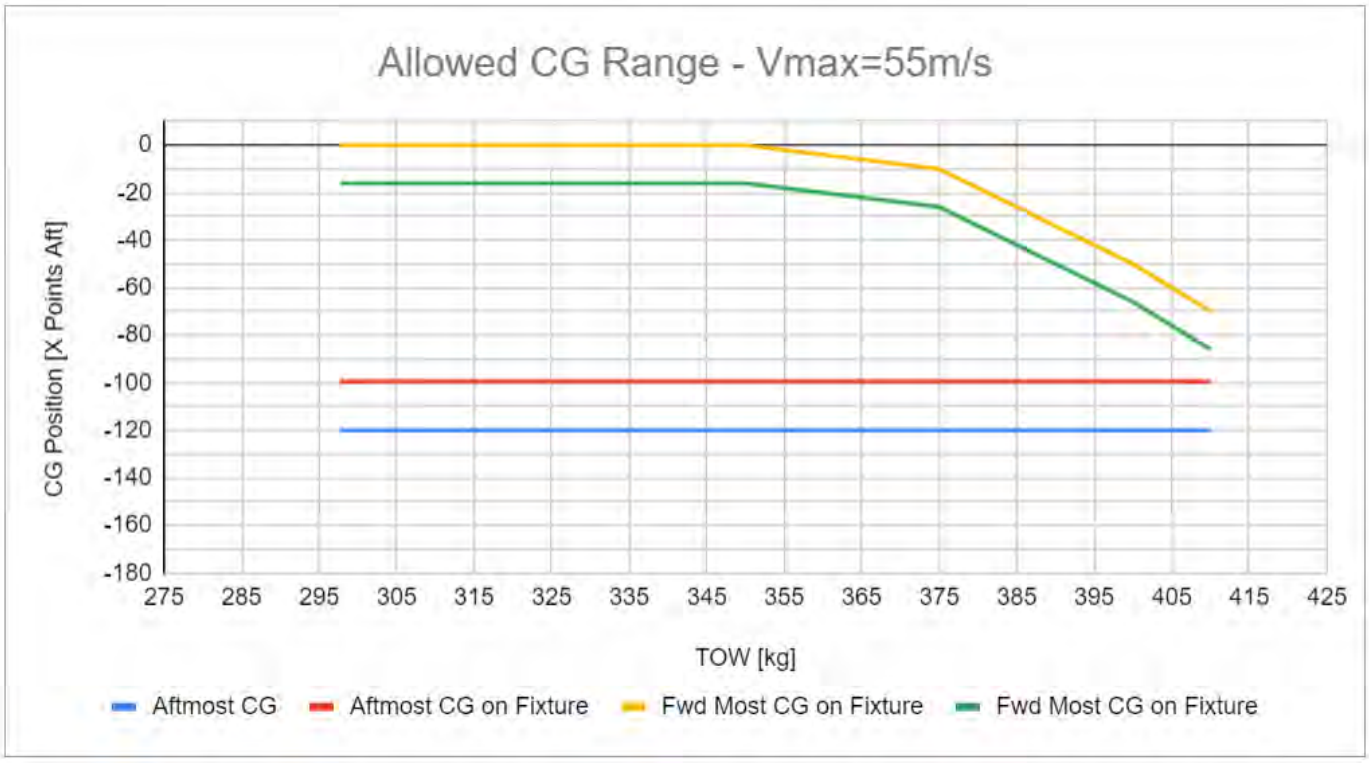
## Heaviside 2 Block 2 Uncrewed

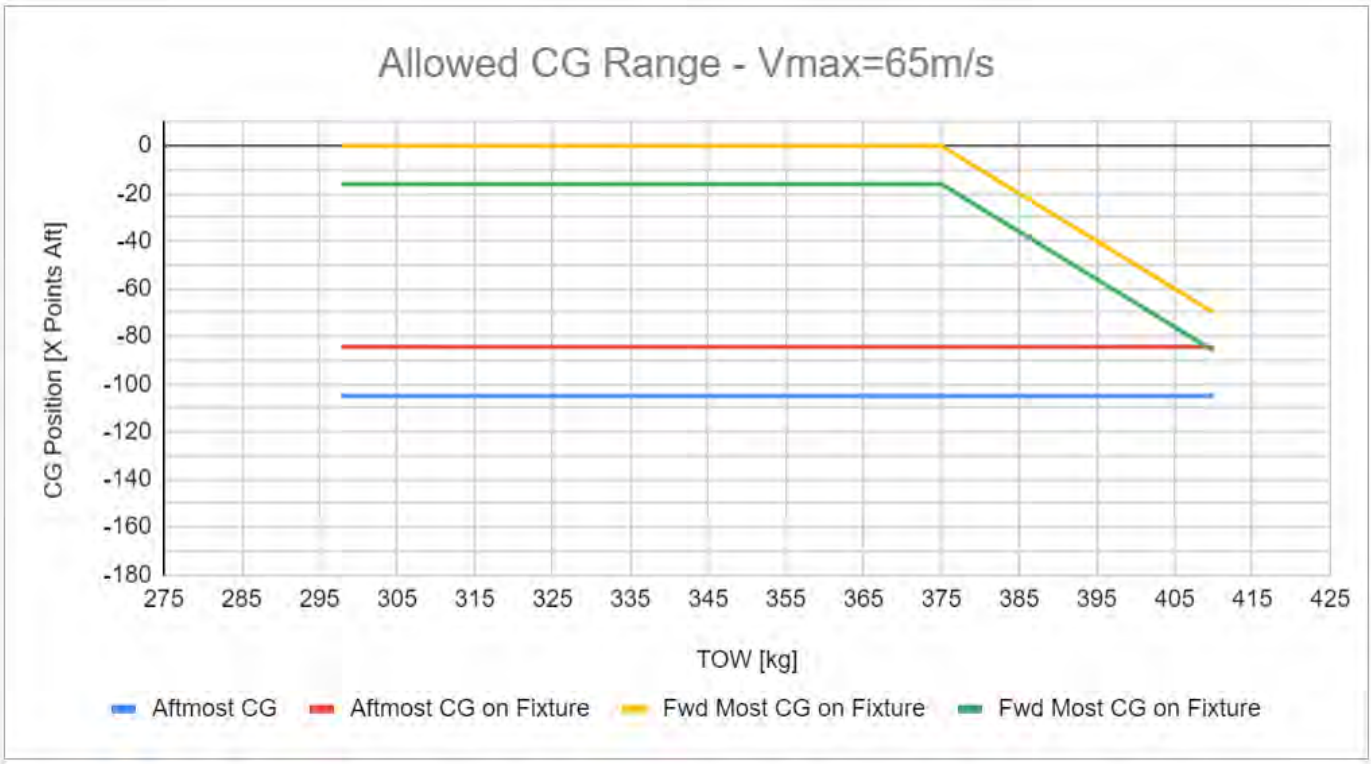
| | Description | Operational Limit | Unit | H2.2 Puma 350 kg | H2.2 Puma 400 kg | Notes |
|---|---|---|---|---|---|---|
| **Vne** | Never Exceed Speed | 78 | m/s; I | 55 | 55 | Currently limited by lack of control surface flutter analysis /testing and forward flight stability due to CG constraints. |
| **V_tilt_max** | Maximum speed in vertical configuration | 40.9 | m/s; I | 40 | 40 | |
| **Va** | Structural maneuvering speed | 59.2 | m/s; I | 59 | 59 | |
| | | | | | | |
| **Min Field Density** | Min density at Hollister Field Elevation | 1.057 | kg/m^3 | 1.057 | 1.057 | Set to 40C at Hollister field elevation of 490m using standard tropospheric model here. Ref: Sea level standard day- At 101.325 kPa (abs) and 15°C, air has a density of approximately 1.225 kg/$m^3$ |
| **Maximum Hover Out of Ground Effect (HOGE)** | Max density altitude for vertical flight with motor out tolerance | 1500 | m | 1500 | 1500 | |
| **OAT** | Outside air temperature range allowed. | 2-40 | C | 2-40 | 2-40 | Use standard atmospheric model to compute cruise temperature in lieu of remote sensing. |
| **Headwind** | Max headwind for takeoff and landing | 30 | kts | 30 | 30 | |
| **Crosswind** | Max crosswind for takeoff and landing | 20 | kts | 20 | 20 | |
| **Motor Out** | Max crosswind for takeoff and landing with motor out | 10 | kts | 10 | 10 | |
| **Tailwind** | Max tailwind for takeoff and landing | 15 | kts | 15 | 15 | |
| **Motor Out** | Max tailwind for takeoff and landing with motor out | 3 | kts | 3 | 3 | |
| | | | | | | |
| **Max gross weight** | Maximum takeoff weight | 400 | Kg | 350 | 400 | |
| **CG Range - Htail Extension** | Center of gravity range when equipped with horizontal tail extensions. | See chart below | mm | See chart below | See chart below | W&B range is dependent on max airspeed. W&B range should be based on the airspeed limit set in the flight controller. If testing of higher speeds is planned, the W&B range should use the most conservative chart based on weight and speed.<br><br>https://docs.google.com/spreadsheets/d/1u21zEOzThhdy2OFeRtERXQJpGT9h8ofz3fz35wCZiPU/edit#gid=706479062 |
| | | | | | | |
| **Max descent angle final approach** | Maximum descent angle during the final approach phase of automated flight | 20 | degrees | 20 | 20 | |
| **Slope Limits** | Landing surface slope | Not Allowed | degrees | Not Allowed | Not Allowed | Currently not in scope for H2 requirements |
| **LV Battery Charge Temp Range** | The LV batteries must be in this range in order to charge. | 0-45 | C | 0-45 | 0-45 | likely will be updated (smaller range) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Min LV SoC** | Minimum reported state of charge to fly. | TBD | V | 22.8 | 22.8 | provides ~10 minutes of reserve power in the event the HVLV and 1 LV battery fails |
| **HV Battery Charge Temp Range** | The HV batteries must be in this range in order to charge. | 10-45 | C | 10-45 | 10-45 | |
| **HV Battery Temp Range Flight** | The HV batteries should be kept within this range prior to starting flight during normal operations | 20-60 | C | 10-60 | 20-60 | **Battery temperature envelope is dependent on state of charge. See chart below.** Battery envelope is currently set for 400 Kg, which is required due to the fleet power limit being set by this configuration.<br><br>Batteries should be heated through auxiliary heat or discharge prior to flight. Operating at colder temperatures may result in voltage drooping below min bus voltage if 1 HV pack goes offline. |
| **Min HV SoC for Transition** | Minimum state of charge before attempting a transition from hover to cruise. | 55% | Ah | 4 | 4.5 | A simple pattern with minimum cruise takes approximately 1Ah. A landing may be required once approach is committed. |
| **Land as Soon as Practical** | Minimum state of charge during normal operations when beginning a standard approach | 50% | Ah | 3.2 | 3.6 | Assume efficient approach landing is committed once below 20 m/s. Allows for 30 seconds of hover in battery out condition. |
| **Nominal hover, zero fault tolerant** | Maximum hover time assuming no battery-out or motor-out protection | 180 | Seconds | 180 | 180 | |
| **Nominal hover, fault tolerant** | If aircraft is landed within this duration, you can experience a motor-out or battery-out at any point during the operation and safely land. | 100 | Seconds | 100 | 100 | |
| **Nominal hover, post-cruise** | Following sustained operation at max cruise power, if the aircraft is landed within this duration, you can experience a motor-out or battery-out at any point in the operation and still safely land.<br><br>This duration is a minimum bound and is set as the limit given any additional hover time bought by flying at a lower cruise power or for less time cannot be precisely known at time of flight | 60 | Seconds | 60 | 60 | |

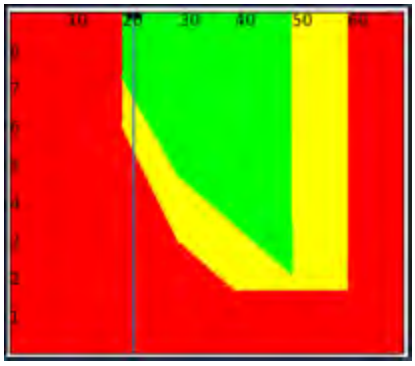
Weight and Balance Chart - With Tail Extensions

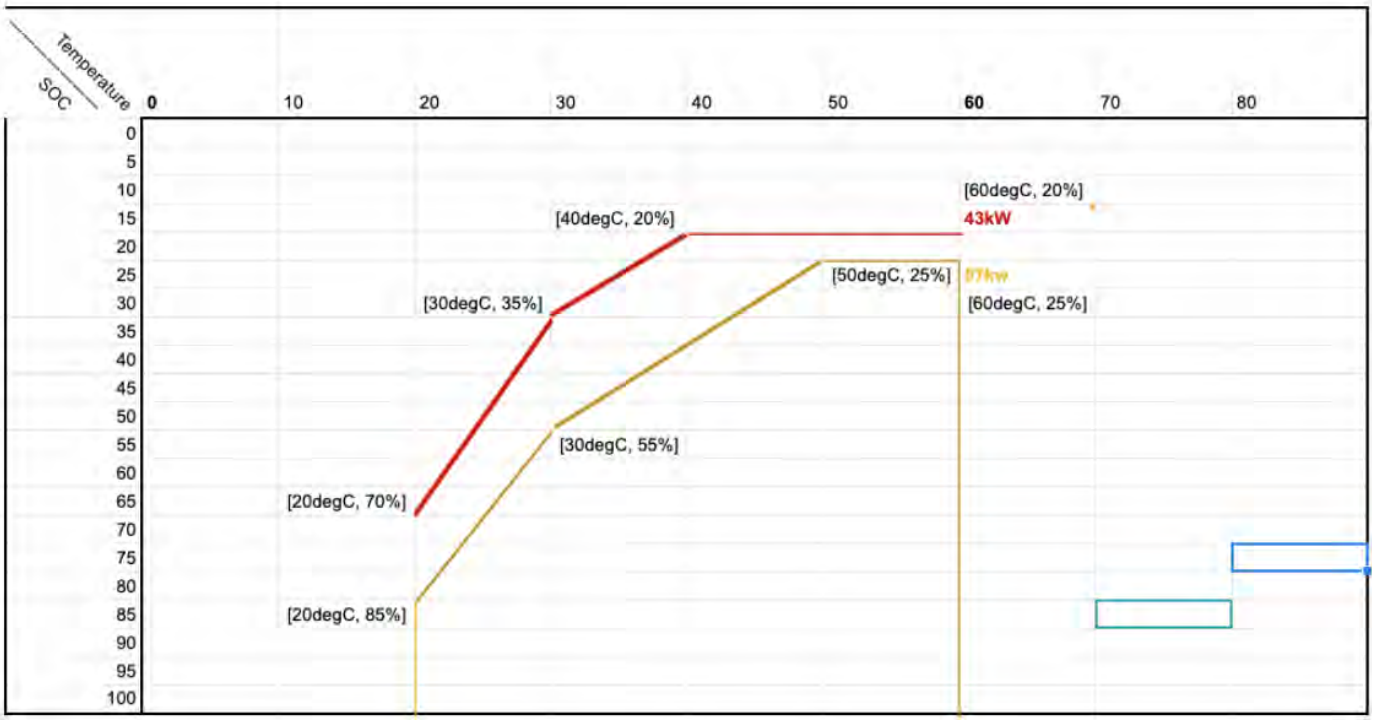

Allowed CG Range - Vmax=45m/s
CG Position [X Points Aft]
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
275
285
295
305
315
325
335
345
355
365
375
385
395
405
415
425
TOW [kg]
Aftmost CG
Aftmost CG on Fixture
Fwd Most CG on Fixture
Fwd Most CG on Fixture


Allowed CG Range - Vmax=55m/s
CG Position [X Points Aft]
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
275
285
295
305
315
325
335
345
355
365
375
385
395
405
415
425
TOW [kg]
Aftmost CG
Aftmost CG on Fixture
Fwd Most CG on Fixture
Fwd Most CG on Fixture




Battery State of Charge Temperature Envelope



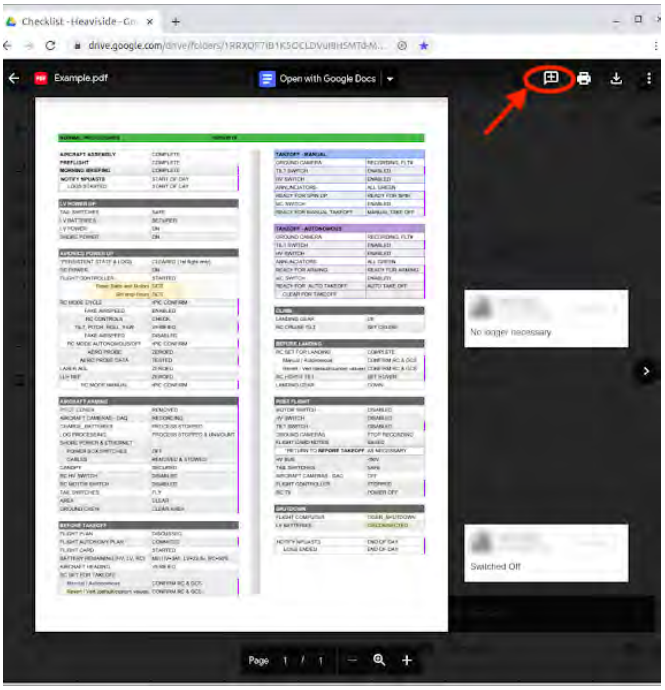

Temperature
SOC
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
[60degC, 20%]
43kW
[40degC, 20%]
[50degC, 25%]
97kw
[30degC, 35%]
[60degC, 25%]
[30degC, 55%]
[20degC, 70%]
[20degC, 85%]

# Checklists, H2.2 - Uncrewed

**Current Checklists (Click to follow link)**

- Current checklists are located on the Heaviside Shared Drive: Heaviside/Flight Test/H2 Aircraft Flight Manual/Checklist
- Checklists located here are the most up to date and are available in PDF format for easy viewing and printing.
- These checklists are “view only” and cannot be edited.
- Changes from a previous version of a checklist are indicated with a purple sidebar.
- The “Archive” sub-directory contains previous versions of the checklists.
- The "Draft" sub-directory contains checklists that are currently being edited or updated. **Do not make changes to these files.**

| Name | Description | Revision |
|---|---|---|
| Inflight Emergency & Downed Aircraft | Actions and procedures for emergencies during a flight, and response to a downed aircraft. | 06/14/2021 |
| Preflight Inspection | Vehicle items and systems to check daily before the first flight. | 06/28/2021 |
| Daily Briefing | Daily safety briefing to discuss test site, planned flight tests, and personnel information. | 08/6/2021 |
| CRM Risk Assessment | Checks for Crew Resource Management and personal risk evaluation. | 04/06/2020 |
| Normal Procedures | Checks and procedures for starting and normal flight operations. | 08/16/2021 |
| Charging & Processing /<br><br>GCS Setup | Checks and procedures for running a charge cycle.<br><br>Checks and procedures for starting the GCS system at the beginning of the day. Also starting NPUASTS required documentation. | 08/6/2021 |
| Automated Flight Planning | A list of items that should be set as default when creating a new flight plan or editing a current plan. | 08/16/2021 |
| Site Safety and Readiness | Checks at the beginning of the day to ensure the site is ready. | 06/14/2020 |




## Requesting Changes

- Changes to checklists can be requested by making comments directly on the PDF document in the current checklist folder.
  - Open the PDF document in Chrome by double-clicking on it
  - Click the comment icon that appears on the top right.
  - Draw a box around the area on which you want to comment.
  - The Flight Test team will review the comments and update the checklist as necessary.

**Heavisde 2, Block 2 - Uncrewed**

**Site Safety and Readiness** **6/16/2020**

| Fire Truck | |
|---|---|
| Check engine bay for rodents or nests | |
| Start Truck | Drive to gate and back |
| Fuel Level | Truck and Pump |
| Check Tank Water Level | |
| Start Water Pump | Quick Guide |
| Fire Extinguisher in Truck | |
| PPE gear bag (2x) in truck | |

| Portable Fire Suppression |
|---|
| Check Fire Extinguisher levels and Expiration |

| First Aid |
|---|
| Locate Emergency Response Manual |
| Check AED battery |
| Check Trauma/First Aid Kit |
| Check Satellite Phone |

| Generator |
|---|
| Check Fuel |
| Check Oil |
| Check DEF |
| Check Coolant |

| Charge Conex | |
|---|---|
| HV Power Supply | |
| LV Power Supply | 450v |
| Microhard Antenna | |
| Weather Station | |

| Solar Panel |
|---|
| Panel Condition |
| Wiring |
| Batteries |

| Charge Box at Pad |
|---|
| Cable intregity |
| Connector condition |
| Connector Clean |
| Switch Position |

**Heavisde 2, Block 2 - Uncrewed**

| **ORM Risk Assessment Tool** | | | **6/28/2021** |
|---|---|---|---|
| **Test Crew** | | | |
| **Illness** | Any illness or other health related issues? | | **Yes** |
| | | | **No** |
| **Medication** | Taking any non-standard medication (or OTC)? | | **Yes** |
| | | | **No** |
| **Alcohol** | Alcohol consumption within 8 hours OR hangover? | | **Yes** |
| | | | **No** |
| **Fatigue** | Duty Day | | **<12 Hours** |
| | | | **12-16 Hours** |
| | | | **>16 Hours** |
| | Rest Period | | **>8 Hours rest** |
| | | | **6-8 Hours rest** |
| | | | **<6 Hours rest** |
| **Experience** | Appropriate training for mission? Recency and Current? | | **Yes** |
| | | | **No** |
| **Aircraft** | | | |
| **Maintenance and Preflight** | Airworthy and ready? Review MX log and deferred actions. | | **Yes** |
| | | | **No** |
| **Environment** | | | |
| **Current Weather** | Visibility appropriate for waiver and mission? | | **Yes** |
| | | | **No** |
| | Thunderstorms in vicinity? | | **Yes** |
| | | | **No** |
| | Wind velocity below wind limits or personal minimums? | | **Yes** |
| | | | **No** |
| | Heat Index / Wind Chill? | | **>104 F** |
| | | | **88-104 F** |
| | | | **32-88 F** |
| | | | **<32 F** |
| **Forecast Weather** | Thunderstorm in forecast? | | **No** |
| | | | **Within 8 Hours** |
| | | | **Within 2 Hours** |
| **Airspace** | Airspace appropriate for mission? | | **Yes** |
| | | | **No** |
| **See and Avoid Strategy** | Method appropriate for mission? | | **Yes** |
| | | | **No** |
| **Bird and Wildlife Activity** | Check http://www.usahas.com/ and visual surrounding area. | | **Yes** |
| | | | **No** |
| **Communication and Notification** | Crew communication and external entities? | | **Yes** |
| | | | **No** |
| **External Pressures** | | | |
| **Operational Pitfalls** | Consider: | | |
| | Goal completion orientation | | |
| | Peer pressure | | |
| | Get-it-done-itis | | |
| | Neglect of proper flight planning | | |

**Orange items require additional mitigation.**

In addition to orange items, list other risks present during the operation and associated mitigations.

**Heavisde 2, Block 2 - Uncrewed**

| **ORM Risk Assessment Tool** | **6/28/2021** |
|---|---|
| **AFRL Form 33A** | |

| **Instructions:** | |
|---|---|
| 1) | Complete this assessment prior to each flight or like series of consecutive sorties. |
| 2) | Maintain completed forms in test log book. |
| 3) | If Total ORM level is Yellow or Red, notify AFRL/SEF and AFRL/DO that approval to continue with testing was sought/garnered by the appropriate level of authority. |
| | Notification should be made within 4 hours of the start of the test. |
| | Preferred method of notification is by e-mailing the completed form to AFRL.SE.Workflow@US.AF.mil and afrl.do.workflow@us.af.mil. |
| 4) | Provide copy of completed forms to AFRL/SEF and AFRL/DO upon the completion of the test program. |

| **ORM EVALUATION** | |
|---|---|
| **GREEN ORM:** | If any specific area is Red, look at ways to lower risk in that area. |
| | Test Director or Test Safety Officer discretion to continue test. |
| **YELLOW ORM:** | Try to mitigate to Green ORM. |
| | Work with Test Director, Vehicle Operator, LNO, and Test Safety Officer to lower ORM risk. |
| | If unable to lower risk, AFRL Branch Chief, SQ/CC, or equivalent level of supervision must be notified and approve test start. |
| **RED ORM:** | Try to mitigate to Green or Yellow ORM. |
| | Work with Test Director, Vehicle Operator, LNO, and Test Safety Officer to lower ORM risk. |
| | If unable to lower risk, AFRL Branch Chief, SQ/CC, or equivalent level of supervision must be notified and approve test start. |

**Heavisde 2, Block 2 - Uncrewed**

**DAILY BRIEFING** **8/6/2021**

| | | |
|---|---|---|
| **Crew Intros and Roles & Responsibilities:** | rPIC: | Fly aircraft. Maintain vehicle situational awareness. |
| | VO: | Observe and report traffic in area. Maintain vehicle situational awareness. |
| | GCS / MC: | Observe and report system health. Run checklists. / Manage work flow. |
| | Engineer: | System diagnosis and resolution. Flight Test support. |
| | Ground Crew: | Preflight, relocate, charge, and maintain vehicles. Flight Test support. |

| | | |
|---|---|---|
| **Guests on site:** | | |
| **Guest Expectations:** | Guests should stay inside the Hangar during flight operations. | Guests permitted outside hangar with permission/escort from KH staff. |
| | Guests in hangar shall observe Sterile Communication during flight ops. | |
| | PPE, Bathroom, Water, Snack Locations | |

| | | |
|---|---|---|
| **Today's Winds & Weather Forecast:** | *KCVH METAR* | Flight opertions are prohibited in visible moisture conditions. |
| **Sunrise/Sunset and End of Operations Time:** | *Sunrise/Set Gilroy* | (End of Ops will likely be earlier than official sunset) |

| | | |
|---|---|---|
| **Emergency Plan:** | *Emergency Action Plan* | Printed copy located at GCS workstation |
| **In event of an emergency:** | Crew is the first priority. Vehicle only after crew and site are safed. | Guests on site should remain clear of activity and assist only when asked. |
| | Assess Situation: | |
| | Call 911 | |
| | Refer to Emergency Action Plan | |
| | All staff should leave the keys on the fridge for quick access. | |

| | |
|---|---|
| **FIRST AID / Medical Kits:** | First Aid/Trauma Kit, and AED located on the shevles near the GCS |

| | | |
|---|---|---|
| **Fire Emergency:** | Fire Extinguishers are locatied in the hangar & placed around our site: | Fire Truck: |
| | 1 in Hangar | Keys on fridge. |
| | 1 inside Charging Conex | Operation instruction on water tank and inside cabin. |
| | 1 inside Fire Truck | *Fire Truck Quick Guide* |

| | |
|---|---|
| **Vehicle Recovery:** | *Emergency Action Plan* |
| | Do not rush to vehicle. Make safe decisions and deliberate actions. |
| | Mission Control Operator will give the okay to approach the vehicle after it has been disarmed by rPIC and verified by GCS. |
| | Ensure disarm. Batteries, wires, and fuselage are all ok to approach. |
| | Only Service, Ground Crew, and Mission Control staff should approach the vehicle (unless they ask for extra assistance). |

| | | |
|---|---|---|
| **Vehicle Failure or Emergency Scenarios:** | What happens when (example)... | RC loss, Sensor failures, Fly-Away, Motor Out |
| | Response to (example)... | Snake Bite, Ankle Injury, Laceration, Electric Shock |

| | |
|---|---|
| **Test Plan/Daily Objectives Overview:** | (Overview of the general plan for the day.) |
| **Vehicle Review:** | (Brief of specific changes to aircraft, maintenance, or test config needed.) |
| | Flight Risk Status Board Review |

| | | |
|---|---|---|
| **Main Hazards:** | The aircraft. Heaviside is an Experimental Aircraft with 8 propellers. | Don't approach the vehicle without approval or supervision of KH staff. |
| **Site Hazards:** | Heat/Cold, Dangerous Wildlife | Ear protection, hats, gloves, sunscreen, water available. |
| | Construction materials, obstacles in the hangar. | Be careful of your surroundings. |

| | | |
|---|---|---|
| **Sterile Communication Areas:**<br>**Critical Personnel Only Areas:** | -GCS Station / Mission Control<br>-Pilot Stand<br>-Hangar<br>-Landing Pad areas | Critical personnel only in these areas.<br>Communications and talk should be flight operations or vehicle specific.<br>Please take casual conversation away from these critial areas. |
| **"Knock it off" / "No" vote** | Everyone has the responsibility to stop a flight or activity if it appears unsafe, confusing or if other pertinent questions arise. | |
| **Do Not Cross Line:** | The "do not cross line" is the west side of the hangar road, and the south end of the pilot stand | |

| | |
|---|---|
| **NPUASTS Items:** | COA Provisions and Limitations |
| | NOTAM Issued |
| | Other NOTAMs checked |
| | Items from last test day addressed: |
| | Risk Mitigations: |
| | NPUASTS Notified |

| **End of Day Debriefing** | |
|---|---|
| **Summary of testing completed:** | |
| **Objectives Met (what went well):** | |
| **Objectives not Met (what did not go well):** | |
| **Lessons Learned:** | |
| **Process Logs Completed?** | |
| **Process Video Logs?** | |
| **Any aircraft maintenance needed?** | |
| **Notify NPUASTS of completion** | via Slack channel |
| **Items to address before next flight:** | Any mx issues, or operational issues that need to be addressed? |
| **Plan for next day:** | |
| **Any other take-aways, questions, comments:** | |
| **Test Report Action Items Assigned:** | |

**Heavisde 2, Block 2 - Uncrewed**

## PREFLIGHT INSPECTION 6/28/2021

| | |
|---|---|
| VEHICLE POWER | OFF |

| AIRCRAFT MAINTENANCE LOGS | |
|---|---|
| Check Vehicle Maintenance Status | Odoo:Vehicles |

| AIRCRAFT WEIGHT & BALANCE | |
|---|---|
| Verify Limits | Docs:Heaviside 2 W&B |

| RC CONTROLLER | |
|---|---|
| Antenna | Secure |
| Switches, Sliders, Sticks | Condition |
| Power | On |
| Battery Level | Charged |
| RF Power | 100mW |
| Power | Off |

| FUSELAGE | |
|---|---|
| Carbon Fiber | No Damage |
| Charge Port | Clear |
| Battery Vent | Clear |
| AGL Sensor | Clean |
| Pitot Blades | Clear |
| Landing Gear | No Damage |
| Naca Duct | Clear |

| CANARD | |
|---|---|
| Carbon Fiber | No Damage |
| Pylons | Inspection |

| WING | |
|---|---|
| Carbon Fiber | No Damage |
| Pylons | Inspection |
| Aileron Flaps | No Damage, Free Movement |
| Nav Lights | Secure |
| Hatch Panels | Closed |
| Avionics Hatch | Secure |

| TAIL | |
|---|---|
| Carbon Fiber | No Damage |
| Transponder Antenna | Secure |
| Microhard Antenna | Secure |
| VHF Antenna | Secure |
| Horizontal Stabilizer Extension | Secure 19 in-lbs, 2.1 Nm |

| EMPENNAGE | |
|---|---|
| Carbon Fiber | No Damage |
| Hatch Panels | Closed |
| Elevator Flaps | No Damage, Free Movement |
| Rudder Flaps | No Damage, Free Movement |
| Tail Switches | Visual Inspection Only |
| GoPro Camera | Secure |
| SD Card | Format |

| CANOPY | |
|---|---|
| Pilot Interface assemblies and equipment | Inspect for looseness, cracks, damage. |
| Logging Tablet | Secure, Connections |
| LV Switches | Visual Inspection |
| LV Batteries | Secure (if installed) |
| Ballast | Secure and Labelled |
| GoPro Camera | Secure (if installed) |
| SD Card | Format |
| Parachute Handle | Secure (Pin Installation) |
| Latch and Hinges | No Damage |

| PYLON/MOTOR INSPECTION (TYPICAL) | |
|---|---|
| Naca Duct | Clear |
| Hatch Cover and Screws | Secure/Taped and Screws tight |
| Tilt Linear Actuator | No Binding/Looseness or Leaks |
| Tilt Linear Actuator Connection | Torque Stripe Check |
| Motor Leads | No Damage |
| Motor Mounts | Tight |
| Motor Hinge | Inspect |
| Tilt Sensor | Clean, Plugged In |
| Screen | Clean |
| Propeller | Smooth with No Excess Movement |
| | Leading Edge Tape Inspection |
| Spinner | No Damage |

| WEEKLY PREFLIGHT | |
|---|---|
| Avionics Hatch Internal Inspections | Secure |
| Wire Harnesses | Secure |
| Wing Bolts | <SN7 Secure 28 ft-lbs, 38 Nm |
| | >SN8 Secure 35.5 ft-lbs, 48.1 Nm Front |
| | 31.1 ft-lbs, 42.2 Nm Rear |
| Parachute Tub | Parachute Bag |
| | Harness |
| | Rocket |
| | Pin |
| Internal FOD | Removed |

**Heavisde 2, Block 2 - Uncrewed**

**Automated Flight Planning** 8/16/2021

| GUIs are updated to vehicle's current status |
|---|
| **TERMINAL** |
| Flight Controller Running |
| **SET-OH-MATIC** |
| "take upstream" 5x |
| "refresh" 5x |

| PLAN_O_MASTER 2000 |
|---|
| Verify Automatic Plan Sanity |
| Load Desired Autonmatic Flight Plan |
| "Location_Pad_LandingDirection_Pattern" |
| |
| Default/Recommended values |
| Common Tab |
| "default airspeed" = 42 m/s Cruise Speed |
| "cruise tilt" = -1.00 (-100% tilt = 0°) |
| "hover tilt" = 1.00 (100% tilt = 90°,84°) |
| takeoff/departure Tab |
| "departure end" = plan (circle D) |
| "takeoff heading" = plan |
| "takeoff airspeed" = 10 m/s |
| "finish tilt distance" = 350 m (red line) |
| "finish tilt airspeed" = 37 m/s |
| approach/landing Tab |
| "approach start" = plan (circle A) |
| "go around end" = plan (circle G) |
| "start tilt distance" = 1000 m (red line) |
| "start tilt airspeed" = 35 m/s |
| "start final airspeed" = 17 m/s |
| "settling length" = 150 m |
| "landing decel" = 1.0 m/s2 |
| "landing heading" = plan |
| "final glide angle" = 10° |
| "final agl offset" = 7 m |
| |
| mode "edit Holding" |
| Verify appropriate altitudes |
| Verify traffic pattern shape |
| Verify traffic pattern direction matches departure/approach |
| |
| mode "edit Approach" |
| Verify heading/landing direction |
| • Verify/*MOVE* landing position to current/desired location |
| Approach angle approx 3° |
| "jigger glideslope" if moved landing position to create/verify 3° slope |
| Red vertical line is "start tilt distance" |
| Red F circle is mode change to "Auto Landing" point |
| Purple L circle is Landing Point |
| |
| mode "edit Departure" (take off) |
| Verify Slope Departure angle |
| Take off transition (TO/TE to Circle 0) ends at approx 40m agl |
| Climb angle approx 6° after Circle 0 |
| |
| mode "edit GoAround" (aborted landing) |
| Verify Slope GoAround angle |
| GoAround transition (F/L to Circle 0) approx 40m agl |
| Climb angle approx 6° |
| |
| "view ac 0" tab |
| "jigger glideslope" |
| "commit" |
| current version = sent version |
| mode "view ac 0" should see both H2 icons |

**Flight Briefing**

| Manual |
|---|
| Which flight plan is loaded |
| Takeoff pad |
| Takeoff direction |
| Speed callouts |
| Manual flight pattern |
| Where to join autnomous flight plan if desired |
| Breakout point (cardinal direction) |
| Breakout path |
| Landing direction |
| Landing pad |

| Autonomous |
|---|
| Which flight plan is loaded |
| Takeoff pad |
| Takeoff direction |
| Initial climb out |
| Climb altitude |
| Holding airspeed |
| Breakout point (cardinal direction) |
| Breakout path |
| Landing direction |
| Landing pad |

Heavisde 2, Block 2 - Uncrewed

## CHARGE & PROCESSING 6/14/2021

| Charge Vehicle | |
|---|---|
| **VEHICLE / CHARGER** | |
| POST FLIGHT checklist | Complete |
| Generator | On |
| HV and LV power supplies | On |
| Ground Power and Charge switches | Off |
| Check other vehicle Net/Power not plugged in | Only One on Network |
| Ground Power and Ethernet cables | Clean and Connect |
| Ground Power and Charge switch | On (fans) |

| CHARGING & PROCESSING | |
|---|---|
| STARTING CHARGE | |
| ./check_serial | Verify Serial # |
| ./charge_batteries | Started |
| Charge Process | Complete |
| Control-c to end early | If Necessary |
| | |
| OFFLOAD LOGS | |
| ./offload_logs | Started |
| Offload Process | Complete |
| Control-c to end early | If Necessary |
| scp ground logs | If Required |
| | |
| PROCESS LOGS | **EOD** |
| Process logs, Generate COA, Agility Prime | Confluence Page |

| RETURN TO FLIGHT | |
|---|---|
| AVIONICS POWER UP checklist | As Necessary |

| SHUTDOWN VEHICLE | |
|---|---|
| SHUTDOWN checklist | As Necessary |

| END OF DAY | 8/6/2021 |
|---|---|
| NPUASTS Heaviside Daily Summary | Daily Summary |
| Afternoon METAR field | Check, Ctrl+c, Ctrl+shift+v |
| If check box doesn't work | KCVH Metar |
| Stop Time | |
| Number of Flights Completed | |
| Objectives Met | |
| Objectives Not Met | |
| Items to Address | |
| NPUASTS Slack | Notified |
| Flight Cards | Saved |
| Flight Logs | Offload, Process, COA, AP |
| GCS program and chrome tabs | Closed |
| GCS computer | Shutdown |
| GCS UPS | Off |
| Airspeed Box | Closed |
| Conex | Closed |
| Headset Hub | Returned |
| RC Power Strip | Cycled |
| RC Extrenal Batteries | Unplugged |
| Lipo Batteries | Unplugged |
| Left-over food | Claimed / Disposed |
| Trash and Recycling | Emptied |
| One Wheels | Inside |
| Daily Debrief | Completed |
| Doors | Locked |

## GCS SETUP 8/6/2021

| Equipment | |
|---|---|
| UPS | On & Charged |
| Crew Radio Base Station | Setup |
| Airspeed Audio Box | Setup on Pilot Stand |
| Microhard Antenna | Inspect |
| Ground Camera | Setup on Camera Pad |

### GCS COMPUTER

| Launch GCS | |
|---|---|
| ./launch_gcs | Started |
| (contains ./launch_datalink & ./launch_guis) | |
| Plot (if desired) | |
| ControlOutputs/Navigation/NavLongitudinal/SpatialTracking/POS/climb | |
| ControlOutputs/Navigation/NavLongitudinal/SpatialTracking/VEL/forward | |

| Setup Microhard to Communicate with Vehicle (before flight) | |
|---|---|
| ./configure_microhard | SN# |
| Web browser: 192.168.254.101 | |
| LI:admin PW:piloterror | |
| Wireless RF | |
| Channel Frequency and Network ID | WIreless Configurations |
| Submit | |

### GCS OR OPERATOR COMPUTER

| NPUASTS | |
|---|---|
| Start Heaviside Daily Summary | Daily Summary |
| Copy Template to new tab and rename to current date | |
| Modify "Flight ID" to include date YYYYMMDD | |
| Morning METAR field | Check, Ctrl+c, Ctrl+shift+v |
| If check box doesn't work | KCVH Metar |
| Fill in "Items from last day" field | |

| Flight Cards | |
|---|---|
| Start new card | Jira FLT-296 |
| Clone template | |
| Remane card: YYYYMMDD H#.#-### | |
| Move to "In Progress" | |
| Change Assignee, Reporter, Observer | |
| Change aircraft | |
| Add vehicle W&B (## kg @ ## mm) | Reference Vehicle W&B Calc Page |
| Add software version X.X.X | |
| Un-Link Clone | |

### CHARGE AND PROCESSING COMPUTER

| Terminal Setup | |
|---|---|
| Laptop ports | USB, Network, Power, Monitor, Mouse |
| Charge Terminal | |
| Offload Terminal | |
| Weather Terminal | |
| ./record_weather | |

| UPDATE VEHICLE | |
|---|---|
| **VEHICLE / CHARGER COMPUTER** | |
| Check for new software release | Release Version Status |
| cd /heavisoft | |
| git fetch && git checkout ######## | (provided release) |
| git status | "Nothing added to commit" |
| ./check_serial | Verify Serial # |
| cd /heavisoft/ground_control/operator | |
| ./deploy_controller | (serial number) |
| PFD Update | (see process) |
| Restart Vehicle | |
| Service Request to update vehicle software | (Odoo) |
| Update vehicle page to current software | (Odoo) |

**Heavisde 2, Block 2 - Uncrewed**

**NORMAL PROCEDURES** **8/16/2021**

| FIRST FLIGHT OF DAY | |
|---|---|
| FLIGHT RISK STATUS | CHECKED |
| AIRCRAFT ASSEMBLY checklist | COMPLETE |
| PREFLIGHT checklist | COMPLETE |
| UPDATE VEHICLE checklist | COMPLETE |
| GCS Bring-Up checklist | COMPLETE |
| MORNING BRIEFING checklist | COMPLETE |
| NOTIFY NPUASTS | START OF DAY - SLACK |
| DAILY SUMMARY & FLIGHT CARDS | STARTED |

| LV POWER UP | |
|---|---|
| TAIL SWITCHES | SAFE |
| RADIO & LIGHT SWITCHES | OFF |
| LV SWITCHES (wait for individual LV batts) | ON |
| GROUND POWER SWITCHES | OFF |
| GROUND POWER CABLE | CLEAN AND CONNECT |
| GROUND POWER SWITCHES | ON (fans) |

| AVIONICS POWER UP | |
|---|---|
| ./CHECK_SERIAL | VERIFY SN# |
| ./CLEAR_PERSISTENT_STATE | CLEARED (1st flight only) |
| ./CLEAR_LOGS | CLEARED (1st flight only) |

| | |
|---|---|
| RC POWER | ON |
| RC MODEL | HVSD |
| ./START_CONTROLLER | STARTED |
| RESET MOTORS | RESET |
| RESET BATTERY ERRORS | RESET |
| LLH REF | ZEROED |
| LASER AGL | ZEROED |
| ACK VOTER RX ERRORS | IF NEEDED |
| RESET AMP-HOURS | RESET (after full charge only) |
| REFRESH & TAKE UPSTREAM | REFRESHED |
| RC MODE | CYCLE |

| FLIGHT CONTROLS | |
|---|---|
| RC TILT | ENABLED |
| RC MODE | VERT |
| FAKE AIRSPEED | ENABLED |
| RC CONTROLS PITCH, ROLL, YAW | CHECK, VERIFIED |
| FAKE AIRSPEED | DISABLED |
| RC CONTROLS | CHECK, NO RESPONSE |
| RC MODE | REVERT |
| RC CONTROLS TILT CYCLE | CHECK, VERIFIED |

| AIRCRAFT ARMING | |
|---|---|
| GROUND POWER SWITCHES | OFF |
| LV BATTERY REMAINING | Min LV≥22.8v |
| NAV LIGHTS (cockpit GoPro) | ON |
| RADIOS | OFF |
| CANOPY BALLAST, PINS, WINDOW, and HATCH | SECURED |
| PITOT COVER | REMOVED |
| GROUND POWER | REMOVED & STOWED |
| AIRCRAFT CAMERAS & DAQ | RECORDING |
| RC HV SWITCH | DISABLED |
| RC MOTOR SWITCH | DISABLED |
| TAIL SWITCHES | FLY |
| AREA | CLEAR |
| RC HV SWITCH | ENABLED |
| ANNUNCIATORS | ALL GREEN |
| ANNUNCIATOR LOG | CLEARED |

| BEFORE TAKEOFF | |
|---|---|
| FLIGHT PLAN | DISCUSSED |
| FLIGHT AUTOMATED PATH | COMMITED (view ac 0) |
| FLIGHT CARD (Log# Flight#, Wind, Temp, D.Altitude) | WX RECORDING |
| BATTERY REMAINING & TEMP | FOR TRANSITION |
| LV | SoC 22.8 V min |
| HV | Temp 30-50 C |
| | SoC Puma 350 kg >4.0 Ah |
| | SoC Puma 400 kg >4.5 Ah |
| RC | 50% V min |
| AIRCRAFT HEADING | VERIFIED |
| RC MANUAL/AUGMENTED / AUTO | CONFIRM RC & GCS |
| RC SPEED SWITCH | CRUISE |
| RC REVERT / VERT (DEFAULT/CUSTOM) | CONFIRM RC & GCS |
| RC TILT | HOVER |
| RC DECK ANGLE TRIM | DETENT |
| RC L2 TRIM | DETENT |
| RC INSTRUCTOR SWITCH | AS NEEDED |
| GROUND CAMERA | RECORDING, SN# LOG# FLT# |
| AIRSPEED AUDIO | AS NEEDED |

| MANUAL/AUGMENTED TAKE OFF | |
|---|---|
| RC MOTOR SWITCH | ENABLED |
| SPIN CHECK - STAND BY | STANDING BY |
| READY FOR MANUAL TAKEOFF | TAKING OFF |

| AUTO TAKE OFF | |
|---|---|
| RC MOTOR SWITCH | ENABLED |
| READY FOR AUTO TAKEOFF | YOUR AIRCRAFT |
| MY AIRCRAFT - TAKING OFF | ("CLEAR FOR TAKEOFF" PRESSED) |

| CLIMB (on auto "go around" / departure) | AUTO/AUGMENTED |
|---|---|
| RC TILT | CRUISE @ 25 m/s |
| ON PATH (ENTERING HOLDING PATH) | |
| LAND AS SOON AS PRACTICABLE | SoC Puma 350 kg <3.2 Ah |
| | SoC Puma 400 kg <3.6 Ah |

| BEFORE LANDING (on auto / approach path) | AUTO/AUGMENTED |
|---|---|
| ON APPROACH (ENTERING APPROACH PATH) | |
| RC MANUAL/AUGMENTED / AUTO | CONFIRM RC & GCS |
| RC SPEED SWITCH | AS NEEDED |
| RC REVERT / VERT (DEFAULT/CUSTOM) | CONFIRM RC & GCS |
| RC TILT | HOVER @ 25 m/s |
| AUTOLAND (AT AUTO FS DOT) | |
| AUTOMATED FLIGHT | TURNED OFF |

| POST FLIGHT | |
|---|---|
| RC MOTOR SWITCH | DISABLED |
| RC MANUAL | CONFIRM RC & GCS |
| GROUND CAMERAS | STOP RECORDING |
| FLIGHT CARD NOTES | SAVED |
| *RETURN TO **BEFORE TAKEOFF** | AS NECESSARY |
| RC HV SWITCH | DISABLED, COMING DOWN |
| HV BUS | <50V |
| TAIL SWITCHES | SAFE |
| AIRCRAFT CAMERAS - DAQ | STOPPED |
| LIGHTS & RADIO (cockpit GoPro) | OFF |
| ./STOP_CONTROLLER | STOPPED |
| RC POWER | OFF |

| CHARGE VEHICLE | |
|---|---|
| CHARGING & PROCESSING checklist | COMPLETE |

| SHUTDOWN | |
|---|---|
| GROUND POWER SWITCHES | OFF |
| GROUND POWER AND ETHERNET CABLES | REMOVED AND STOWED |
| CABLE BOX | CLOSED |
| ./SHUTDOWN_TIGERBOARD | PROCESS STARTED |
| LV SWITCHES | OFF |

**Heavisde 2, Block 2 - Uncrewed**

## INFLIGHT EMERGENCY 4/19/2021

| Definitions | |
|---|---|
| **Land Immediately** | Execute landing without delay |
| **Land as Soon as Possible** | Land at first safe area |
| **Land as Soon as Practicable** | Extended flight not recommended |
| | Land at first available test site |
| **Ditching Procedure** | Point vehicle away from personnel |
| | Transition to hover configuration |
| | Prior to impact, turn off motors and HV (0.5 seconds) |

| In-Flight Fire | Land as soon as possible |
|---|---|

| Single Motor Failure | Land as soon as practicable |
|---|---|
| | Reduce airspeed to less than 45 m/s |
| | Land normally, max crosswind of 5 kts |

| Multi-Motor Failure | Land as soon as practicable |
|---|---|
| | Reduce airspeed to less than 45 m/s |
| | Minimum controllable airspeed 15 m/s |
| | Land with maximum crosswind of 5 kts |

| Single Tilt Failure | Land as soon as practicable |
|---|---|
| | Reduce airspeed to less than 45 m/s |
| | Land with maximum crosswind of 5 kts |

| GPS Signal Lost | Switch to manual control |
|---|---|
| | Land as soon as practicable |

| GCS Lost Link | Be ready for Manual flight |
|---|---|
| | Maintain sight of aircraft |
| | Confirm lost link connection |
| | Switch to manual flight |
| | Land as soon as practicable |

| RC Lost Link | Check RC power and transmitter module |
|---|---|
| Expected Behavior - Auto | Enter holding path, then |
| | Enter approach path, then |
| | Autoland |
| | Else, land in place after four minutes |
| Expected Behavior - Manual | Three seconds lost link, then |
| | Auto-hover and land in place |
| Attempt to reconnect | Replace TX module into fully charged RC |
| **Force RC Lost Link** | **(Follows RC Lost Link Behavior)** |
| ./force_rc_lost | terminate |

| HV Battery Failure | Land as soon as practicable |
|---|---|

| HVLV or LV Distro Failure | Land as soon as practicable |
|---|---|
| | May have up to 20 minutes of flight |

| LV Battery Failure | Land as soon as practicable |
|---|---|
| | Prepare for land as soon as possible |

| Degraded Flight Controls | Switch to manual flight |
|---|---|
| | Evaluate controlability of aircraft |
| Controllable: | Land as soon as possible |
| Uncontrollable: | Initiate ditching procedure |

| Single Control Surface Failure | Land as soon as practical |
|---|---|
| | Reduce airspeed to less than 45 m/s |

| Multiple Control Surface Failure | Immediately transition to hover configuration |
|---|---|
| Controllable: | Land as soon as possible |
| Uncontrollable: | Initiate ditching procedure |

| Loss of Laser AGL | Land as soon as practicable in manual mode |
|---|---|

## Downed Aircraft 6/2/2021

| Roles | |
|---|---|
| GCS Operator | Coordinator, 911, data preservation |
| RC Pilot | Fireskid passenger, fireskid operator |
| VO | Fireskid driver. PPE gear, radios |
| Walkie Talkies | 438.5 Mhz |

| Fire | |
|---|---|
| Scope | Assess, evacuate if necessary |
| Cal Fire | Notify via 911 if necessary |
| Data | GCS operator |

| No Fire | |
|---|---|
| GCS | Monitor and coordinate |
| RC Motor Switch | Disabled |
| RC High Voltage Switch | Disabled |

| HV State Unknown OR Battery Damage Likely | |
|---|---|
| HV Protective Equipment | Donned |
| LV Batteries | Disconnected |
| HV Batteries | Disconnected |
| HV Ports | Measured (multimeter) |
| HV Batteries | Removed |
| HV Batteries Moved | Place on asphalt pad |

| Vehicle Disassembly | |
|---|---|
| Vehicle | Secured |
| NTSB | Notified (as required) |
| Data | Preserved |

| Resources | |
|---|---|
| Full EAP | French Ranch Emergency Action Plan |
| Fireskid Operation | Fireskid Quick Operation Guide |
| Shortened EAP | Emergency Action Plan Summary |
| Emergency Phone Tree | Emergency Response Coordinator: |
| | Robert True: (408) 908-8771 |
| | Backup: |
| | Guillaume Beauchamp: (514) 776-6672 |
| | Chuck Taylor: (949) 294-4928 |

**Onsite Aircraft Assembly** **03/19/2021**

| PRE-ASSEMBLY | |
|---|---|
| Tail Switches | Safe |
| LV Batteries | Installed & connected |
| HV Batteries | Installed & connected |
| Avionics Bay | If able: Inspect installed equipment & connections |
| | If required: See "Parachute Tub Relocation" |

| WING AND PARACHUTE ATTACHMENT | |
|---|---|
| Parachute Tub (pre-installed) | Inspect (update coming from parachute team) |
| Wing | Move into position |
| Parachute Harness | WIth wing elevated, connect risers to wing lugs. |
| | Stow excess harness material in foward part of tub |
| | Secure risers with small zipties on top of wing |
| Sensor/Servo/Power Plugs | Connect 4x (fore) |
| | Secure wiring to standoff with zip tie |
| HV Plug | Connect 1x (aft) |
| Xsens Modules | Connect 3x (top) |
| | Secure wiring to standoff with zip tie |
| Wing Bolts | <SN7 Secure 28 ft-lbs, 38 Nm |
| | >SN8 Secure 35.5 ft-lbs, 48.1 Nm Front<br>31.1 ft-lbs, 42.2 Nm Rear |
| Parachute Pull Handle | Route cabling under parachute risers |
| | Mount bracket to firewall using 4 screws, hand tight |

| WING HATCH | |
|---|---|
| Parachute Rocket | Remove Pin |
| Wing hatch | Install & Secure |

| HORIZONTAL STABILZER EXTENSIONS | |
|---|---|
| Install | Secure 19 in-lbs, 2.1 Nm |

| Parachute Tub Relocation (for Avionics Bay inspection only) | |
|---|---|
| Parachute Rocket | Install Pin |
| Remove Mounting Screws | 6x |
| Can this just be lifted (and twisted or...) out of the way now? Or how far does this need to come apart? | |
| | |

# Checklists - Expanded, H2.2 - Uncrewed

The expanded checklists are explanations of the normal checklists used in flight operations. These documents follow the same steps as the normal checklists, but in more detail. The expanded checklist is used for training and as a supplement to the normal checklists. It is not meant to be referred to in flight.

# Emergency Procedures

## Heaviside Block 2 (Uncrewed)
## Emergency Procedures Expanded Checklist

Note: Items in **bold** shall be memorized and performed without reference to a checklist.

## Definitions

- **Land Immediately:** Execute a landing without delay. Depending on the nature of the emergency, the pilot in command may elect to land in trees or ditch in water.
- **Land as soon as Possible:** Land at the first site at which a safe landing can be made.
- **Land as soon as Practicable:** Extended flight is not recommended. The landing site and duration of the flight are at the discretion of the pilot in command. Usually, this would mean landing at the next airport if enroute, or at the landing pad at a test site.
- **Ditching Procedure:** Orient the aircraft away from personnel. Begin an immediate transition to a hover and initiate a descent. Prior to ground impact, disable the motors and HV system. (If capable, disable HV system a half second (0.5 sec) before impact due to debounce timing of switch)
- **Flight Termination:** Range safety feature forcing the aircraft into a spin with motors and HV disabled. Used as the last line of defense with an uncontrollable aircraft. https://kitty-hawk.atlassian.net/wiki/spaces/FT/pages/1554907145/Aircraft+Control+and+Logic#Flight-Termination
- **Lost Link Contingency:** A description of the automatic lost link continency response can be found in https://kitty-hawk.atlassian.net/wiki/spaces/FT/pages/1554907145/Aircraft+Control+and+Logic#Lost-Link

## Emergency Procedures

### In-Flight Fire

- **Land as soon as possible.**

### Single Motor Failure

- **Land as soon as practicable.**
- **Reduce airspeed below 45 m/s IAS**.

### Multi-Motor Failure

- **Land as soon as practicable.**
- **Reduce airspeed below 45 m/s IAS**.
- **Maintain at or above the minimum controllable airspeed, 20 m/s IAS, throughout the approach and landing.**
    - Vmca may vary based on the nature and extent of the failure. Consider ditching or flight termination.

### Single Tilt Actuator Failure

- **Land as soon as practicable.**
- **Reduce airspeed below 45 m/s IAS.**

### GPS Signal Lost

**Beyond Visual Line of Sight**

- **Switch to ACP**
- **Use heading commands to return to VLOS**

**Visual Line of Sight**

- **Switch to manual control.**
- **Land as soon as practicable.**

Return to GPS based flight modes is not approved

### Ground Control Station (GCS) Lost Link

If in External Pilot control:

- **Land as soon as practicable**

If in Remote Pilot control:

- ***Lost Link Contingency will initiate after 10 seconds***
- *Land as soon as practicable*
- *Allow aircraft to complete lost link flight plan*

If required and within VLOS

- EP take control in manual to deviate from lost link path and land

### Remote Control (RC) Lost Link

If in External Pilot Control

- ***Lost Link Contingency will initiate after 3 seconds***
- **Check the power on the RC controller.**
- **As required: Transfer R9M to back up X10s.**
- **As required: Use FrSky handoff procedure for power up**
- **Land as soon as practicable**

### HV Battery Failure

- **Land as soon as practicable.**

### Low Voltage Distribution Bus (LV Distro) or High Voltage to Low Voltage Converter (HVLV) Failure

- **Land as soon as practicable.**

Note: If the aircraft loses the low voltage distribution bus or is no longer generating 24V power from the high-voltage batteries, flight time is limited to approximately 20 minutes before critical flight systems become inoperative as low-voltage batteries are exhausted.

### LV Battery Failure

- **Land as soon as practicable.**

Note: With a failure of either or both low voltage batteries, the aircraft can operate normally because the HVLV will provide the 24V power required. However, any subsequent failure of the HVLV would result in either a “land as soon as possible” emergency (if only one LV battery failed) or a likely-catastrophic loss of flight systems (if both LV batteries had failed).

### Control Surface Failure

- Reduce airspeed below 45 m/s IAS.
- Land as soon as practicable.

### Degraded Flight Controls

If beyond visual line of sight:

- Land as soon as possible
- Consider Flight Termination

If within visual line of sight:

- Switch aircraft to manual mode.
- Evaluate the controllability of the aircraft.
- If the aircraft is controllable:
    - Land as soon as possible.
- If the aircraft is uncontrollable:
    - Initiate ditching procedure or flight termination

### Force RC Lost Link

- Remove module from X10s
- if required, **./**force_rc_lost
    - enter “terminate” to confirm command

Note: Used for fly away mitigation. This command termites the RC process on the flight computer. This command is not reversible and requires a flight computer restart on ground to recover.

### Flight Termination

- Automatically triggers if all links are lost in addition to GPS

or

- Select and confirm Flight Termination in GCS
- Complete downed aircraft procedures

Note: Used for fly away mitigation. Flight Termination cannot be cancelled. Requires a flight computer restart on ground to recover.

# Preflight

## Preflight Expanded Procedures

Preflight is usually completed while the vehicle is turned off. This allows you to be able to move the flaps by hand and examine tight areas without moving parts or wires being active.

### Aircraft Maintenance Logs

**Check Vehicle Maintenance Status - Odoo: Vehicles**

Look up in Odoo the vehicle being preflighted. Check that there are no known issues that would ground this vehicle.

### Aircraft Weight & Balance

Verify the aircraft is within limits. Heaviside 2 W&B

### RC Controller

**Antenna - Secure**

Check that the transmitter module and the antenna are securely attached to the RC Controller

**Switches, Sliders, Sticks - Condition**

Check the condition and the free movement of all the moving parts of the controller. Ensure that the tilt slider is fully in hover position and the rest of the trims and sliders are centered.

**Power - On**

Make sure the unit is functional

**Battery Level - Fully Charged**

Check that the unit is fully charged. The battery life is not extremely long, a low battery might not last long enough to complete an extended flight regimen.

**RF Power - 100mW**

Check that the power output is set to 100mW to have the best balance of range and battery life.

**Power - Off**

Turn the controller off to preserve battery level until ready for the next flight.

### Fuselage

**Carbon Fiber Body - No Damage**

Look for indications of damage. Discoloration, cracks, deformations. Seams are completely bonded. Vinyl wrapped surfaces may have discolorations, tears, rough appearance, or bubbles

**Charge Port - Clear**

Inspect the charge port door, housing, and connections for condition and debris. Clean out any foreign matter from the area using non-conductive tools.

**Battery Vent - Clear**

Inspect the battery vent under the belly of the aircraft for foreign matter. Clean out this area, avoid pushing the material further into the vent.

**AGL Sensor - Clean**

Inspect the Laser AGL sensor under the belly of the aircraft. Clean the lenses with compressed air then a microfiber cloth. Take care not to scratch the lenses.

**Pitot Blades - Clear**

Inspect the three pitot blades on the underside of the belly. They should be securely attached to the fuselage and the holes are completely open. Take care not to loosen the rivets or push material into the holes.

**Landing Gear - No Damage**

Inspect the landing gear for damage. Check tire condition. Carbon seams and attachment points are bonded.

**NACA Duct - Clear**

Inspect the air intake for cooling the internal systems. Clean out this area, avoid pushing the material further into the duct.

## Canard

**Carbon Fiber - No Damage**

Look for indications of damage. Discoloration, cracks, deformations. Seams are completely bonded. Vinyl wrapped surfaces may have discolorations, tears, rough appearance, or bubbles.

**Pylons - Typical Inspection***

See Pylon/Motor Typical Inspection section

## Wing

**Carbon Fiber - No Damage**

Look for indications of damage. Discoloration, cracks, deformations. Seams are completely bonded. Vinyl wrapped surfaces may have discolorations, tears, rough appearance, or bubbles.

**Pylons - Typical Inspection***

See Pylon/Motor Typical Inspection section

**Aileron Flaps - No Damage, Free Movement**

Inspect for damage or deformations. Manually move with little applied force, careful not to overextend. Movement should be smooth with no grinding noise. Approx 1/8" play in linkage.

**Navigation Lights**

Inspect for damage, cracks or deformations. If vehicle is powered up, turn on lights to confirm operation.

**Hatch Panels - Closed**

Inspect that the hatch panels are fully closed. Refit bulging covers and replace worn or loose tape.

**Avionics Hatch - Secure**

Various attachment methods and taping techniques. Hatch should be securely in place with no damage. May need to check all securements from different sides of the aircraft.

## Tail

**Carbon Fiber - No Damage**

Look for indications of damage. Discoloration, cracks, deformations. Seams are completely bonded. Vinyl wrapped surfaces may have discolorations, tears, rough appearance, or bubbles.

**Transponder Antenna - Secure**

Inspect the small wire antenna on the underside of the tail.

**Microhard Antenna - Secure**

Inspect the small blade antenna on the underside of the tail. Check that the metal grounding plane is intact.

**VHF Antenna - Secure**

Inspect the long angled wire antenna on the top side of the tail.

**Horizontal Stabilizer Extensions - Secure (if present)**

Alignment is correct and bolt torque stripe is not broken, torqued to 19 in-lbs (2.1 Nm).

## Empennage

**Carbon Fiber - No Damage**

Look for indications of damage. Discoloration, cracks, deformations. Seams are completely bonded. Vinyl wrapped surfaces may have discolorations, tears, rough appearance, or bubbles.

**Hatch Panels - Closed**

Inspect that the hatch panels are fully closed. Refit bulging covers and replace worn or loose tape.

**Elevator Flaps - No Damage, Free Movement**

Inspect for damage or deformations. Manually move with little applied force, careful not to overextend. Movement should be smooth with no grinding noise. Approx 1/8" play in linkage.

**Rudder Flaps - No Damage, Free Movement**

Inspect for damage or deformations. Manually move with little applied force, careful not to overextend. Movement should be smooth with no grinding noise. Approx 1/8" play in linkage.

**Tail Switches - Visual Inspection Only, No Damage**

Visual inspection only for damage - moving the switch to “ON” will power the High Voltage system if avionics are on.

**GoPro Camera - Secure**

GoPro camera is installed, charged and securely attached.

**SD Card - Format**

Format the SD Card in the GoPro to ensure enough free space to record the day’s flights.

## Canopy

**Pilot Interface and Assemblies - Inspect**

Inspect interface and assembles for looseness, cracks, or other damage. Primarily due to vibrations, or other unknown effects to this new equipment.

**Logging Tablet - Inspect**

Inspect interface and assembles for looseness, cracks, or other damage. Primarily due to vibrations, or other unknown effects to this new equipment.

**LV Switches - Visual Inspection**

Visual inspection for damage. Moving the switch to “ON” position with power the avionics system.

**LV Batteries - Secure (if installed)**

Secure in place, connections secure, no damage

**Ballast - Secure**

Secure in place. Installed per test card requirements. Weight and Balance limit calculations performed.

**GoPro Camera - Secure (if installed)**

GoPro camera is installed, charged and securely attached.

**SD Card - Format**

Format the SD Card in the GoPro to ensure enough free space to record the day’s flights.

**Parachute Handle - Secure (Pin Installation)**

Handle is securely attached and pin is installed or removed as required.

**Latch and Hinges - No Damage**

No damage. Operates without binding or excess movement.

## Pylon / Motor Inspection (Typical)

**Naca Duct - Clear**

Air intake for cooling motor controller and motors. Inspect intake area for blockage.

**Hatch Cover - Secure, Taped, and screws tight.**

Cover on the outboard side of the pylon. Removing provides access to the motor controller and tilt actuator. Inspect tape and ensure securely attached. Screws are tight and have not backed out.

**Tilt Linear Actuator - No Binding**

Only the Rod of the Tilt Actuator is visible while the Hatch Cover is installed. Check for grease on the rod, indicating a compromised wiper. Check attachment to motor mount horn. There should be no play at horn attachment.

**Tilt Linear Actuator Connection - Torque Stripe**

Check the torque stripe is not broken, indicating loosening of the linear actuator connection point.

**Motor Leads & Grounding Wire - No Damage**

Three motor lead wires are bundled into one group by heat shrink or nylon web. The grounding wire is attached on the outside of the bundle with wax string or zip ties. Inspect for damaged insulation, heatshrink, or web. Grounding wire is securely attached to the motor mount.

**Motor Mounts - Tight**

All the motor mounts are tight and torque stripe, if present, is not broken.

**Motor Hinge - Inspect**

Perform visual inspection detailed in this document.

**Tilt Sensor - Clean, Plugged in.**

Magnet securely attached to hinge. Sensor securely plugged in and approx 1/8” from magnet, which is the same width as bracket.

**Screen - Clean**

Screen not clogged or excessively dirty, free from debris, deformation or tears.

**Propeller - Smooth, No Excess Movement**

Leading Edge Tape: No hole, bubble, or flap in the tape larger than 0.5cm (in any direction), and/or accumulation of holes in the tape totaling 2 cm, when holes are measured along their longest dimension

Leading Edge Bare: No cracking, delamination, or splinters forming.

Surface: No deformations

Pitch Change: In hover tilt position, gently twist two props simultaneously and release to original position. Movement should be smooth with moderate resistance.

Rigidity: Check for only a small amount of lateral movement.

Spin: Check the props spin smoothly, and decelerate as expected.

**Spinner - No Damage**

Securely taped. No damage.

## Weekly Inspections (if required)

### Avionics Hatch Internal Inspections

**Wire Harnesses - Secure**

Check all the connections and wires for damage and that they are securely attached.

**Wing and Battery Bolts - Torque Stripe**

All the mounting bolts are tight and the torque stripe, if present, is not broken.
SN7 and earlier aircraft wing bolts torqued to 28 ft-lbs (38 Nm).
SN8 and later aircraft wing bolts torqued to 35.5 ft-lbs (48.1 Nm) front and 31.1 ft-lbs (42.2 Nm) rear.

**Parachute Tub - Inspections**

Perform visual inspections on the following items: Parachute bag, Harnesses, Rocket, Pin

**Internal FOD - Removed**

Inspect inside the fuselage for foreign objects and debris. Clean as necessary.

# GCS Bring Up

## GCS Bring-Up Expanded Procedures

### Equipment Setup

#### UPS - On and Charged

Universal power supply. Check that the front of the unit is displaying charge state. Only plug laptops into the power strip with the tape blocking off most of the plugs. This strip is directly plugged into the UPS and should only be used for critical equipment.

#### Crew Radio Base Station - Setup

Put in a fresh battery. Turn the volume button to full. Press the Conference button on the front so the red light illuminates. Attach station to pilot stand on one of the securing ratchets.

#### Airspeed Audio Box - Setup on Pilot Stand

Set up airspeed audio callout box on connex. Test audio level with GCS.

#### Microhard Antenna - Inspect

Inspect the Microhard antenna for debris. Since the weather station is also located on the same mast, ensure it is facing north.

#### Ground Camera

Set up camera on camera pad. Hook up tracking computer and launch tracking software.

- (More info needed here on this set up - in development.)

### GCS Computer

#### Launch_GCS

Launch the GCS interface using the ./launch_gcs command. This command runs both the ./launch_guis and ./launch_datalink in order.

Plot the default plots if necessary.

#### Setup Microhard to Communicate with Vehicle (before flights)

Open Chrome web browser. In the address bar type “192.168.254.101”. This is the Mircohard for the ground station. Login is “admin” and the password is “piloterror”. Go to Wireless  RF and set the appropriate settings: Network and Data Link

Verify that the settings are correct on the “Status” page.

Alternatively:

./configure_microhard and enter the SN# of the desired vehicle.

### GCS or Operator Computer

### NPUASTS

#### Start Heaviside Daily Summary

From: https://docs.google.com/spreadsheets/d/1DuvmPwB4qSBKG6_8nCpCV_1k0Mf4vmr97xug0_Y7ecE/edit#gid=0

Right click on “Template” and “Duplicate”. Rename the new tab to the date as “YYYYMMDD”. Fill out the flight ID and Morning METAR. Currently the METAR time is hardcoded so if it does not retrieve information from the website it will need to be done manually. If information is successfully retrieved copy the box with “ctrl-c” and paste it into the same box with “ctrl-shift-v”. This removes the webhook and stops the page from updating when reloaded. For other boxes look at previous days for examples but keep things brief.

### Flight Cards

**Start new card**

From:

https://kitty-hawk.atlassian.net/browse/FLT-296

From the template, “Clone” and then fill in the appropriate information. Refer to previous cards for examples.

- Rename card in “YYYMMDD H#-###” format
- Move to “In Progress”
- Change aircraft in drop down list
- Add vehicle W&B from W&B Calculator based on currently installed ballast (Verify ballast configuration. Do not rely on the current state of the sheet)
- Add software version in x.x.x format. There should not be an rc# for software on test ready vehicle.
- Change “Assignee” “Reporter” and “Observer” to current crew
- Un-link clone to original template

## Charging and Processing Computer Setup

**Terminals Setup**

Plug in the required cables

- Power, Network, Weather Station USB

Set up terminals to be ready for workflow - /heavisoft/gcs/operator

- Charge Terminal
- Offload Terminal
- Weather Terminal
    - Start ./record_weather process

## Update Vehicle

**Check for new software release - Software Release Page**

Navigate to the Jira software release page for the newest software branch.

**Git fetch && git checkout ########## - (provided release)**

In a terminal navigate to /heavisoft. Type the git command to load the current release on to the computer.

**Git status - "Nothing added to commit"**

In the terminal type git status. it should respond with “Nothing added to commit” and review to make sure there is nothing local that could affect the deployment.

**Check Serial - Verify Serial #**

Ensure that you are connected to the vehicle that you want to deploy to.

**./deploy_controller - (serial number)**

In a terminal navigate to /heavisoft/gcs/operator, and type the deploy command. It will ask for what serial number you want to deploy on to. It will then deploy to that vehicle. This process takes several minutes.

Note: This process will report a failure if the wrong version of Petalinux, the operating system, is present. To correct the issue, execute the deploy_petalinux script, power cycle the aircraft, then deploy_controller.

**PFD Update**

Updates the PFD to current software release. Follow steps outlined on the software confluence here.

**Restart Vehicle**

The vehicle must be restarted for the changes to take effect.

Restarting the vehicle also ensures no state from the previous software version or update process carries over.

### Service Request to update vehicle

Create a Service Request to track the software update in Odoo.

### Update vehicle information page

Edit the vehicle information page to reflect the software update in Odoo.

# Normal Procedures

## Normal Procedures Expanded Checklist

- All “./”commands all located in /heavisoft/gcs/operator (or desktop shortcuts)

### Flight Risk Status

**Flight Risk Status - Checked**

Check the Flight Risk Status confluence page for any grounding issues or other flight risks.

### LV POWER UP

**Tail Switches - Safe**

Prevents the HV battery contactors from closing which keeps the vehicle in a low voltage state.

**Radio & Light Switches - Off**

Set to the OFF position. This prevents overloading the pre-charge circuit on the LV batteries during power up.

**LV Switches - On**

Set to the ON position. This powers up the flight controller (but does not run it) and sub-systems. The vehicle can now be connected via the Microhard wifi or direct ethernet connection.

**Ground Power Switches - Off**

Check the switches are in the off position so the connections are not live.

**Ground Power Cable - Clean and Connect**

Plug the vehicle into Ground Power before turning switches on.

**Ground Power - On**

Plugged in and in ON position. This powers the vehicle from the external power source to conserve LV battery charge before and between flights. The small power supply in connex should be powered on with output engaged and set to 450-530V.

### AVIONICS POWER UP

**./check_serial**

Verify the vehicle you are logged in to is the vehicle you are intending to use.

**./clear_persistent_state**

Clearing the “Persistent State” clears battery data from previous flights which sets the batteries to their serial number specific default maximum charge state. The flight number is also reset back to Zero. This should only be run before the first flight of the day with fully charged batteries. (Generally on the first power up of the day)

**./clear_logs**

Clears all the previous flight data off the vehicle’s memory. This is typically only run before the first flight of the day. Clearing the logs between sequential flights will break the daily automatic log processing system due to duplicate folder names.

**RC Power - ON**

Set to the ON position. Turning on the RC power before starting the controller in the next step ensures that the Controller is receiving valid control commands.

**RC Model - HVSD**

Confirm the model on the RC is set to Heaviside. There may be other models on the RC as the instructor or custom set-ups for unique testing needs which may affect control.

**./start_controller**

Starts the flight controller application and associate device drivers on the flight computer after which telemetry information will be displayed on the GCS.

To set the heading of the aircraft add:

```
-h 0-360
```

To set the gyro bias add:

```
-z 0-60
```

The numerical values between 0 and 360; & 0 and 60 will vary from flight to flight depending on the actual position of the aircraft.

**Reset Motors**

Press the “reset motors” button on the “ground_control 2000” resets panel. The motors need to be reset due to a comms timeout before the controller was running.

**Reset Battery Errors**

Press the “reset battery errors” button on the “ground_control 2000” “resets” panel. The batteries need to be reset due to a comms timeout before the controller was running..

**GNSS FIX = TRUE**

Open the Xsense annunciator tab and verify that the GNSS Fix flag is green and reads “true” before continuing with the checklist. If this is false, it is likely that the aircraft will need to be power cycled before proceeding.

**LLH Ref - Zeroed**

The control system is written in a North-East-Down cartesian frame.  Zero LLH Ref sets the origin of this frame.

**Laser AGL - Zeroed**

Clicking this button will set the current AGL sensor data reference to zero.

**Ack Voter Rx Errors - If Needed**

Clicking this button will set any red voter errors to puke green. The vehicle sometimes will start with battery voter errors as a known bug.

**Reset Amp-Hours**

The state of charge is tracked by the flight computer and is not automatically reset after a charge. This button will reset the state of charge to 100% and should only be done after a full charge. **Partial charging is not supported.**

**Refresh & Take Upstream**

Press the “refresh” button on the “set-ho-matic 2000” several times (due to timing in system).

Press the “take upstream” button on the “set-ho-matic 2000” several times (due to timing in system). This captures the current settings from the vehicle.

**RC Mode - Cycle**

Cycle the RC Mode to Automated and back to Manual. The flight controller starts in “Lost Link” mode and needs to be cycled to gain control from the RC.

## Flight Controls

**RC Tilt - Enable**

Enables tilt for grounds checks and flight. Tilt commands are ignored until it is enabled.

**RC Mode - Vert**

Change the mode of the RC to “Vert” to allow the custom settings from the “set-ho-matic 2000” app to be utilized.

**Fake Airspeed - Enabled**

Enable “Fake Airspeed” to allow testing of the flight control surfaces. “Fake Airspeed” is found in the “set-ho-matic 2000” app under: “signals> controller> attitude> airspeedScheduling> fakeAirspeed”. Change “use fake airspeed” from “False” to “True”. Press the “commit” button to activate the change on the flight controller. A red annunciator will appear on the GCS that fake airspeed has been enabled.

**RC Controls Check - Pitch, Roll, Yaw**

Check that control inputs form the RC are being translated to the vehicle control surfaces. Only the commanded axis needs be correct. Listen for unusual noises. Check that the proper control surface and motor commands are displayed in the GCS.

- Pitch: Pitch Up command should make the elevator flaps move up. Pitch down will make them move down.
- Roll: Roll right will make the Starboard aileron flaps go up and the port aileron flaps go down. Roll left - port up, starboard down.
- Yaw: Yaw right will make the rudder flaps go right, and yaw left the rudder flaps will move left.

*If operating with dual FrSky’s (handoff/buddy box) both RC controls should be verified during this step.*

**Fake Airspeed - Disabled**

Disable “Fake Airspeed” to stop the testing of the flight control surfaces: “Fake Airspeed” is found in the “set-ho-matic 2000” app under: “signals> controller> attitude> airspeedScheduling> fakeAirspeed”. Change “use fake airspeed” from “True” to “False”. Press the “commit” button to activate the change on the flight controller. The red Fake Airspeed annunciator will turn green on the GCS.

**RC Controls Check - No Response**

Check the control surfaces do not move with Fake Airspeed turned off. The control surfaces should be centered.

**RC Mode - Revert**

Change the mode of the RC to “Revert” to ignore any custom settings from the “set-ho-matic 2000” app and return all settings to their default values.

**RC Tilt - Cycle**

Slew the tilt actuators from full hover to full cruise and back to full hover. All motors should tilt and stop at approximately the same speed and time. Listen for unusual noises. Check GCS for red annunciators. Visually confirm the motors are moving to their full extents.

*If operating with dual FrSky’s (handoff/buddy box) both RC controls should be verified during this step.*

## AIRCRAFT ARMING

**Ground Power Switches - Off**

Turn off external power to the vehicle at the charge box. Set the Charge switch to OFF. Set the Shore switch to OFF.

**LV Battery Remaining - >22.8v**

Check to make sure the LV batteries are charged and functional. Being on shore power “hides” this information since the bus is held at higher voltage by the HVLV. Minimum of 22.8v to initiate a flight. This is checked on the GCS.

**Nav & Strobe Lights- On**

Confirm PFD is powered up and receiving telemetry. Switch the Navigation and Beacon lights to ON for flight.

**Radios - Off**

Confirm radios are set to OFF.

**Canopy Ballast, Pins, Windows, and Hatch - Secured**

Ensure the canopy pins are secured in the locked position, preventing the canopy from opening in flight.

**Pitot Cover - Removed**

Ensure that the pitot covers are removed.

**Ground Power and Ethernet Cables - Remove and Stow**

Disconnect the cables from the vehicle and stow them in the charge box.

**Aircraft Cameras & DAQ - Recording**

Start recording on the GoPro mounted to the tail of the aircraft, inside the cabin, and/or anywhere else on the aircraft. Start other relevant DAQ systems or instrumentation.

**RC HV Switch - Disabled**

Ensure the RC HV switch is set to disabled as a safety protocol for Tail Switches in next steps.

**RC Motor Switch - Disabled**

Ensure the RC Motor switch is set to disabled as a safety protocol for Tail Switches in next steps.

**Tail Switches - Fly**

Set Tail Switches to “Fly”. There is one switch for each battery. These switches allow the HV battery contactor to close. The vehicle is now ready to be fully powered up, and all personnel should clear the area.

**Area - Clear**

Ensure the Take Off / Landing area is clear of FOD and personnel.

**RC HV Switch - Enable**

This switch enables the HV bus by initiating the precharge sequence.

**Annunciators - All Green**

Check the GCS that all systems are green. Check any red or yellow annunciators and troubleshoot issues.

**Annunciator Log - Clear Log**

Clear the annunciator log to remove events captured during ground checks in preparation for flight.

## BEFORE TAKEOFF

### Flight Plan

Discuss the Flight Plan / Flight Card with the crew. Ensure everyone is aware of the flight conditions and parameters. If the flight will be conducted in manual or autonomous mode. How long the flight will last in terms of amp-hours and how the landing will be performed.

### Flight Automated Path/Geofence

Ensure the required or an acceptable flight path and geofence is loaded into the “plan_o_master 2000” and committed to the flight controller even if only a manual flight will occur. Refer to Automated Flight Planning page for detailed information.

### Flight Card

Update the Flight Card with the current information required by the COA and KH logs. Check Density Altitude is within range. Verify that the weather logs are recording. State log and flight number for test card notes.

### Battery Remaining & Temperature (LV, HV, RC)

Ensure there is enough state of charge (SoC) and thermal margin remaining in the batteries to complete the flight plan.

- LV: Vehicle batteries used primarily for flight computer, tilt and control surfaces. These are charged by HV during normal operations.
- HV: Main vehicle batteries used for motors and to charge LV batteries.
- RC: RC Controller batteries used for Manual/Augmented and Auto flight modes.

### Aircraft Heading

Check if the vehicle’s heading sensor matches the actual heading of the aircraft. Take Off in Auto mode should not be attempted with an actual and/or reported heading offset more than 45 degrees off the auto flight path.

### RC - Manual/Auto Hover/RP Off

Verify between the External Pilot and the GCS display that the Manual/Auto Hover/RP OFF mode is set as desired.

### RC - Revert / Vert (Default/Custom)

Verify between the rPIC and GCS display that the Revert / Vert mode is set as desired.

### RC Tilt - Hover

Ensure RC Tilt is set to “Hover” in preparation for Take Off sequence.

### RC Hover Pitch Trim - Detent

Ensure RC hover pitch trim is in the center detent in preparation for Take Off sequence.

### RC Cruise Pitch Trim - Detent

Ensure RC cruise pitch trim is in the center detent in preparation for Take Off sequence.

### Instructor Switch - As Needed

Ensure the instructor switch is set as appropriate. This enables the instructor FrSky to take over the Student’s FrSky.

### Ground Camera - Recording

External ground camera recording is started and tracking the vehicle. State the SN# and Flight# out loud into the camera.

### Airspeed Audio - As Needed

Check the airspeed speaker is on and announcing the correct airspeed.

## MANUAL/AUTO-HOVER TAKE OFF

**RC Motor Switch - Enabled**

MC switch on the RC is set to Enabled. The motors will immediately start to spin.

**Spin Check - Stand By**

A momentary pause to allow the rPIC to verify all props spinning and everything visually appears to be correct, also the GCS operator to verify all systems are green before take off.

**Ready for Manual Takeoff**

A call out from GCS to rPIC to take control of the vehicle for take off.

Response from rPIC is “Taking Off.”

## AUTO TAKE OFF

**RC Motor Switch - Enabled**

MC switch on the RC is set to Enabled. Motors should not start to spin.

**Ready for Auto Takeoff**

A call out from GCS to rPIC to prepare for the vehicle to automatically take off.

Response from rPIC is “Your Aircraft.”

**My Aircraft - Taking Off**

A call out from GCS that the vehicle will immediately start auto take off.

Click the “clear for take off” button on the “commands” tab of “ground_control 2000” app.

Motors will start to spin, and immediately take off automatically.

## CLIMB - Auto / Augmented

**RC Tilt - Cruise @ 25 m/s**

Call out for the rPIC to transition the tilt to Cruise configuration to match the automated setting of the vehicle.

**Land as Soon as Practicable - SoC**

Monitor the SoC chart and vehicle configuration for the minimum SoC required for battery fault tolerant return flight.

## HAND-OFF PROCEDURE FrSky 1 to FrSky 2

**Confirm RP Mode**

Ensure that the external pilot flight mode switch is set to RP (auto) and the GCS reflects this by showing the aircraft in the “Remote Pilot” flight mode.

**FrSky 1 - Power Off**

The external pilot with the primary RC controller powers off their transmitter. This is FrSky 1, the transmitter that will be positioned near the departure pad.

**Validate FrSky 2 Switches**

Ensure that all switches on FrSky 2 are matched to the FrSky 1 positions.

This is to include:

HV enabled

Motor Switch Enabled

Flight Mode Switch: Manual/Auto Hover/Remote-Pilot

Revert/Vert

Tilt Enabled

Tilt Cruise/Hover

Throttle Stick Centered

## !!THIS IS CRITICAL OR HV AND MOTORS WILL DISABLE IN FLIGHT IF SWITCHES ARE NOT MATCHED PROPERLY BEFORE THE HANDOFF IS EXECUTED!!

**FrSky 2-Power On**

The external pilot at the destination pad holding the FrSky 2 transmitter powers on the RC.

**Switch Warning -Enter to Skip**

The external pilot with the FrSky2 transmitter pushes enter on the RC controller at boot up when the the transmitter prompts to “skip the switch warning”. This is needed because the RC is being powered on with the switches matched to FrSky1 as described in the steps above, and the RC is generally powered on with all of the switches in the “safe” position.

### BEFORE LANDING (on approach path) - Auto / Augmented

**RC Manual / Autohover / Remote Pilot**

Ensure the RC is set to the proper mode for flight plan.

**RC Revert / Vert (Default/Custom)**

Ensure the RC is set to the proper mode for flight plan.

**RC Tilt - Hover @ 25 m/s**

Auto Mode: Monitor “view ac0” and call out “Hover Tilt” at the “Auto Transition Line” or 25 m/s, confirm via tilt indicators. rPIC will mimic commands on the RC.

Augmented Mode: Monitor airspeed and call out “Hover Tilt” at 25 m/s, confirm via tilt indicators. rPIC will mimic commands on the RC.

**Autoland (At auto FS dot)**

Auto Mode: Monitor “view ac0” and at the Auto “FS” dot call out that the vehicle has started the Autoland process once verified in the “ground control 2000” window.

**Automated Flight - Turned Off**

After “Idle - Spindown” the vehicle will turn off the motors, but remain in Auto mode.

### POST FLIGHT

**RC Motor Switch - Disabled**

MC switch on RC is set to Disabled. Motors will stop immediately in manual. Motors should disable automatically in auto after touchdown.

**RC EP Manual - Confirm RC & GCS**

External pilot set sets the flight mode switch on the FrSky to manual mode. Ensure that the vehicle has completely exited the auto state.

**Ground Cameras - Stopped**

External ground camera recording is stopped.

**Flight Card Notes**

Call out to rPIC and GCS Operator to write any notes on the Flight Card.

***Return To Before Takeoff as Necessary**

At this point, if an additional flight on this charge cycle is applicable, return to the BEFORE TAKEOFF section on the checklist to prepare for the next flight.

**RC HV Switch - Disabled, Coming Down**

HV switch on RC is set to Disabled. The HV bus will turn off, opening the contactors, and disabling power to the motors. Confirm the HV bus voltage is decreasing.

**HV Bus - <50v**

Ensure HV Bus voltage is below 50v before approaching the vehicle and proceeding to the next step.

**Tail Switches - Safe**

Set Tail Switches to “Safe”. There is one switch for each battery. These switches prevent the HV battery contactors from closing.

**Aircraft Cameras & DAQ - Stopped**

Stop recording on the GoPro mounted to the tail of the aircraft, inside the cabin, and/or anywhere else on the aircraft and relevant DAQ systems /instrumentation.

**Lights & Radio Switches - Off**

Set Navigation and Beacon light switches to OFF for ground operations. Confirm Radio switch is off.

**./stop_controller**

When the controller is OFF, the vehicle is available for other commands such as charging batteries and processing logs.

**RC Power**

Turn the RC Controller off. Plug it in to the charger if necessary.

## CHARGE VEHICLE

**CHARGING & PROCESSING checklist**

Refer to the Charging and Processing checklists to complete these tasks.

## SHUTDOWN

**Ground Power Switches - Off**

Turn off external power to the vehicle at the charge box. Change the Charge switch to OFF. Change the Shore switch to off.

**Ground Power and Ethernet Cables - Remove and Stow**

Disconnect the cables from the vehicle and stow them in the charge box.

**Cable Box - Closed**

Shut the charger box and place the weight on the lid.

**./shutdown_tigerboard**

This turns off the avionics system on the vehicle. This command must be issued before turning the vehicle completely off in the next step.

**LV Switches - Off**

Set to the OFF position. This powers down the flight controller and sub-systems. The vehicle is now completely powered down.

# Charging and Processing

## Charge and Processing Expanded Procedures

### On Vehicle / Charger

**Post Flight Checklist - Complete**

Ensure that the vehicle is in a state that is safe and ready to start charging.

**Generator - On**

The generator is on. There is sufficient fuel in the generator to complete a charge cycle.

**HV and LV Power Supplies - On**

Both of the power supplies are turned on. These are located inside the conex. Shore power supply set to 450 V.

**Shore Power and Charge Switches - Off**

Check the switches are in the off position so the connections are not live.

**Check other vehicle Network and HV Power not plugged in.**

Only one vehicle can be plugged into the network at a time. This will cause errors and charging or processing to fail

**Shore Power/Charger and Ethernet cables - Clean and Connect**

Check that there is no damage to the cable. Check in particular where the cables enter the connector. Check that there is no debris in either the cable connector or the vehicle connector and the pins are straight. When making the connection, ensure the connection is secure with a tactile notch when the connector is fully seated.

**Shore Power and Charge Switches - On**

Turn the switches to the On position enabling the vehicle to charge and receive shore power. The smaller switch is the Shore Power and the larger switch is the Charger power. Turn the Shore Power switch to ON, and twist the Charger switch to ON.

### Charging / Processing Computer

**./charge_batteries**

Start the ./charge_batteries process. The terminal will show battery statistics while the process is running. When the batteries are fully charged, the process should end automatically.

If necessary use control-c to end the charge process early.

**./offload_Logs**

Start the ./offload_logs process. The terminal will ask for a destination directv. Unless explicitly needing to write to a custom location, accept the default directory which should be the vehicle's SN# and today's date. The terminal will show the offloading progress while the process is running. When the logs have finished transferring, the process should end automatically.

If necessary use control-c to end the offload process early.

**scp ground logs - If Required**

Run the scp command to retrieve the ground logs that are being logged while the vehicle is not flying. These logs are not offloaded by the ./offload_logs command. It is not typical to offload these logs, but may be needed for a bug that occurred while not flying.

scp root@192.168.254.1:/media/logs_####/onboard_control_telem_logger_ground*.kitty_native.lz4

For SW version 0.12.0+ with logging tablet installed:

scp root@192.168.254.20:/home/heaviside/logs_####/onboard_control_telem_logger_ground*.kitty_native.lz4

**Process logs, Generate COA Report, Agility Prime Data**

Follow the instructions and guidelines provided on the Log Processing Confluence Page.

## Return To Flight

Return to Normal Procedures Checklist - Avionics Power Up

## Shutdown Vehicle

Return to Normal Procedures Checklist - Shutdown

# RC Transmitter

Heaviside 2 uses the FrSky X10S Express (https://www.frsky-rc.com/product/horus-x10s-express/) with the R9M 900mHz radio module (https://www.frsky-rc.com/product/r9m/).

| | |
|---|---|
| **Model Configuration** | HVSD V3 |
| **X10s Express Firmware** | V1.0.10 |
| **R9M 2019 ACCESS Firmware** | V1.3.0 |
| **R9 Slim + OTA** | V1.3.1 |


To safe the transmitter during start up set to the following. Note, the transmitter will warn the user if not set to the safe start during power up. This warning can be skipped if needed during testing or dual FrSky handoff.

- **All Switches:** Up and back
- **Tilt Slider:** Down
- **Hover Pitch Trim:** Center detent

- **Cruise Pitch Trim:** Center detent

| TX Label | Function | Description |
|---|---|---|
| SC | Not Used (Previously Speed Mode) | Not Used |
| SF | HV (high voltage) Control | 2-position locking switch:<br>Away (down) -HV disable.<br>Towards (up) -HV enable. |
| SE | Motor Control (MC) | 3-position switch:<br>Away (down) -Motors disable.<br>Mid/Towards (up) -Motors enable. |
| Blue Left Slider | Tilt slider | Up- tilt to cruise.<br>Down- tilt to hover. |
| SA | Tilt Enable switch | 3-position switch.<br>Away- tilt disable<br>Mid/Towards- tilt enable |
| Pink left stick | Standard RC throttle, yaw (Mode 2) | In Manual mode: throttle down is 0 throttle, up is 100%.<br>In Autohover mode: throttle mid is maintain altitude. |
| Yellow Rotary | Cruise Pitch Servo Trim | Adds positive or negative pitch moment only in forward flight through the use of the control surfaces. Does not affect hover. Slider down adds pitch up moment) |
| Teal Right Stick | Standard RC roll, pitch (Mode 2) | Manual: attitude control<br>Autohover: Lateral speed, centered will hold position |
| Blue Right Slider | Deck Angle (Hover Pitch) trim slider | Mirrors right stick pitch directions. |
| SG | Flight mode toggle switch | 3-position switch:<br>Down (away) - Manual flight<br>Mid- Autohover<br>Up (towards)- Automated (enabled) |
| SH | Settings switch | 2-position switch:<br>Down (away) - Revert (Default settings loaded on vehicle)<br>Up (towards) - Vert (changes committed from settings_app) |

## Setting up the Buddy Box as Master/Slave For Training Flights

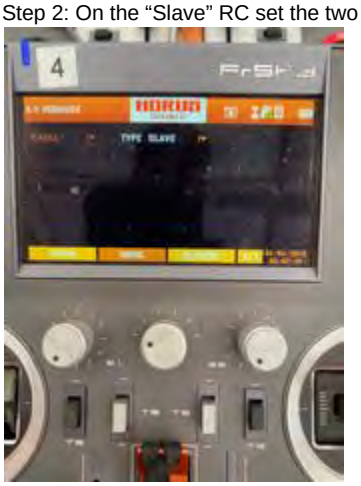
The following applies to the X12s and X10s. Additionally, the X10s can use bluetooth to link transmitters.

Equipment Needed:

- Two FrSky X10s RC Transmitters
- The module for the aircraft to be flown installed in the “Master RC”
- A 3.5mm aux cable

Step 1: On Both RC’s go to the “Model Menu” and Select “Trainer”


Step 2: On the “Slave” RC set the two Menu Options to “Cable” and “Slave” as shown below.




Step 3: On the “Master” RC select “Cable”; “Type Master” ; & “ SW SWB_DN”.

Step 4: Ensure that Channels 1 through 8 are set to “Replace” on the Master. The “Percent” should be “050” on all channels.


FrSky
TYPE MASTER
MODE
PERCENT
SOURCE
CH 5
REPLACE
050
CH 6
REPLACE
050
CH 7
REPLACE
050
CH 8
050

# Weight and Balance

## Aircraft Serial Number W&B

The following spreadsheet is used to track the empty weight and balance for each aircraft. Each aircraft tab includes a weight and balance calculator allowing the user to enter payload amounts for the seat and floor to compute the weight and balance.

## Weight, CG and Inertia Estimation

# H2-009

| Hover Tilt Empty (used for W&B calcs) | | | |
|---|---|---|---|
| | Weight (kg) | Arm (m) | Moment (kg*m) |
| Canard | 165 | 1.734 | 286.11 |
| Tail | 125 | -2.83 | -353.75 |
| TOTAL | **290** | **-0.233** | -67.64 |

**3/16/2021 new empty with tail extensions and no ballast plate or DAQ. Does include DAQ cables, chokes, and accels.**

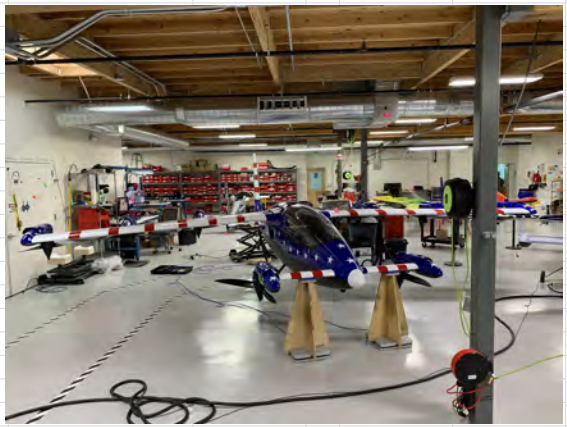
| W&B Calculator | | | | |
|---|---|---|---|---|
| | Weight (kg) | Arm (m) | Moment (kg*m) | Weight (lb) |
| Basic Empty Weight | 290 | -0.233 | -67.64 | |
| Floor Ballast | 8.25 | 1.270 | 10.48 | **18.2** |
| Seat Ballast | 51.70 | 0.565 | 29.21 | **114** |
| | | | | |
| TOTAL | **349.95** | **-0.080** | -27.95 | |

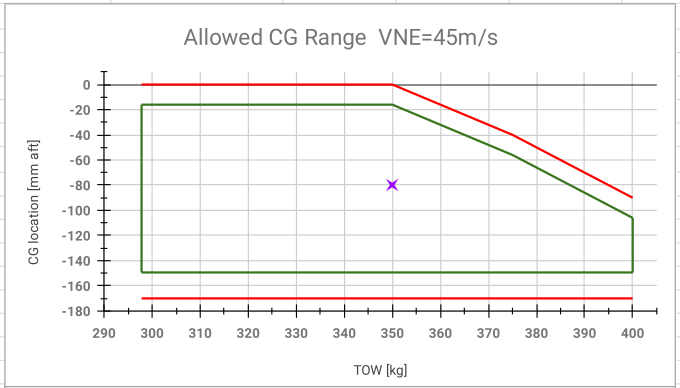
| Calculated Ballast Arm | CAD |
|---|---|
| -0.233 | 1.27 |

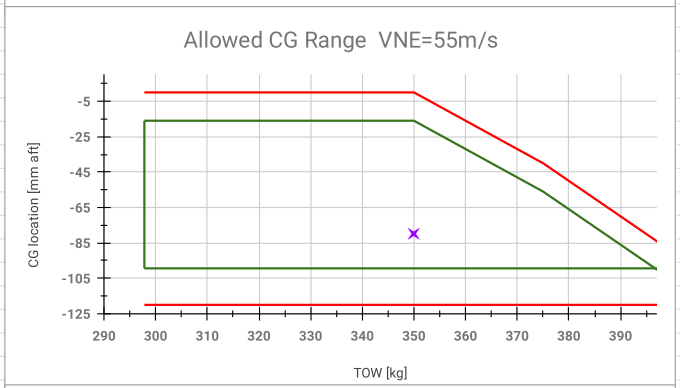
| Kg -> lbs | |
|---|---|
| 51.7 | 114.00 |

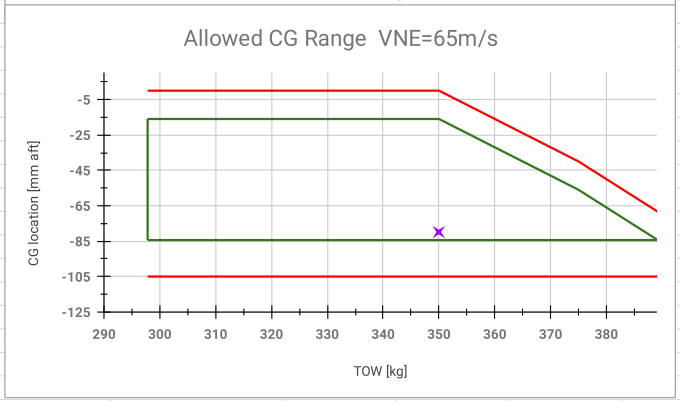
| lbs -> Kg | |
|---|---|
| 18.2 | 8.25 |

| Calculated Ballast Arm | CAD |
|---|---|
| -0.233 | 0.565 |





| Vmax= 45 m/s | Aftmost CG | Aftmost CG on F | Fwc | Fwd Most CG on Fixture | CG | Min l | Max line |
|---|---|---|---|---|---|---|---|
| 297.8 | -170 | -149.3822165 | 0 | -16 | | | |
| 325 | -170 | -149.3822165 | 0 | -16 | | | |
| 350 | -170 | -149.3822165 | 0 | -16 | | | |
| 375 | -170 | -149.3822165 | -40 | -56 | | | |
| 400 | -170 | -149.3822165 | -90 | -106 | | | |
| 349.95 | | | | | -79.85770751 | | |
| 297.8 | | | | | | -149 | |
| 297.8 | | | | | | -16 | |
| 400 | | | | | | | -149.3822165 |
| 400 | | | | | | | -106 |
| | | | | | | | |
| Vmax= 55 m/s | Aftmost CG | Aftmost CG on F | Fwc | Fwd Most CG on Fixture | CG | Min l | Max line |
| 297.8 | -120 | -99.38221647 | 0 | -16 | | | |
| 325 | -120 | -99.38221647 | 0 | -16 | | | |
| 350 | -120 | -99.38221647 | 0 | -16 | | | |
| 375 | -120 | -99.38221647 | -40 | -56 | | | |
| 400 | -120 | -99.38221647 | -90 | -106 | | | |
| 349.95 | | | | | -79.85770751 | | |
| 297.8 | | | | | | -99.3 | |
| 297.8 | | | | | | -16 | |
| 400 | | | | | | | -99.38221647 |
| 400 | | | | | | | -106 |
| | | | | | | | |
| Vmax= 65 m/s | Aftmost CG | Aftmost CG on F | Fwc | Fwd Most CG on Fixture | CG | Min l | Max line |
| 297.8 | -105 | -84.38221647 | 0 | -16 | | | |
| 325 | -105 | -84.38221647 | 0 | -16 | | | |
| 350 | -105 | -84.38221647 | 0 | -16 | | | |
| 375 | -105 | -84.38221647 | -40 | -56 | | | |
| 400 | -105 | -84.38221647 | -90 | -106 | | | |
| 349.95 | | | | | -79.85770751 | | |
| 297.8 | | | | | | -84.3 | |
| 297.8 | | | | | | -16 | |
| 400 | | | | | | | -84.38221647 |
| 400 | | | | | | | -106 |

# Network and Data Link

## Network Devices

All devices are set to static IP. More than one of the listed devices cannot be connect to the same network.

| Device | IP Address |
|---|---|
| FCU C | 192.168.254.1 |
| FCU B (triplex only) | 192.168.254.2 |
| FCU A (triplex only) | 192.168.254.3 |
| PFD / Logging Aux Computer | 192.168.254.20 |
| Microhard Radio - Aircraft | 192.168.254.100 |
| Microhard Radio - Ground | 192.168.254.101 |
| GCS Computer | 192.168.254.50 |
| Support Computer (charge/logs) | 192.168.254.51 |
| Charging Watchdog | 192.168.254.71 |
| Charging Power Supply | 192.168.254.70 |

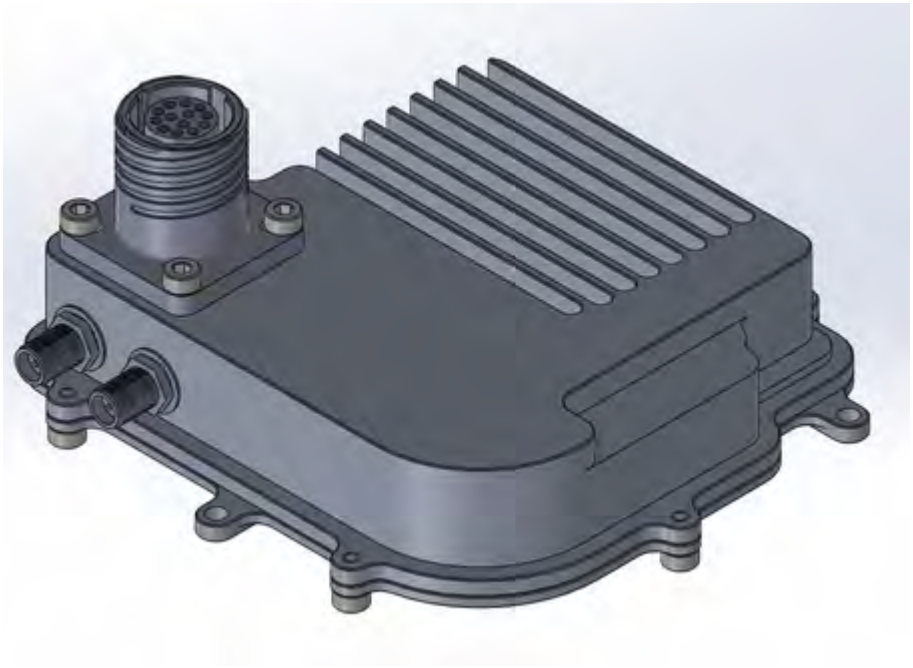
## Microhard

Microhard wireless digital link is used for command and control of the aircraft from the GCS. Notable features:

- Adjustable high power 2.4GHz transmission up to 1W with excellent rx sensitivity
- Up to 25 Mbps data rate (trade sensitivity/range with data rate)
- Master - Remote operating mode in a point to point topology
- 2x2 MIMO
- Dual 10/100 Ethernet ports

OEM Manual: https://drive.google.com/file/d/10LDG4PjF0zd0WWJDd5034N96nDztW3oK/view?usp=sharing

The Microhard radio is packaged into a custom enclosure to enhance passive cooling performance and protect the unit from exposure to dust and moisture.



## Microhard Antennas

The aircraft and ground station use various antenna styles to take advantage of the strengths of each when coupled to the RF diversity offered by the 2x2 diversity.

| Aircraft | |
|---|---|
| Top of vertical stabilizer | Haigh Farr Button 13140 (SMA Female) |
| Fuselage belly | Haigh Farr Blade 6130-2 (SMA Female) |

| GCS | |
|---|---|
| Antenna 1 | L-com 2.4 GHz 2 dBi Omnidirectional Antenna - N-Female Connector |
| Antenna 2 | L-com 2.4 GHz 4 dBi Omnidirectional Antenna - N-Female Connector |

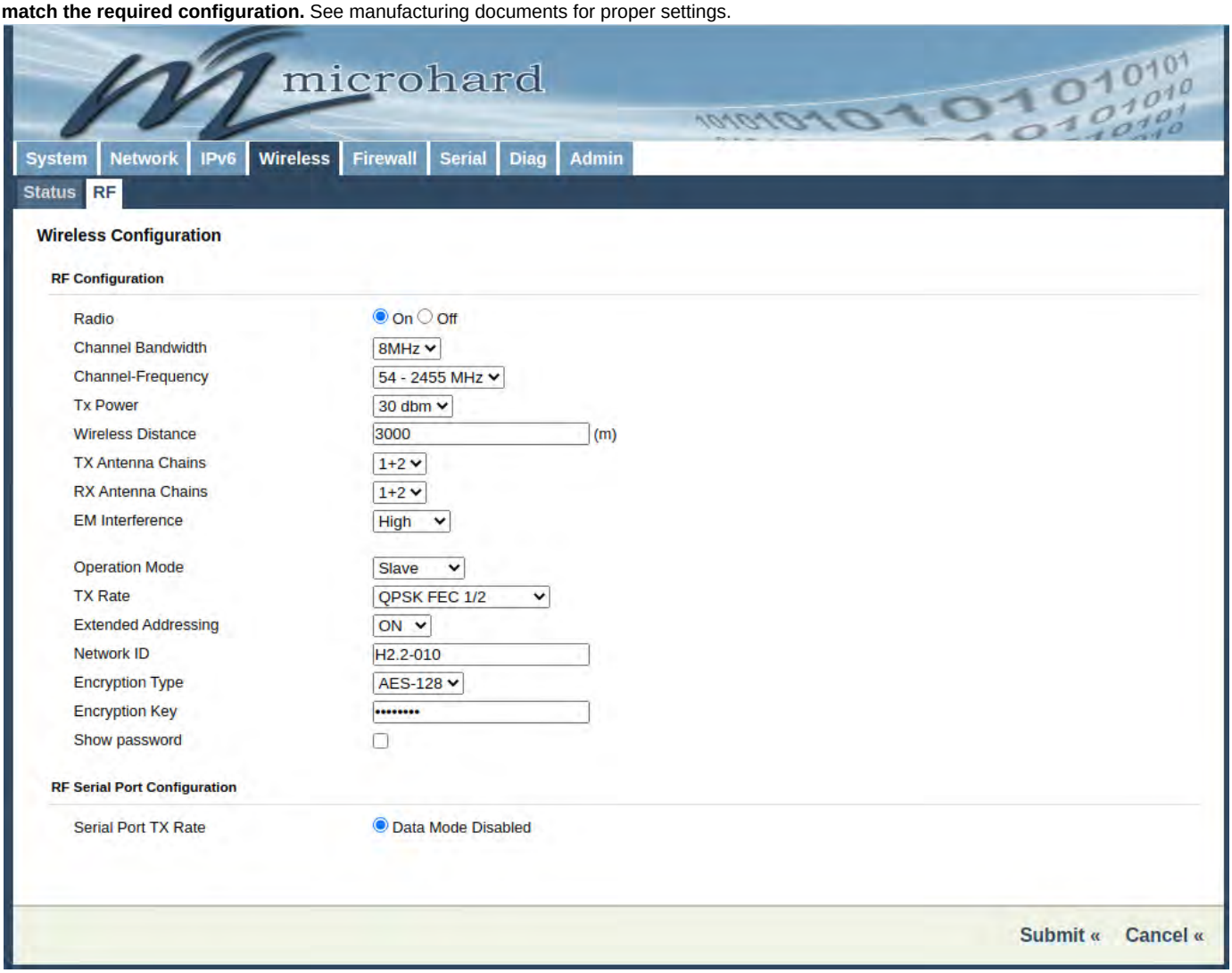
## Microhard Aircraft Settings

Aircraft settings should not need to be reconfigured once manufacturing is competed. Each aircraft uses unique RF settings to prevent cross talk and IP conflicts with other aircraft.

To connect to an aircraft, open 192.168.254.101 in a browser.

- Username: Heaviside
- Password: piloterror

Navigate to the following page and change only the settings listed in the table below. **This screen is for reference only. The values do not match the required configuration.** See manufacturing documents for proper settings.



| Aircraft SN= Network ID | Channel |
|---|---|
| **H2.2-004** | 6 |
| **H2.2-005** | 14 |
| **H2.2-006** | 22 |
| **H2.2-007** | 30 |
| **H2.2-008** | 38 |
| **H2.2-009** | 46 |
| **H2.2-010** | 54 |
| **H2.2-011** | 62 |
| **H2.2-012** | 70 |
| **H2.2-013** | 6 |
| **H2.2-025** (LV HITL I) | 174 (outside available range) |
| **H2.2-026** (LV HITL II) | 22 |

# Pilot Audio Box

## Overview

The pilot audio box is a simple system that allows the pilot to have the airspeed of the aircraft read out automatically in the pilot stand. It works by using a bluetooth connection between a TX connected to the GCS computer; and a RX located in the Pilot Audio box. The RX is wired to a speaker which annunciates the airspeed when it is activated. Inside the box the power to the speaker is wired into a foot switch; this way the pilot is able enable/disable the airspeed audio call outs during different phases of flight with minimal distraction from flying the airplane.

## Components and Assembly

The components in the box consist of:

- Pelican Case
- 120vAC inlet (standard 3 prong extension cord plugs in to provide power).
- A three way outlet splitter.
- 3.5mm aux cord
- The computer speaker
- The Bluetooth RX
- A foot switch
- The components at the GCS consist of:
    - Bluetooth TX
    - 3.5mm Aux Cord

## Using the Pilot Audio Box:

Preconditions:

- GCS is Running
- Aux cord is plugged into the GCS computer
- Audio output is enabled through the 3.5mm jack on the computer in Ubuntu.
- Step 1: Ensure the Bluetooth TX is powered on, and the switch is set to TX.
- Step 2: Plug in the pilot audio box to an extension cord using the 120v inlet on the left side of the box.
- Step3: Ensure the Bluetooth RX is powered up and the switch is set to RX.
- Step 4: Check that the system is working by hitting the foot switch and you should hear airspeed audio call outs start and stop accordingly when the switch is pushed.