VORTEX

Vertically Optimized Research, Testing, & EXploration

Test Readiness Review

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Team

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Project Overview

Mission Statement

In order to expand the capabilities of the IRISS center and TORUS project in gathering meteorological data and understanding the formation of supercell thunderstorms, the VORTEX team will bring Vertical Takeoff and Landing (VTOL) functionality and extended endurance to the RiteWing Drak airframe.

Mission CONOPS

Levels of Success

	Level 1	Level 2	Level 3
Flight	Show on a static test stand that the propulsion system is capable of producing enough thrust to provide a TWR greater than 1	Maintain tethered hover at 2m altitude for 30 seconds as well as demonstrate capability to transition to horizontal flight while aircraft is mounted to a test stand	Aircraft shall demonstrate takeoff ability via RAP Cat launch system as well as demonstrate full transition from vertical to horizontal flight modes.
Budget	The aircraft shall cost no more than $1250, not including IRISS avionics package.	The aircraft shall cost no more than $1000, not including IRISS avionics package.	The aircraft shall cost no more than $900, not including IRISS avionics package.
Endurance	The propulsion system shall maintain required thrust output for the equivalent of 1 hour cruise and 2 takeoffs and landings (approximately 1 hr 16 minutes) on a static test stand in simulated freestream conditions of 18 m/s with >15% battery remaining	-	Demonstrate 1 hour of flight cruise as well as 2 takeoffs and landings
Airframe	A finite element analysis of the modified airframe will be performed to demonstrate that it can withstand the required forces with a FOS of 1.7	The aircraft will have full integration capabilities with RAPCat launch system, and show that it can withstand the forces due to acceleration.	The airframe shall with stand axial and lateral forces up to 10G.
Avionics & Electronics	All motors and actuators shall be successfully inte grated with the flight con troller. The telemetry link shall be maintained with less than 25% packet loss within 1 km of the ground station.	All external (non-native) sensors are successfully integrated with the avionics system.	-

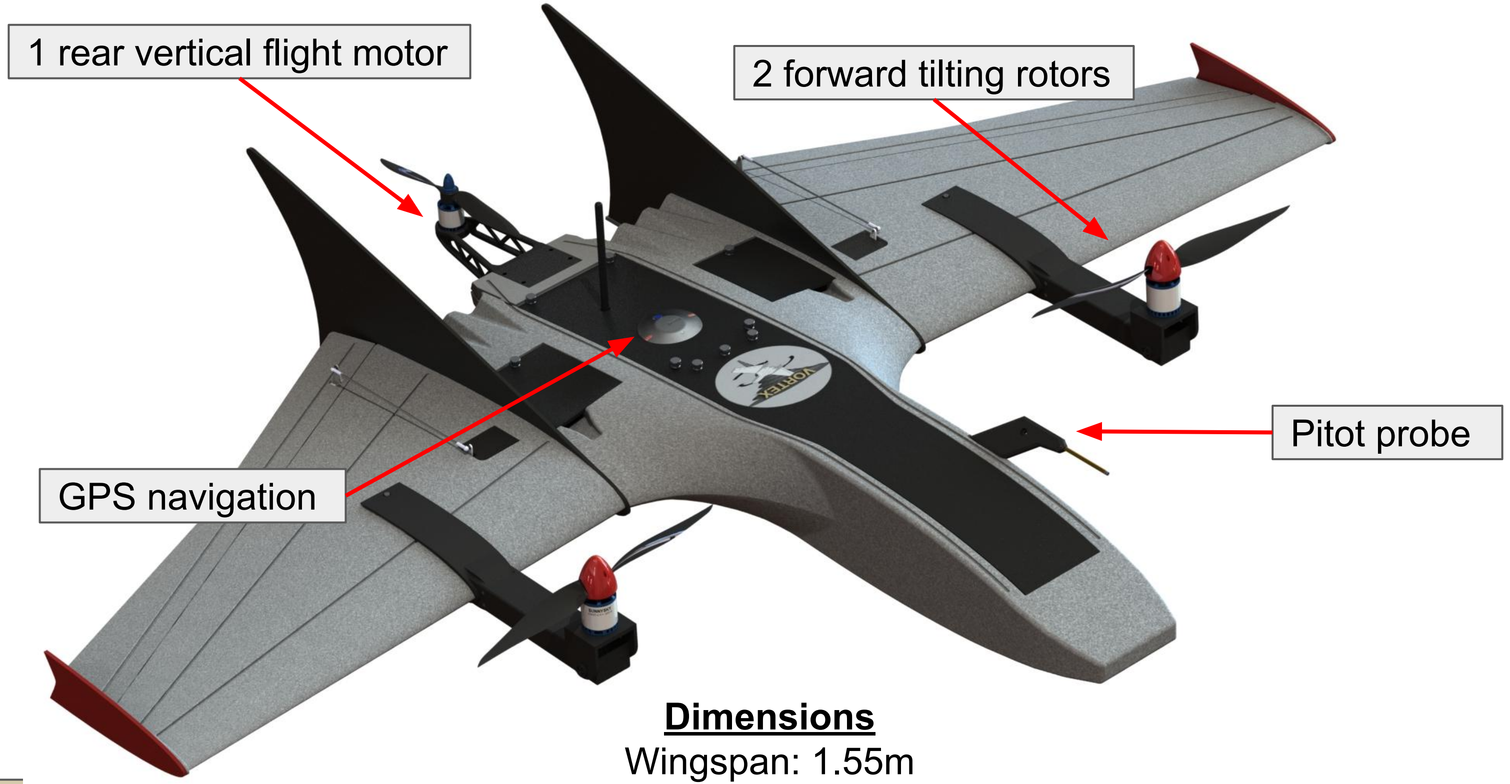
Critical Project Elements

Element	Justification
Vertical Takeoff and Landing **(VTOL)**	Primary deliverable of project.
Structure **(STR)**	Structure must withstand forces of takeoff, flight, and landing.
Endurance **(END)**	Aircraft must be able to maintain flight for the required duration of 1 hour plus takeoffs and landings.
Automation **(AUT)**	Aircraft must autonomously perform mission flight profile as well as controlling takeoff, landing, and transitions.

Functional Requirements

FR1	**VTOL**	The aircraft shall be a VTOL conversion of the COTS Ritewing RC “Drak” airplane kit
FR2	**END**	The aircraft shall have an endurance of 1 hour with 2 takeoffs and landings
FR3	**AUT**	The aircraft shall be able to autonomously execute all aspects of its mission from first takeoff through final landing
FR4	**AUT**	The aircraft shall maintain communication with the ground station up to a distance of 2km
FR5	**STR**	The aircraft shall be capable of carrying a 0.5kg payload
FR6	**STR**	The aircraft shall be capable of taking off from existing RAPCat launch system
FR7	**VTOL**	The airframe, propulsion system, and required mounting hardware shall cost no more than $1000 per aircraft

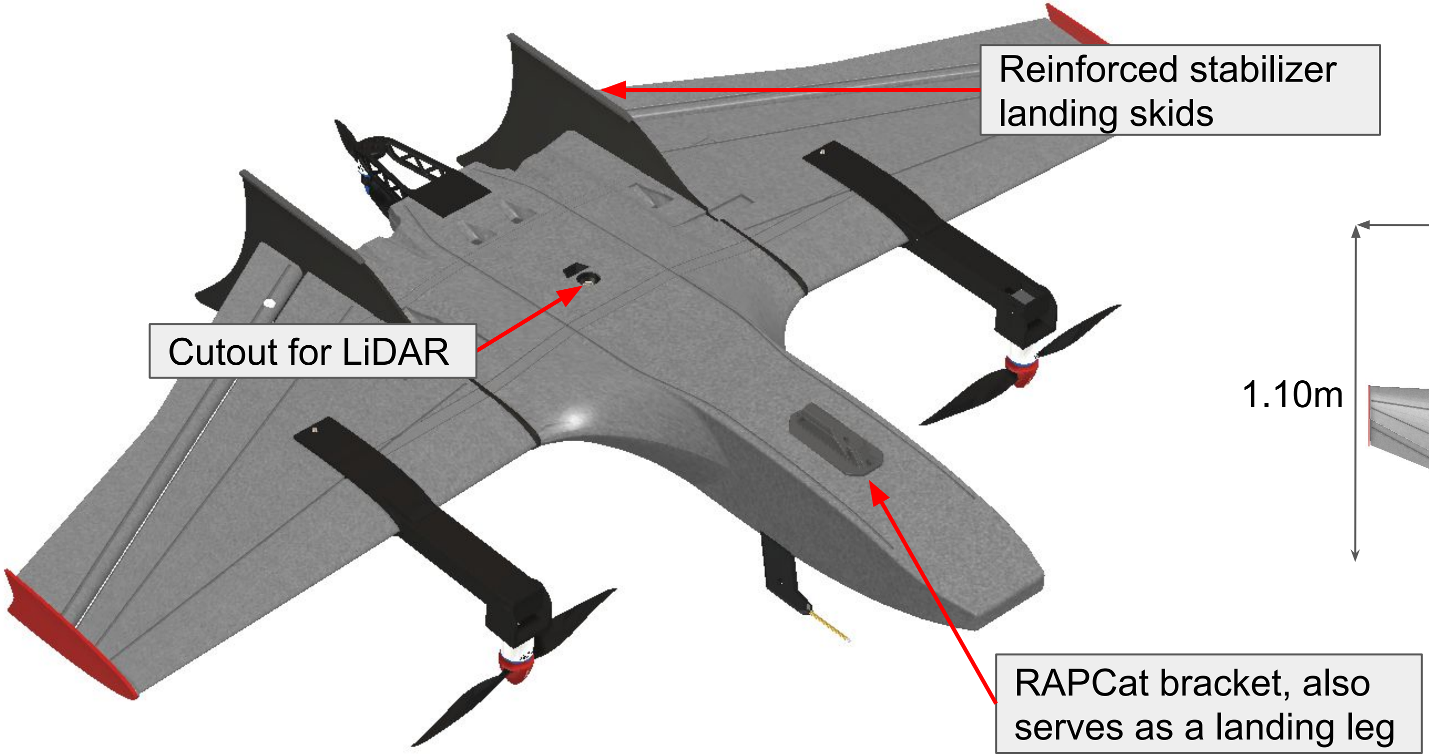
Baseline Design (CDR)

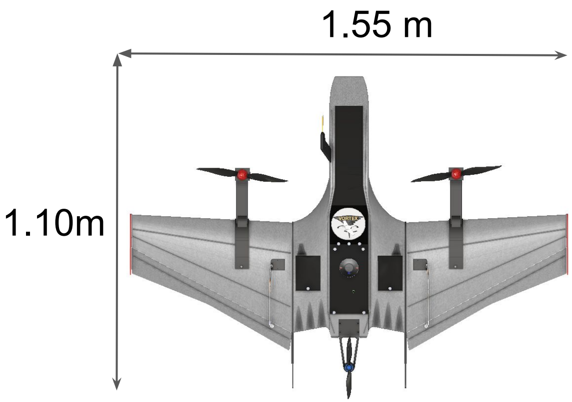


Dimensions

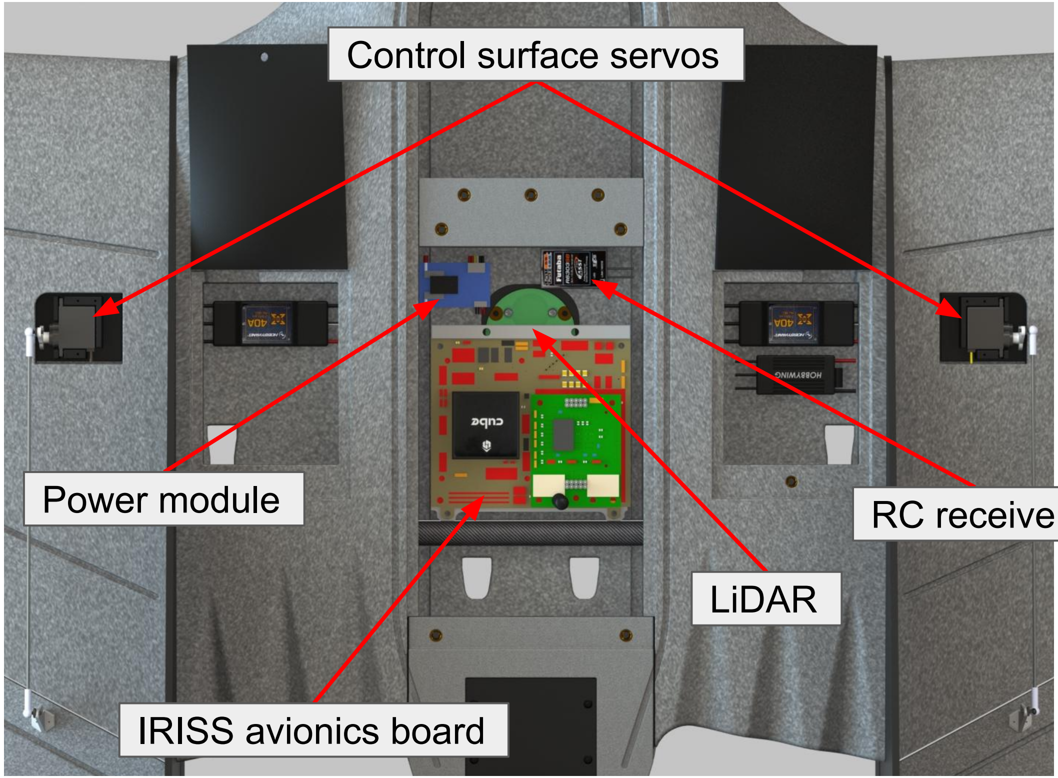
Wingspan: 1.55m
Nose-to-tail: 1.10m

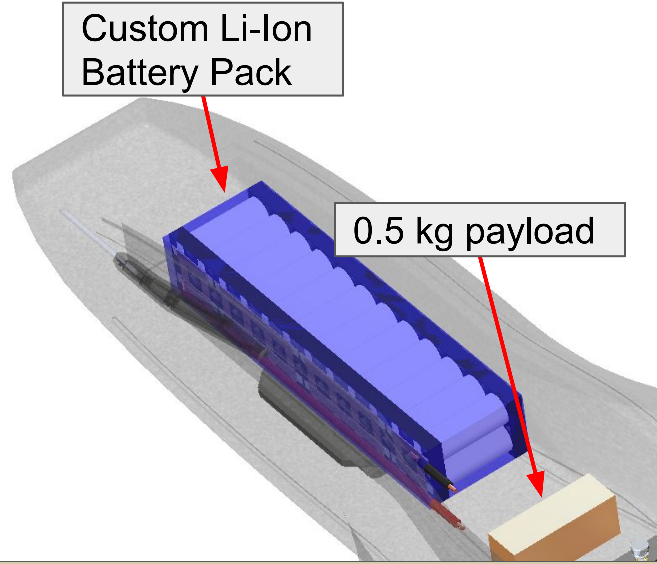
Baseline Design (CDR)



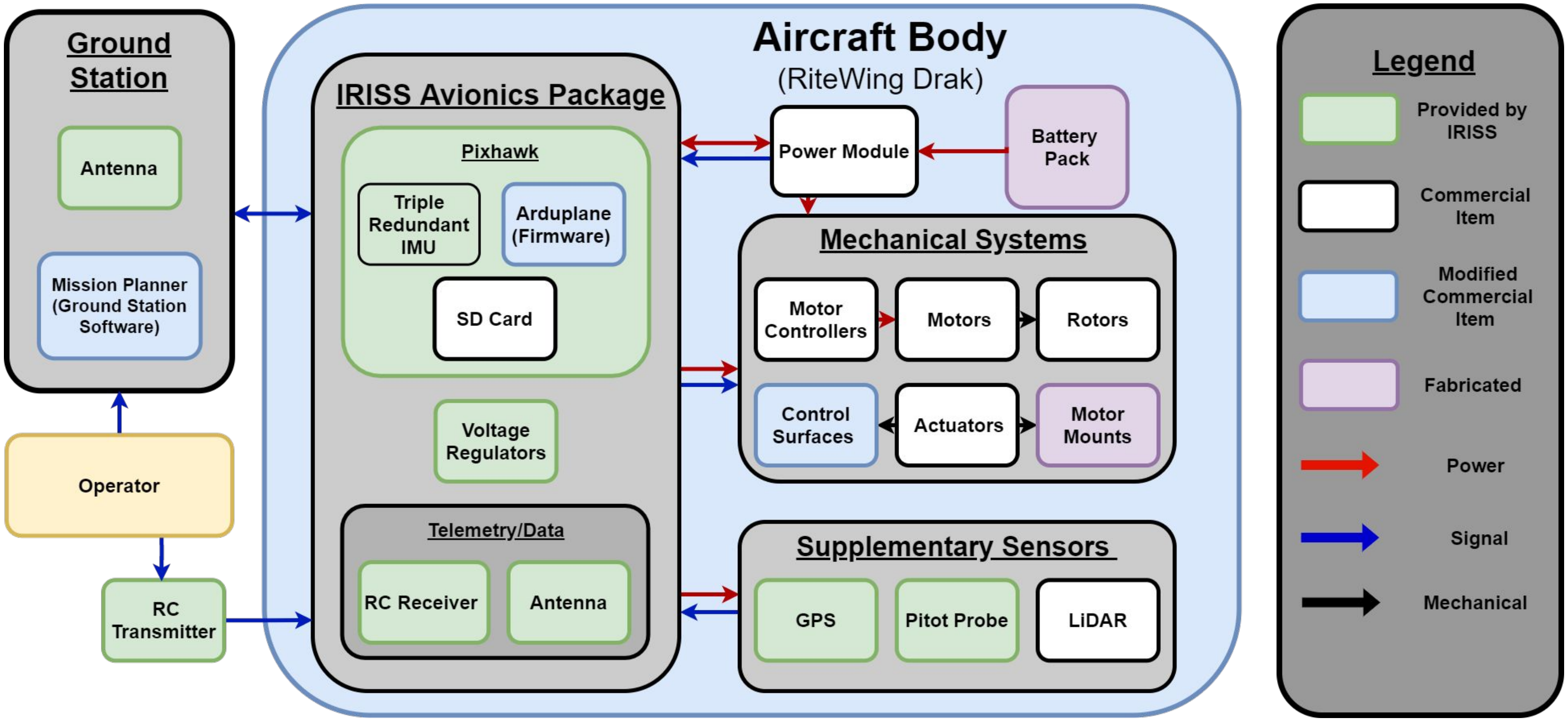


Baseline Design (CDR)

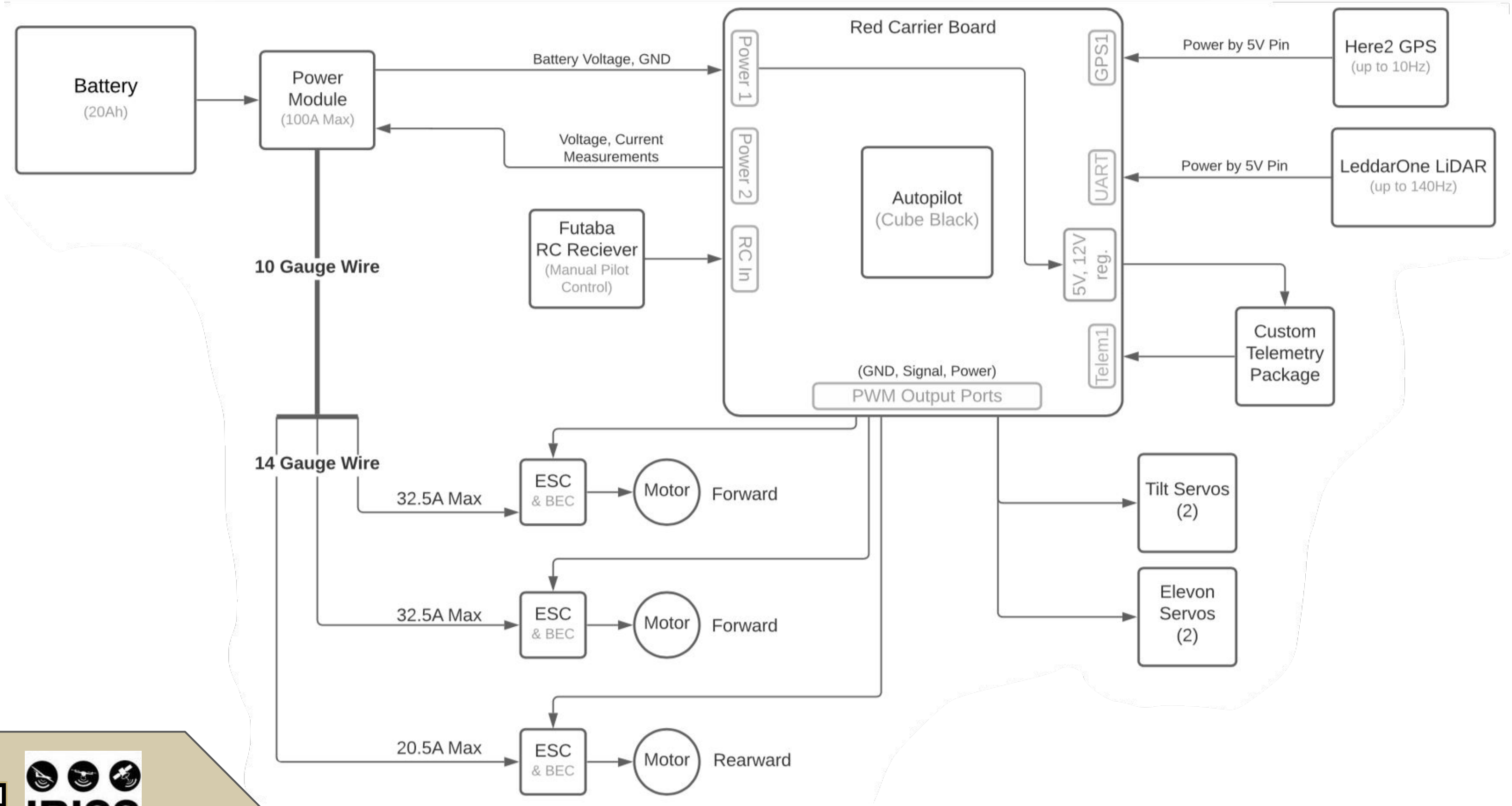




System Functional Block Diagram



Avionics Functional Block Diagram



Manufacturing Update Since MSR

Overall Manufacturing Update

Completed Manufacturing	Remaining Manufacturing
Base wing kits Glued and ready to be used in testing Cutouts for test mounts and modifications complete	First Prototype Modified Drak Fully operational and calibrated/configured
Preliminary motor mounts Wing attachments Motor arms Tilt brackets	Second Prototype model May or may not include motors and/or battery depending on budget
Li-Ion Battery pack	Additional Drak test configurations (tail & canard)
Avionics package Lidar is functioning	Further iterations of 3D printed parts

Drak Manufacturing Update

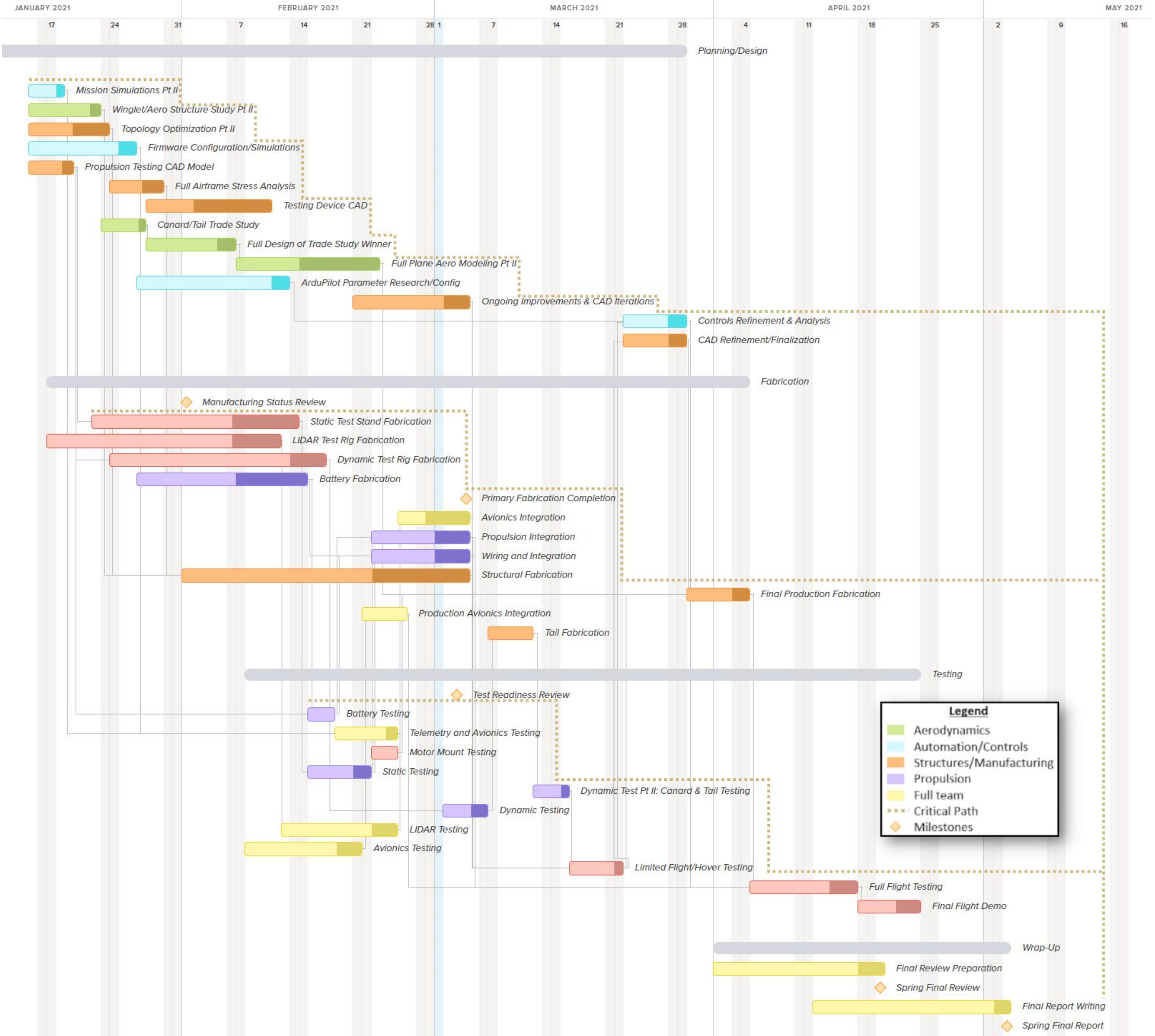
Completed:
- Fully assembled wing kit (right)
- Motor mounts attached in place

In Progress:
- Motor arm iteration/improvements
- Wire channeling
- Subsystem component installation
    - Avionics board
    - Battery
    - Propulsion systems
- Tail integration

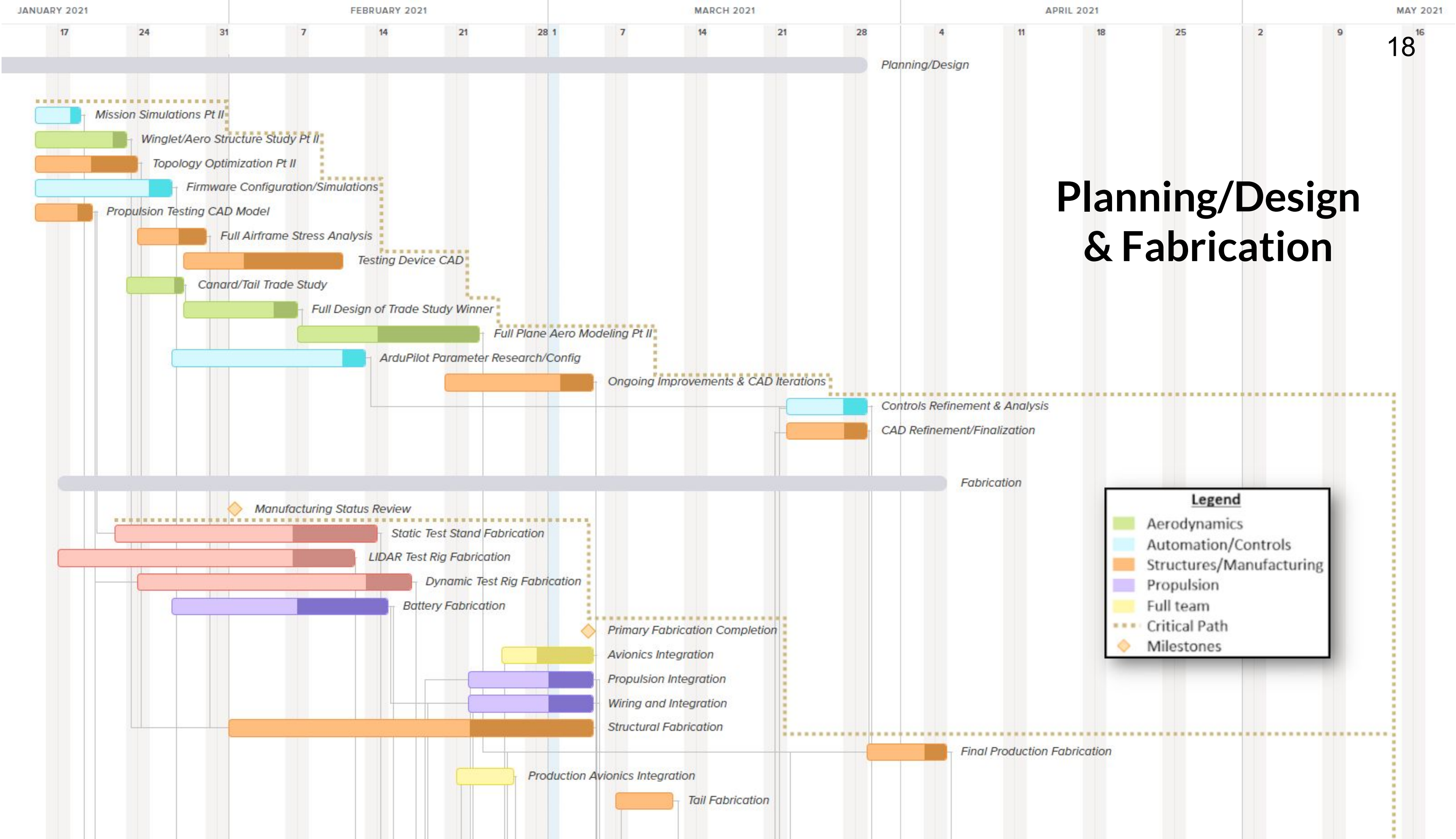
Dimensions
Wingspan: 1.55m
Length: 2.14m

Schedule

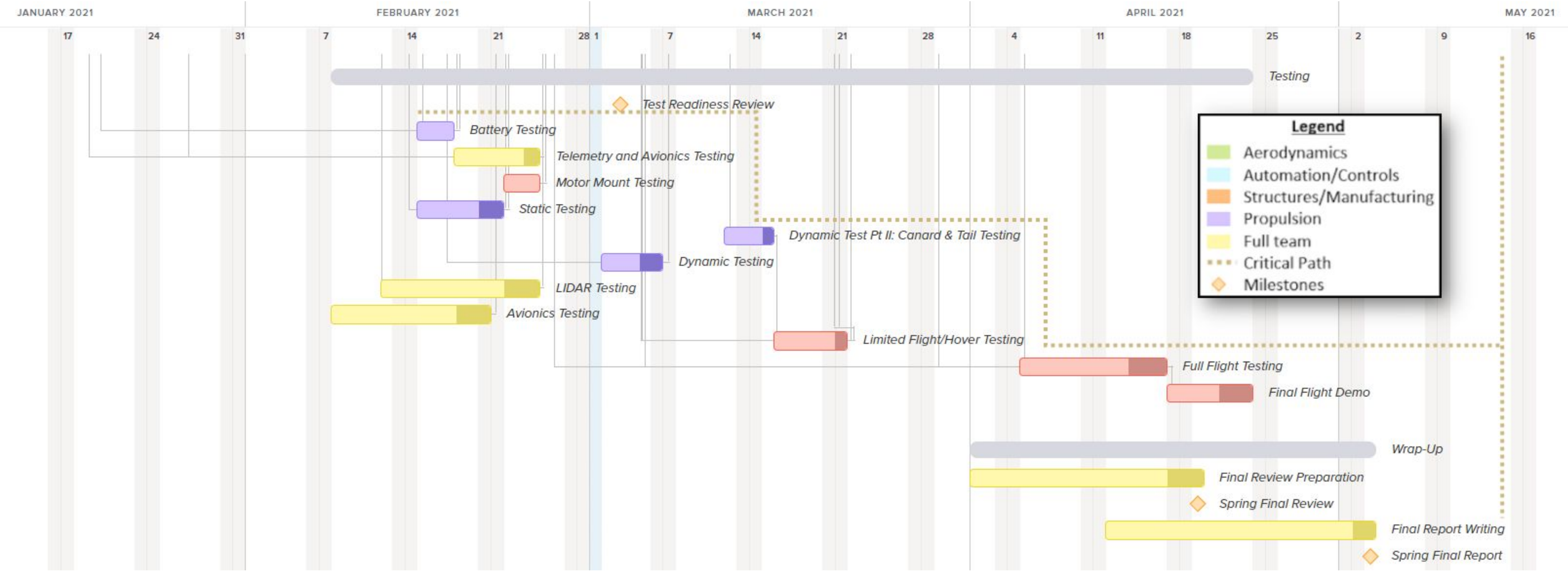
Full Project Gantt Chart - Second Semester



Planning/Design & Fabrication



Testing Gantt Chart



Testing

Test Overview

	Functional Requirement	Element	Test	Description	Status
1	FR6	STR	**Wing Motor Mount Stress**	Verification of FEM model and testing structural limits of wing motor mounts	In Progress
2	FR2	END	**Battery Endurance**	Verify and prove the assembled battery meets modeled capacity performance	Complete
3	FR1	VTOL	**Static Motor**	Testing thrust and power draw in static conditions	In progress
4	FR3	AUT	**Controls**	Verify that control surfaces actuate properly	Complete
5	FR3	AUT	**LiDAR**	Testing LiDAR system for accuracy	In progress
6	FR4	AUT	**Telemetry**	Verify/test avionics package and communications	In Progress

Test Overview

	Functional Requirement	Element	Test	Description	Status
7	FR2	END	**Dynamic Motor**	Testing thrust and power draw in flight conditions	Planned by 3/8
8	FR2	END	**Car Top Aerodynamic**	Obtain aerodynamic forces to validate CFD	Planned by 3/8
9	FR6	STR	**RAPCat Integration**	Validate that Drak fits into existing RAPCAT bracket and test launch procedure	Planned 3/21
10	FR1	VTOL	**Hover**	Verify stability in hover	Planned 3/16
11	FR2	END	**Full Flight**	Verify that Drak can execute the mission	Planned 4/5

Wing Motor Stress Testing

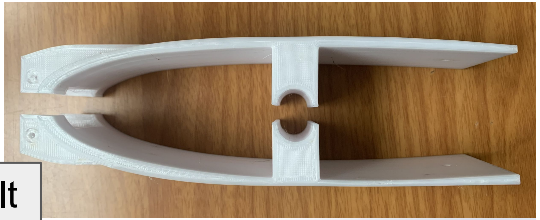
What and Why:

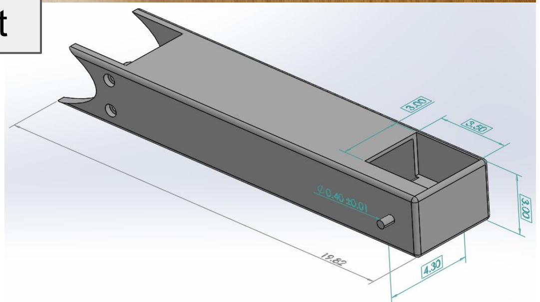
- Verification of FEM simulations; ensuring requirements met
- Increasing load applied to end of motor arm / wing assembly
- Removes risk of failure during maximum loading in flight

Testing Procedure:

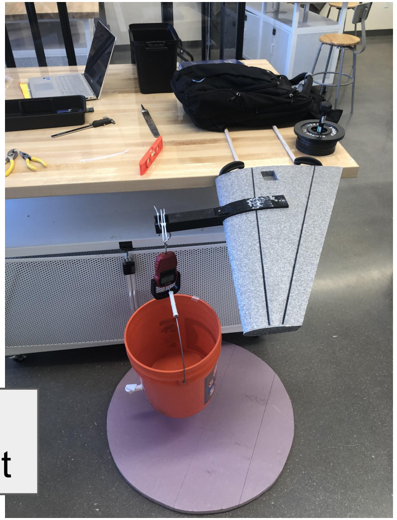
- Wing spars clamped to table
- Weight incrementally added to the end of the motor arm in 0.5kg increments

In Progress





3D printed tilt motor mount



Motor mount structural test

Requirement	Description
FR 6	RAPCat Compatibility
DR 6.2	Withstand 5G acceleration during RAPCat launch
DR 6.5	Withstand 10G during takeoff and landing operations

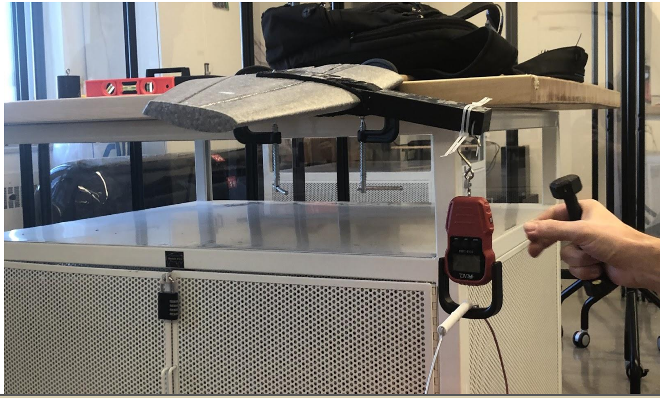
Wing Stress Testing Results

Downward Stress (Landing):

- 10G requirement is 1.9kg (18.65N)
  - Tested to 2.1kg (20.5N)
  - No FOS calculation
- Small bending in arm and wing

Upward Stress (Takeoff):

- Requirement of 2.5kg (24.5N)
  - Tested incrementally to 6.6kg (64.7N)
  - 2.6 FOS
- Extreme bending in arm and wing
- Only small plastic deformation after test



In Progress

RAPCat Launch/Compatibility

- Upcoming

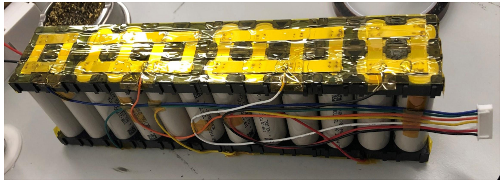
Battery Endurance Testing

What and Why:

- Verification of custom battery assembly functionality
- Reduces the risk of power capabilities for the aircraft

Testing Procedure:

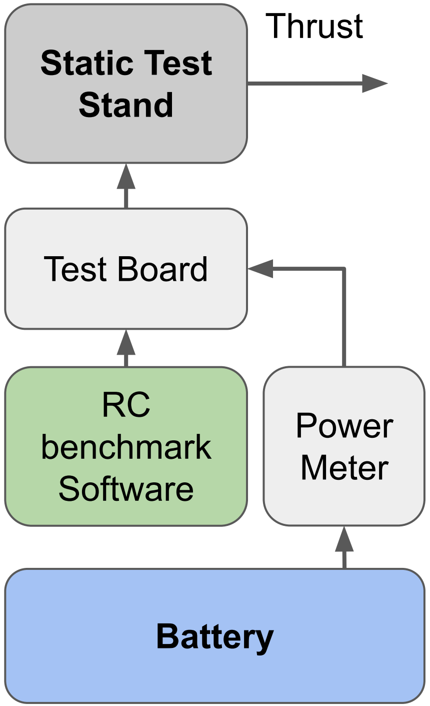
- Verify battery cell balanced voltage
- Maintained a cruise condition current draw until battery voltage drops below 18V

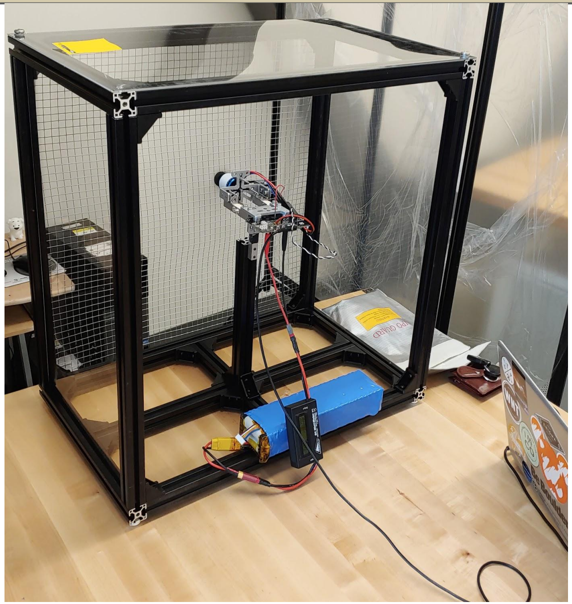


Exposed battery view

Complete

Test Overview





Static Test Setup (in-action)

Requirement	Description
FR 2	Endurance of one hour with two takeoffs and landings

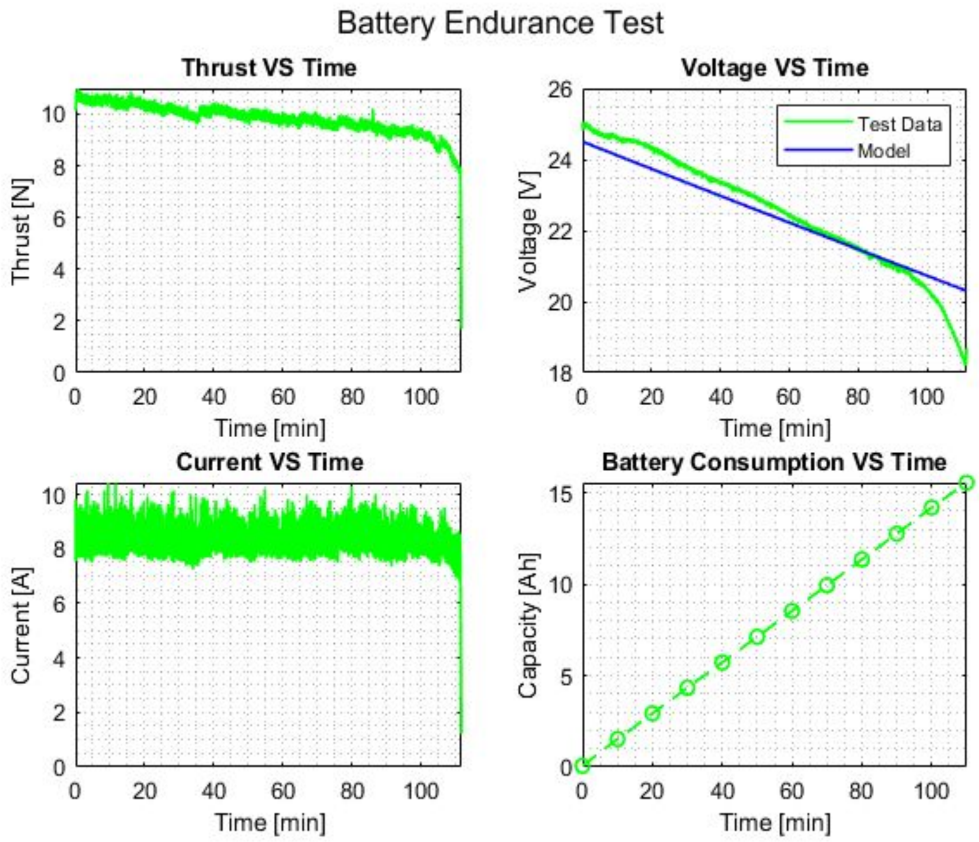
Battery Endurance Testing Results

- **Endurance Test:**
  - Manually maintained expected cruise current draw of 8-8.3A

Total run time: 110 minutes

- **Conclusion:**
  - Battery capacity meets expected performance for 1 hour cruise flight

Complete



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Static Propulsion Test Stand

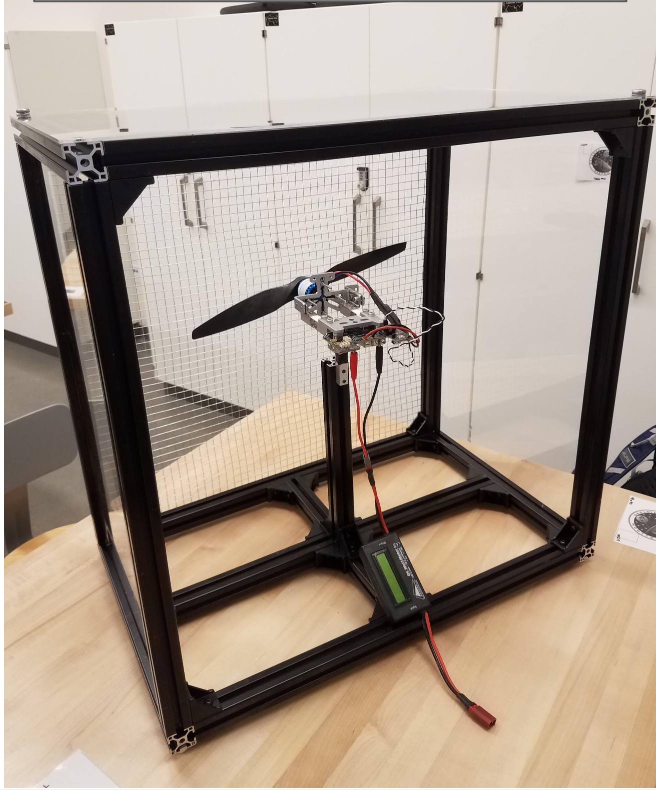
What and Why:

- Test for thrust and endurance requirements
- Using RC Benchmark software to track specific test properties
- Motor and load cells contained in plexiglass & chicken wire box

Testing Procedure:

- Configure battery, motor, ESC, and propeller
- Use RC benchmark software to manually toggle throttle power input

Propulsion test stand setup



Requirement	Description
FR2	Endurance of one hour with two takeoffs and landings

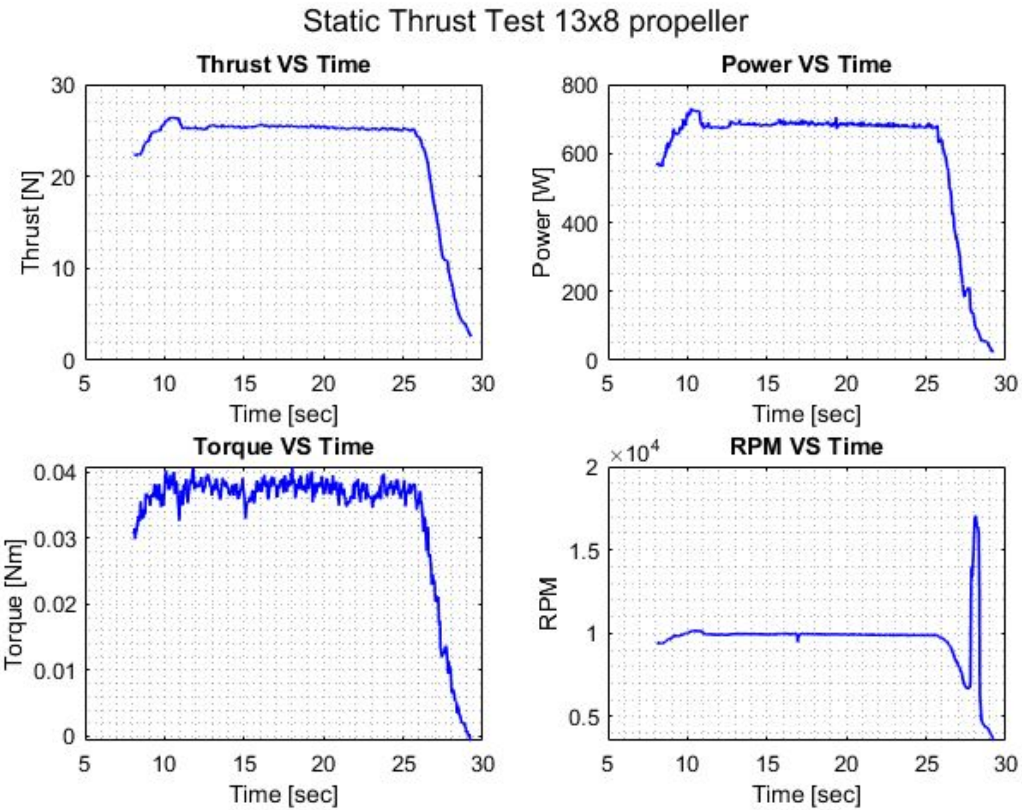
In Progress

Static Propulsion Test Stand Results

Preliminary tests have been done on the static test stand showing promising results

Planned testing:

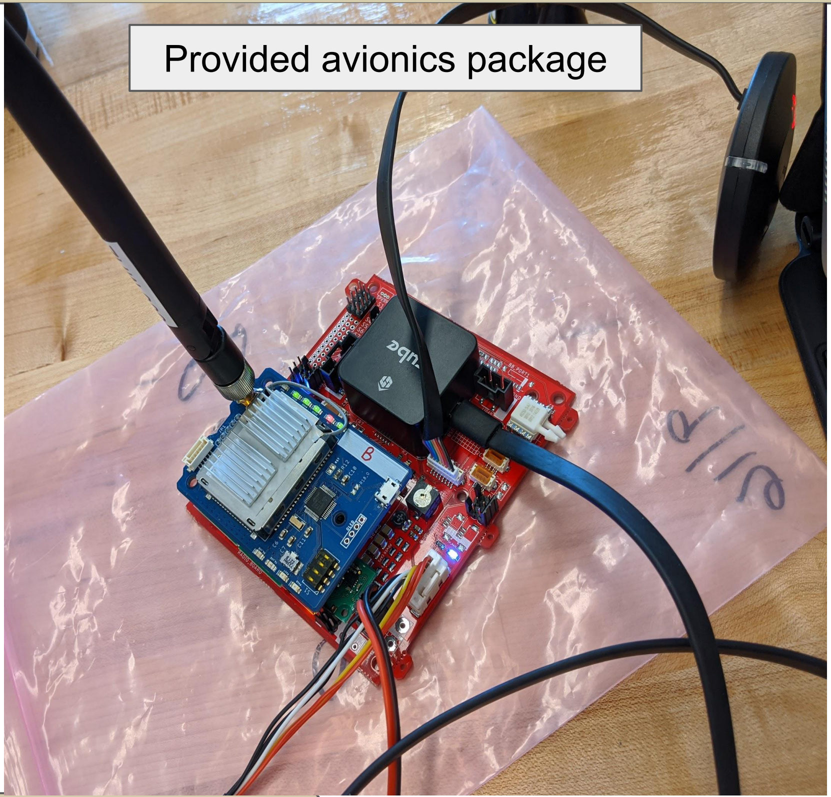
- Front motor X2820
  - 13x7 *[Diameter x pitch]*
  - 13x8
- Rear Motor X2216
  - 9x5
  - 9x6
  - 10x5
  - 10x6
  - 10x7

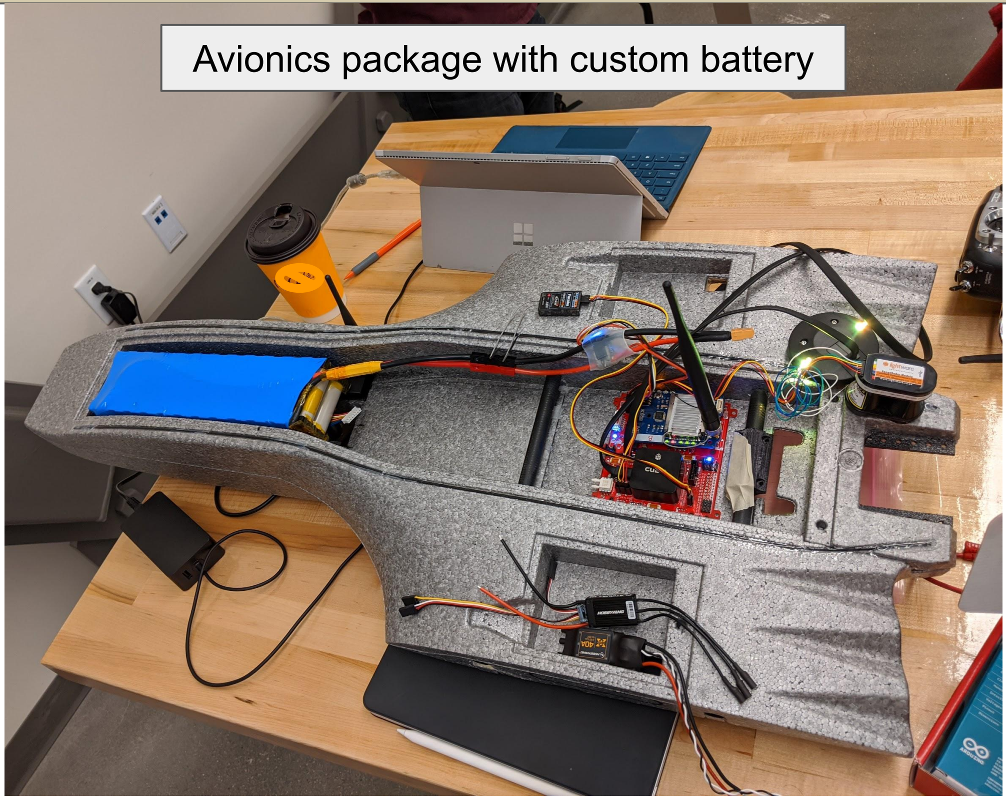


In Progress

*Software is in progress to format and compare the model with test data

Avionics System





Telemetry Test

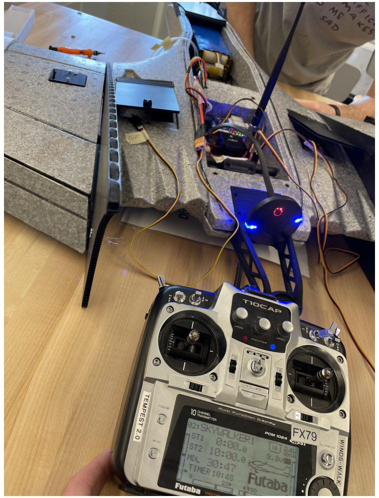
What and Why:

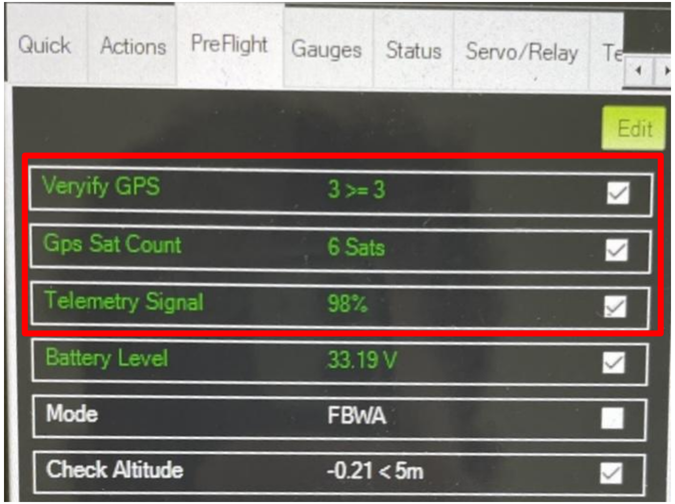
- Aircraft must to maintain communication with GS computer up to 2km

So Far:

- GS computer successfully communicating with flight controller at short range
- Radio Transmitter successfully communicating with SBUS Receiver
- Exploring options to power ground station radio for long-distance telemetry test

In Progress





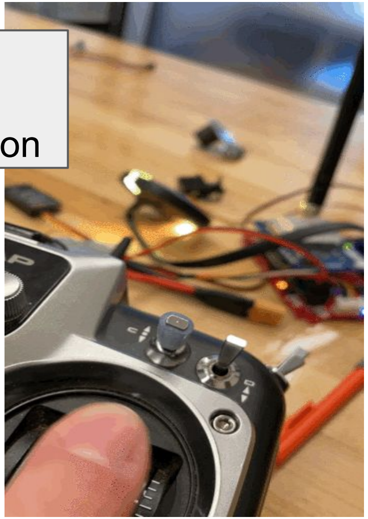
Requirement	Description
FR 4	The aircraft shall maintain communication with the ground station up to a distance of 2km

Controls Test

So Far

- Servos configured, connected, and actuating
- Servos responding to RC stick input
- Servos responding automatically to attitude changes

Successful servo RC communication



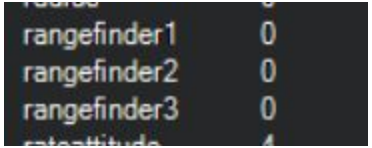
In Progress

Requirement	Description
FR 3	Verify that control surfaces actuate properly

LiDAR Test

Issues:

- Rangefinder data not being read by Mission Planner



- Most likely a bad telemetry port
- New PCB being fabricated by IRISS

In Progress

3D printed LiDAR mount

Requirement	Description
FR 3	Autonomous mission execution
DR 3.4	Vertical accuracy of <10cm is desired in takeoff and landing when below GPS altitude of 5m
DR 3.5	Complete mission profile without pilot input

LiDAR test stand assembly

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Avionics System Progress

Component	Progress	Details
Servos	Functional	Actuating and Connecting, Need final calibration and permanent connection. See slide 30
Telemetry	Functional	99% on Mission Planner,Ground Station Communicating
GPS	Functional	GPS verified on Mission Planner, Showing position accurately
Pitot-Static Tube	Installed	Needs Final Calibration
Lidar	Close to Functional	Issues with hardware connections, most likely PCB
Battery	Functional	Need final configuration, Failsafe not in place
ESC's/Motors	Not installed	Need to be connected, Simple Procedure
Other	Close to Functional	IMUs need calibration, need hover test verification

Aerodynamic Test Stand

Summary:

- Testing for aerodynamic forces
- Drak too large for wind tunnel
- Working with CASP to use a private road

Testing Procedure:

- Mount test stand to vehicle using U-bolts
- Adjust angle of attack to desired value
- Drive in a straight line at 18m/s (~40mph) for at least 45-60 seconds
    - Obtain enough data to be able to filter out noise

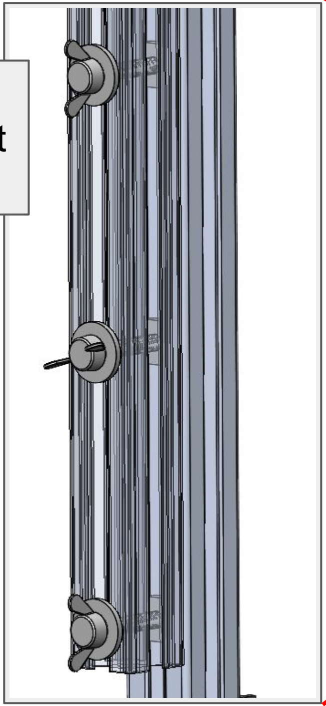
Planned 3/8

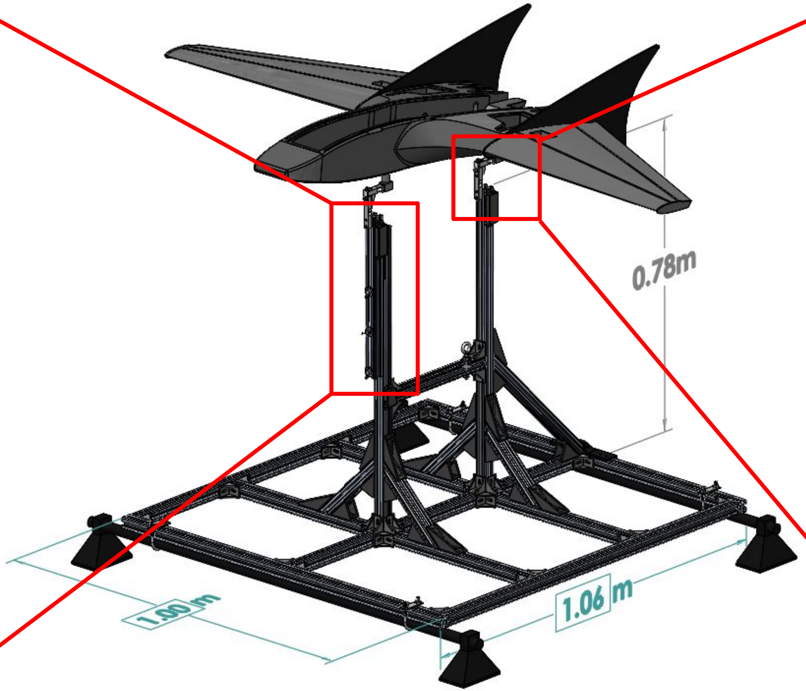
Aerodynamic test stand mounted

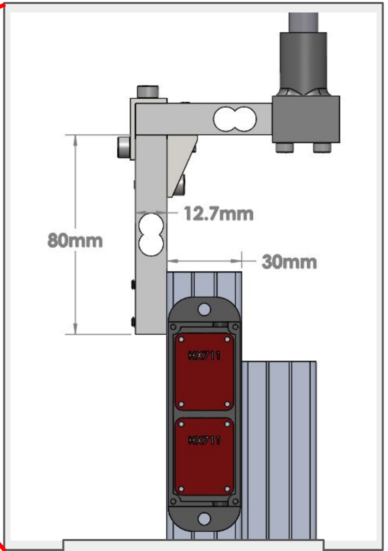
Requirement	Description
FR 2	1 Hour endurance, 2 Takeoffs and Landings
DR 2.7	Cruise speed shall be at least 18 m/s

Aerodynamic Test Stand

AoA adjustment capability







Load cell & amplifier configuration

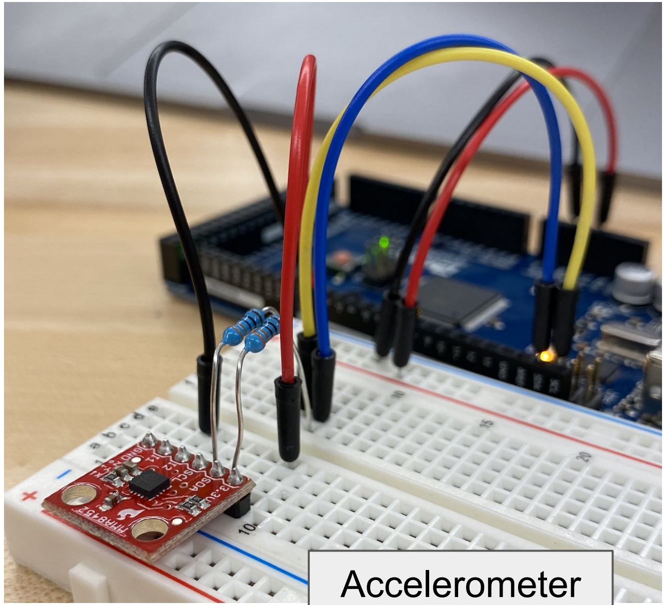
Aerodynamic Test Stand - Electronics

Electronics Successes:

- Accelerometer (for error estimation) configured
- Amplifiers soldered to load cells

Electronics Issues:

- Load cell calibration trouble with Arduino
- Micro SD card module not saving data



Accelerometer configuration

In Progress

Dynamic Motor Testing

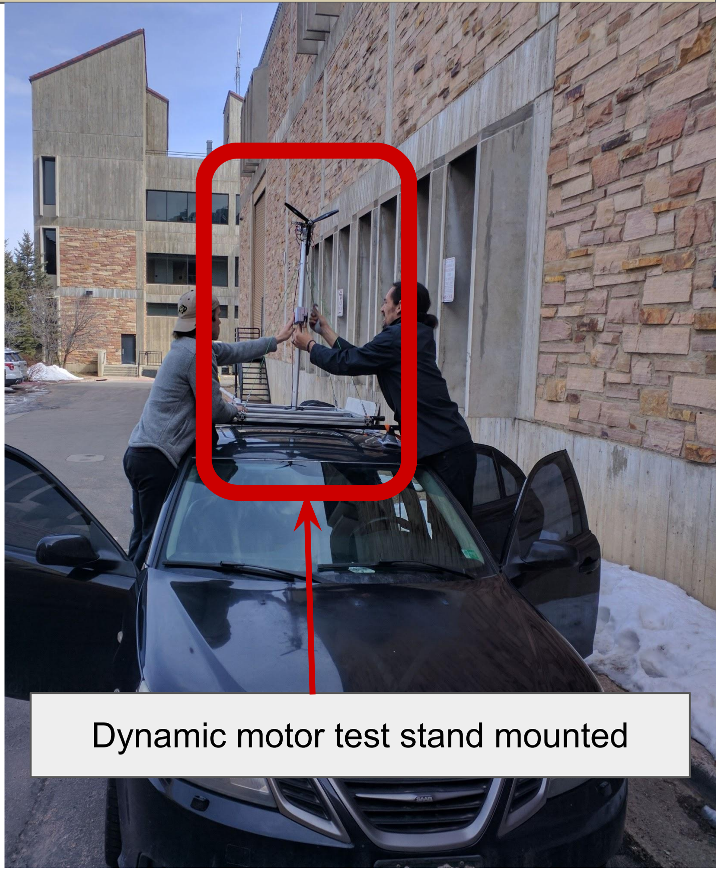
Summary:

- Test thrust requirements in dynamic cruise conditions (loss in efficiency)
- Using RC Benchmark software to track specific test properties
- Motor and load cells elevated on car top test stand traveling at cruise speeds (40 mph)

Testing Procedure:

- Similar to static test stand: configure battery, motor, ESC, and propeller
- Use RC benchmark software to manually toggle throttle power input

Planned 3/8



Dynamic motor test stand mounted

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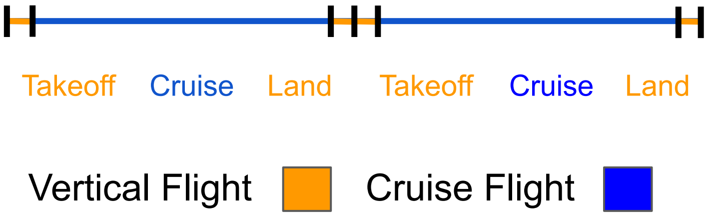
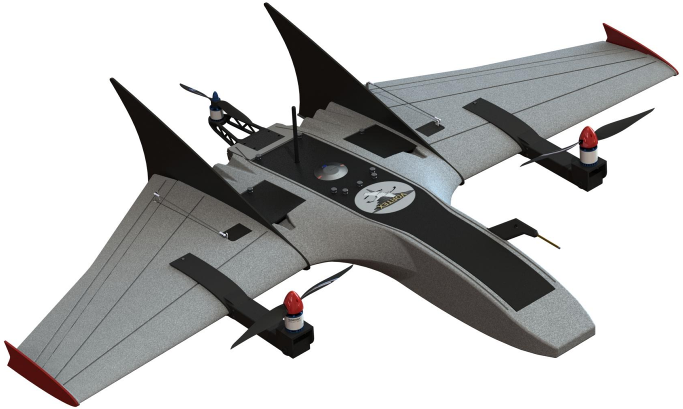
Future Tests

Flight mission profile

60 minutes





RAPCat Integration

Planned 3/21

- Verify the connector fits correctly
- Execute launch procedure
-

Hover Test

Planned 3/16

- Execute static full mission profile
- Show stability in hover

Full Flight Test

Planned 4/5

- Execute realistic full mission profile similar to CONOPS

Budget

Parts/Material Procurement

Important Parts	Application	Status
LiDAR Sensor	Avionics, Testing	Received
Servos	Controls	Received
Batteries	Endurance, Testing	Received
Front and Rear Motors	Propulsion	Received
Front and Rear Propellers	Propulsion, Testing	Received
Front and Rear ESCs	Endurance/ Propulsion	Received
Ritewing Drak Kit	Structures, Testing	Received

Important Parts	Application	Status
Ritewing Drak - Extra Wings	Testing	Received
Nuts/Screws/Bolts etc.	Manufacturing	Received
Aluminum Extrusion	Testing, Manufacturing	Received
LiDAR Test Stand	Testing	Received
Load Cells	Testing	Received
Adhesives	Manufacturing	Received
Misc Battery Fabrication Materials	Testing	Received

Parts/Material Procurement

Important Parts	Application	Status
Standoffs	Avionics, Testing, Flight	Ordered
SD Card	Avionics	Ordered
USB Connector Cable (Transmitter)	Avionics, Testing, Flight	Ordered
3D Printer Filament	Manufacturing	Ordered
Additional Propellers	Propulsion, Testing	Ordered
Additional ESCs	Propulsion	Ordered
Tail	Controls	Awaiting Test Data

Per Unit Budget

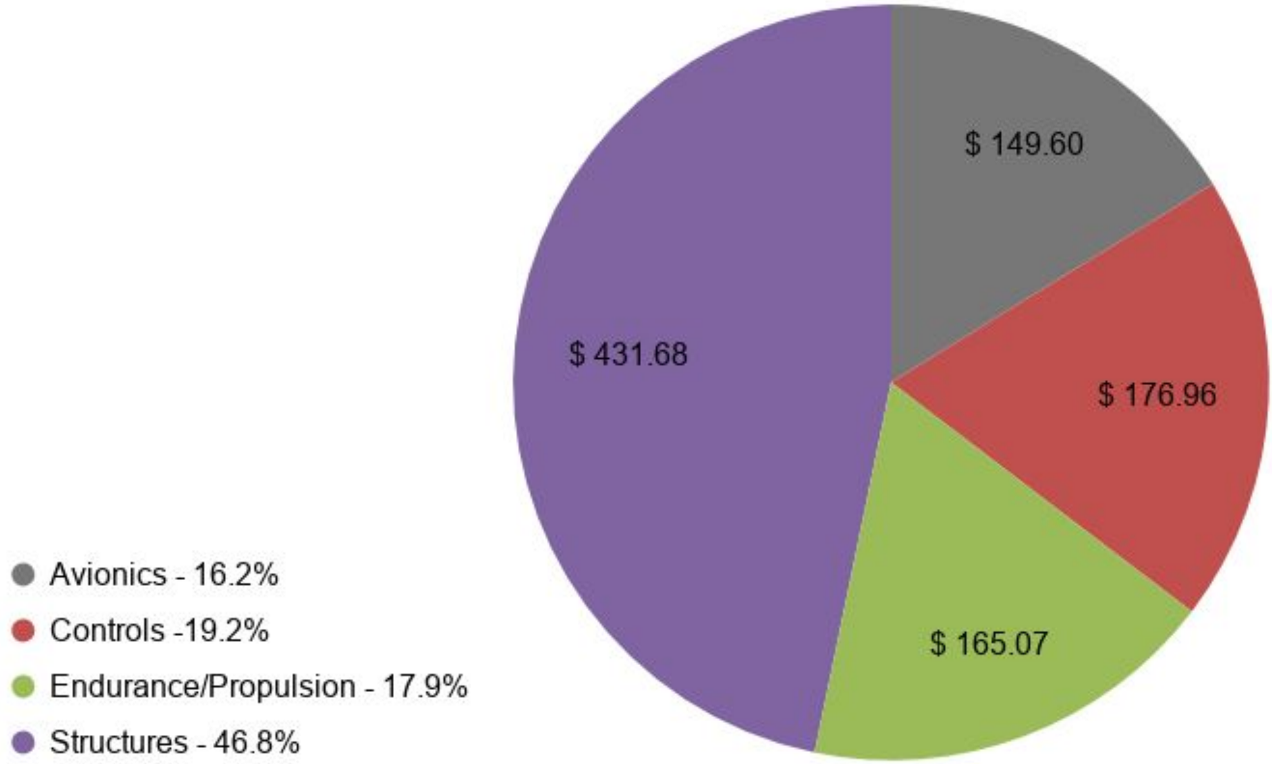
Unit Budget Breakdown:

Target Budget: $1,000.00

Avionics: $149.60
Controls: $176.96
Endurance/Propulsion: $165.07
Structures: $431.68*

Final Cost Per Unit: $923.31

***Note:** Includes rough estimate for cost of materials to construct tail.



Financial Status/ Budget

VORTEX Budget Breakdown:

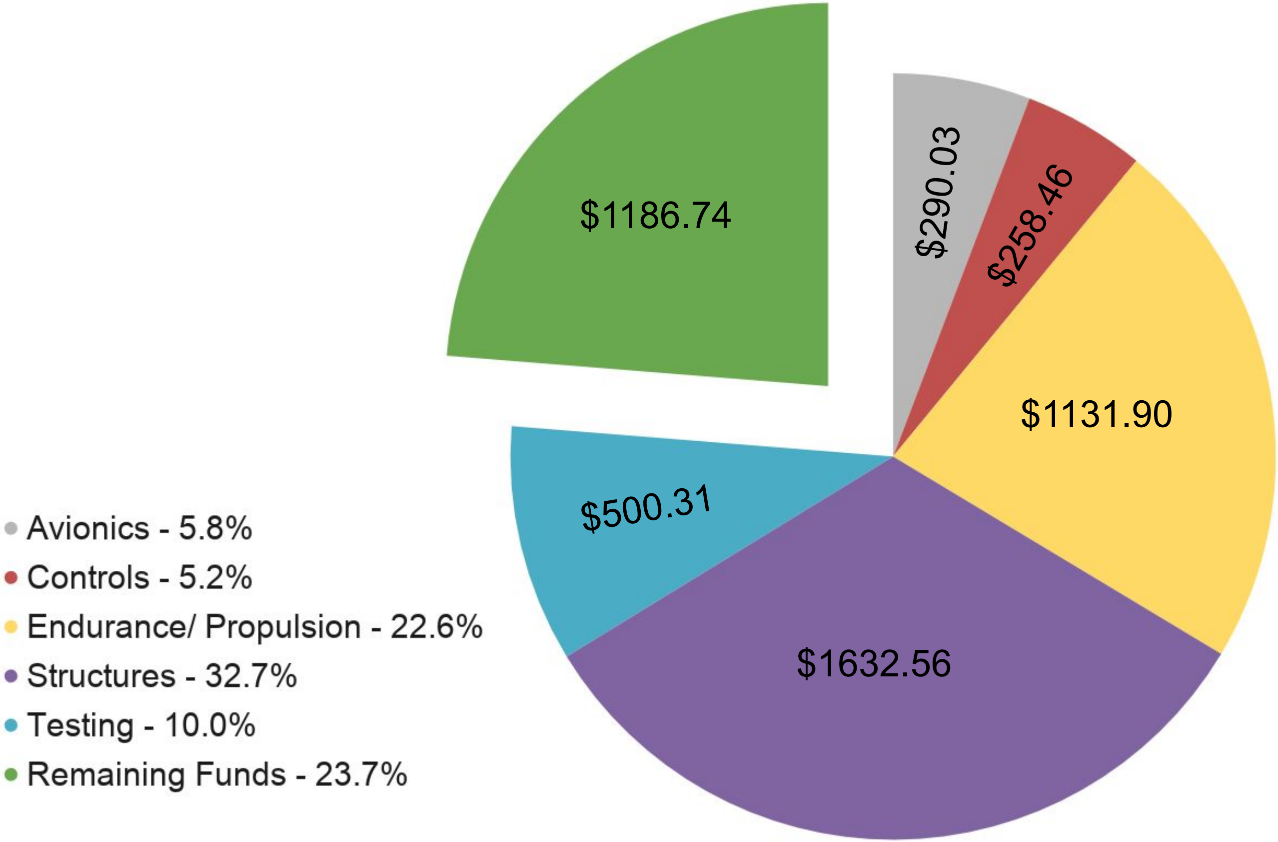
Total Budget: $5,000.00

Confirmed Purchases: $4,013.26
Pilot Lab Deposit: -$200.00 (assuming is returned)
Contingency Budget: $1000.00 *

Total Expenses: $4,813.26

Estimated Final Balance: $186.74

***Note:** Estimated final balance assumes entire contingency/complication budget is used.



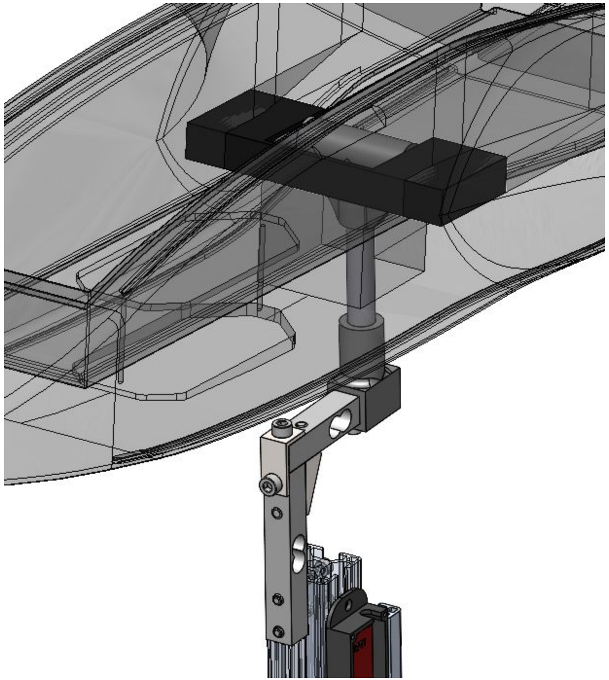
Thank You!

Questions?

Backup Slides

Aerodynamic Test Stand Adjustable Angle Bracket

- Internal bracket allows spar to slide forwards and backwards to change angle
- Horizontal carbon fiber rod slides inside internal bracket
- Internal bracket will be 3D printed out of PETG



Overview and Scope

The purpose of the early manufacturing stages with regards to the VORTEX project is to both build and test individual subsystems.

1. Assemble basic functioning subsystems
2. Assemble testing apparatuses
3. Test and simulate realistic performance against modeled performance

Moving forward, each subsystem will be iteratively improved to meet desired performance. Full system testing can begin.

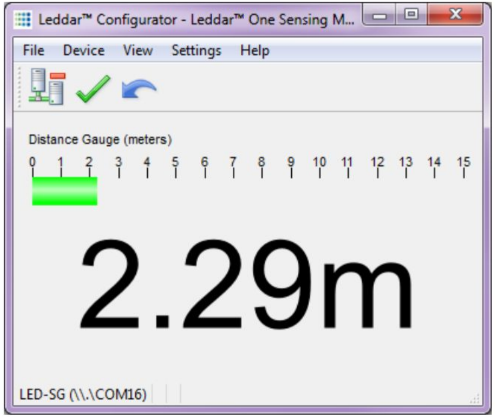
Subsystem	Testing Equipment
Autonomy	• Ardupilot • Pixhawk • LIDAR Test Stand
Structures	• Dynamic Test Stand
Propulsion	• Static Test Stand • Construction Battery • Dynamic Test Stand

Key
Software (in-house)
Custom Hardware (in-house)
Borrowed Hardware

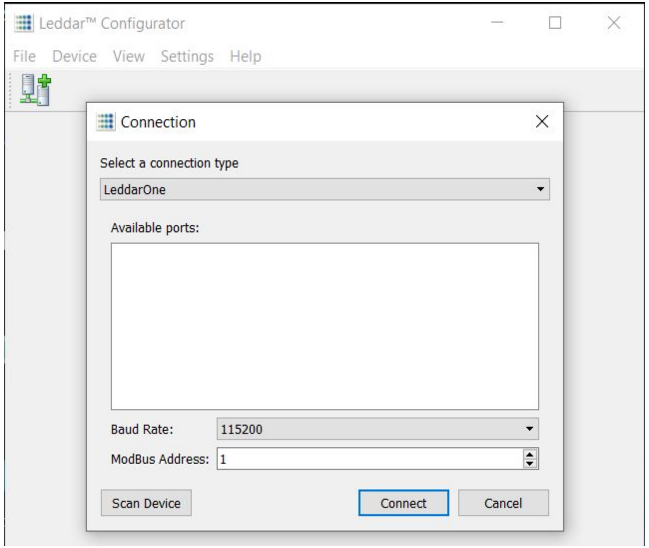
Testing the purchased LiDAR sensor to verify 10cm accuracy

LeddarTech Configurator
- Exports data to .txt file
- USB to UART cable to laptop

LeddarOne Sensor



LeddarTech Configurator



Canard vs Tail Trade Study

Options Considered
- Static Canard
- Static Tail
- Tail with Elevator

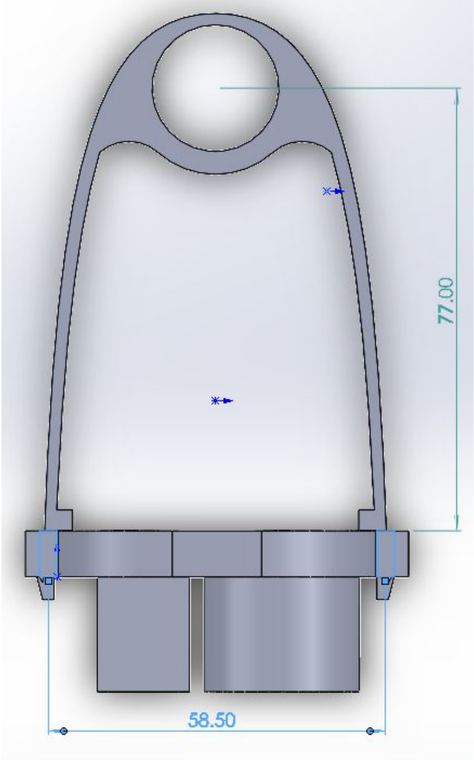
Tail with Elevator won out
- Reduces elevon deflection
- Used by IRISS
- Heavier than Canard though
- Easy to manufacture

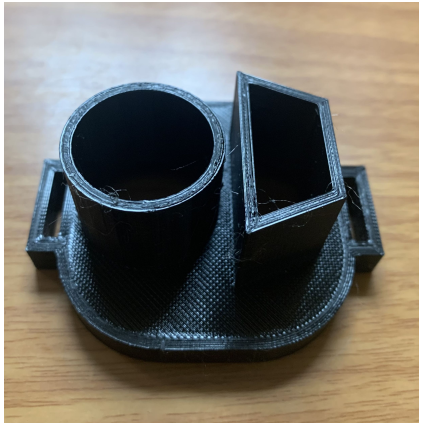
Criteria	Things to Consider	Criteria Weight
LIft and Drag Performance	• Trim Lift Deficit Calculations • Estimate Drag, NACA airfoil, Parasite, Induced, etc. • Effect on Elevon deflection at trim	25%
Stability	• Static Margin Calculations • Trim Moment Deficit Calculations • Stall performance • Static, dynamic stability	30%
Weight	• Weight of supplementary components ○ Servos, Spars, Foam • Shift in center of gravity	15%

Complexity	• Supplementary Components
	• Electronics
	• Structure required
	• Manufacturability
	  ○ Materials and Methods
	• Design Optimization
	  ○ Expected effort to optimize the design
		30%

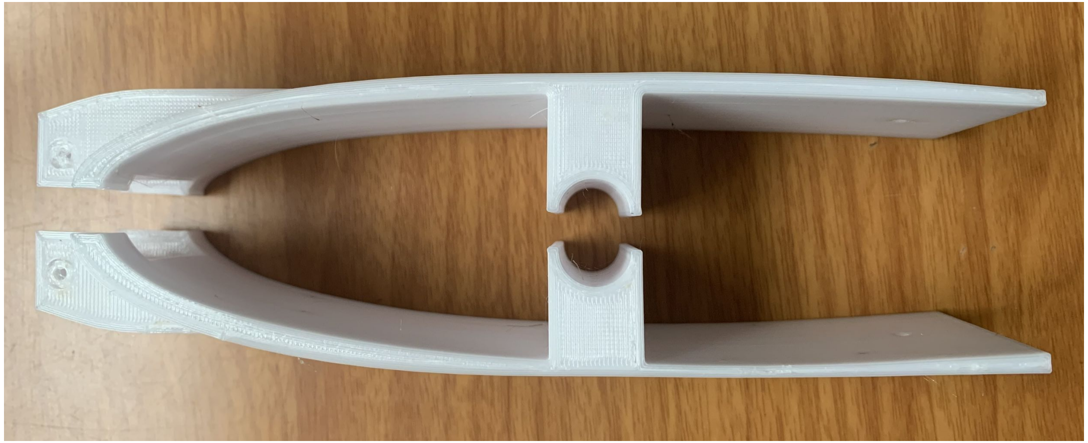
IRISS
INTEGRATED REMOTE & IN SITU SENSING

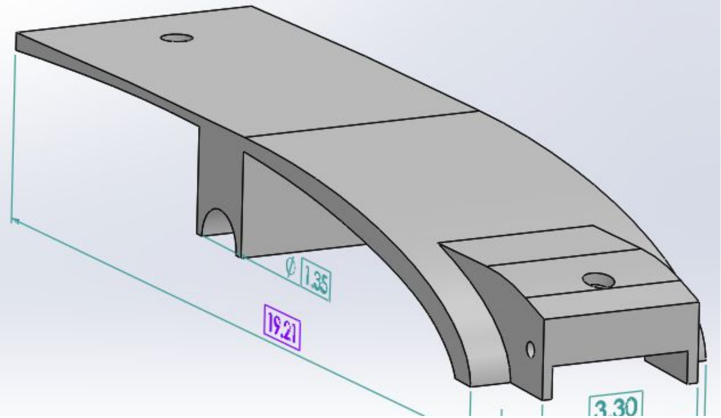
LiDAR Test Stand

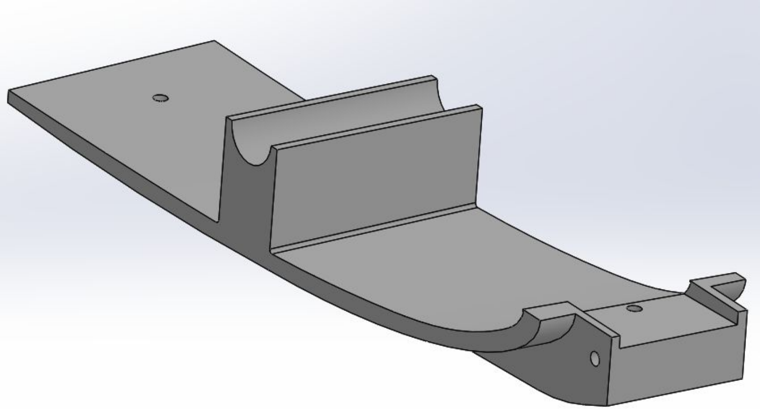




LiDAR Test Stand







Aerodynamic Test Stand - 3D Printed

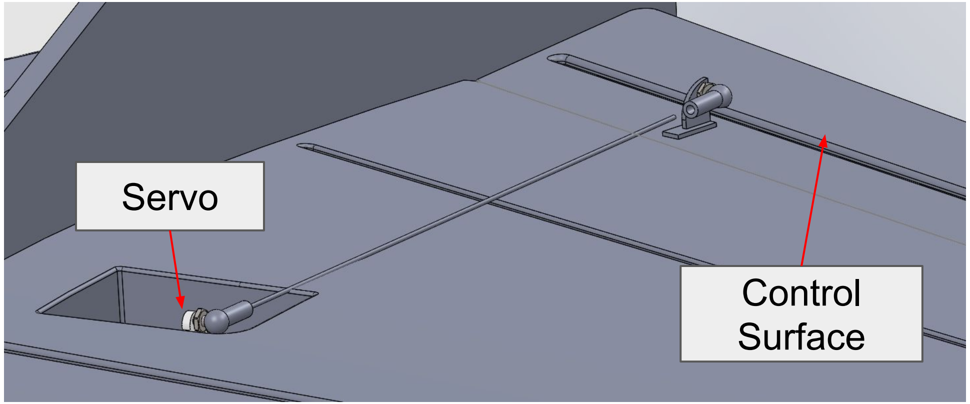
Custom Battery Progress

- On Hand:
  - Insulator rings
  - XT90 connectors
  - XT60 connectors
  - MT60 connectors
  - 10 AWG Wire
  - Wire Kapton tape
  - 100x LiPo battery cells
- Barriers to Progress
  - Balancing cable not delivered
  - Waiting on R2R
  - Spot welding to connect cells
  - Spot welder supplied by IRISS

Waiting on R2R approval and balancing cable to begin manufacturing

Manufacturing Extra Control Surfaces

- Control Surface
  - Same material and manufacturing method as horizontal tail
  - Mounted using Z-Tape
- Servo
  - Mounted inset into the horizontal tail
  - Connected to control surface same as wing
- Foam and servo still need to be purchased



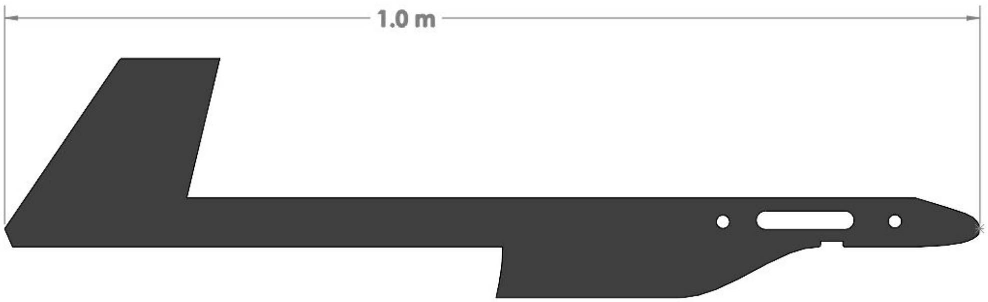
Mounting example from the wing

Manufacturing of horizontal tail and control surfaces is scheduled to be completed by Feb 11th

Manufacturing the Tail

- Cut Foam Horizontal Tail
  - CNC Hot Wire Foam Cutter
  - XPS foam

- Tail Booms
  - Laser Cut Coroplast
  - 8 mm thick



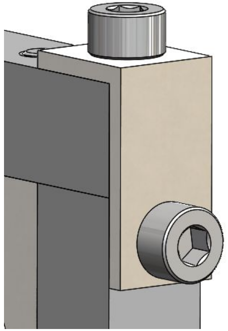
- Preliminary Dimensions (Subject to Change)
  - 1 m length
  - V_h= 0.6
  - S = 0.089 m^2
  - c = 0.22 m

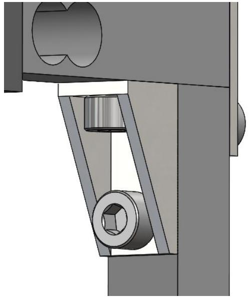
Aerodynamic Test Stand: Load Cells

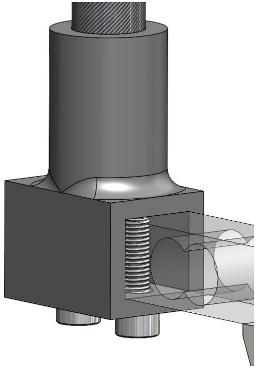
Manufacturing Sufficient Brackets

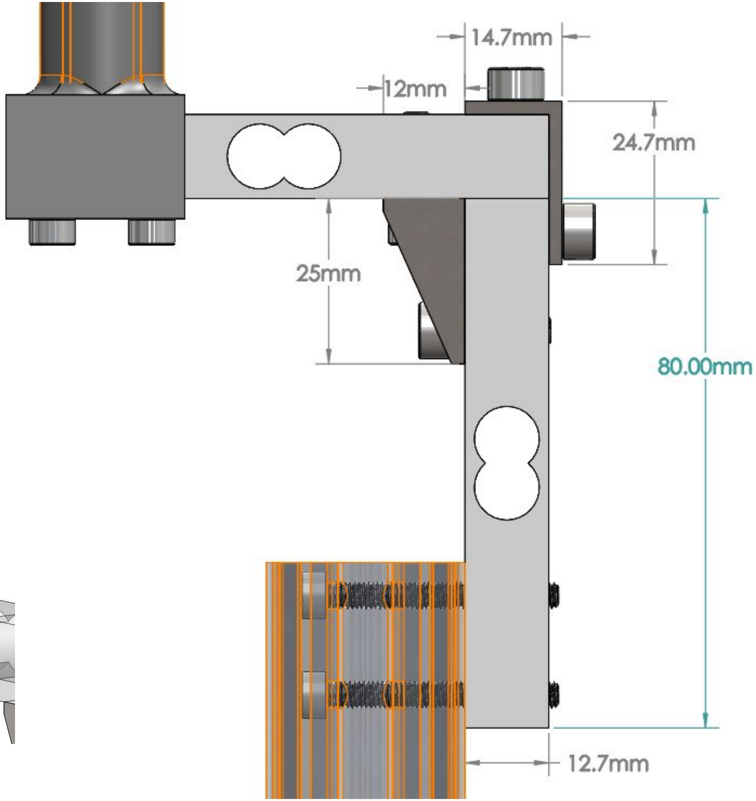
Solution:

- Nylon Alloy 3D print bracket for cell to carbon fiber rod
- 90° inner and outer brackets milled from a low carbon steel block







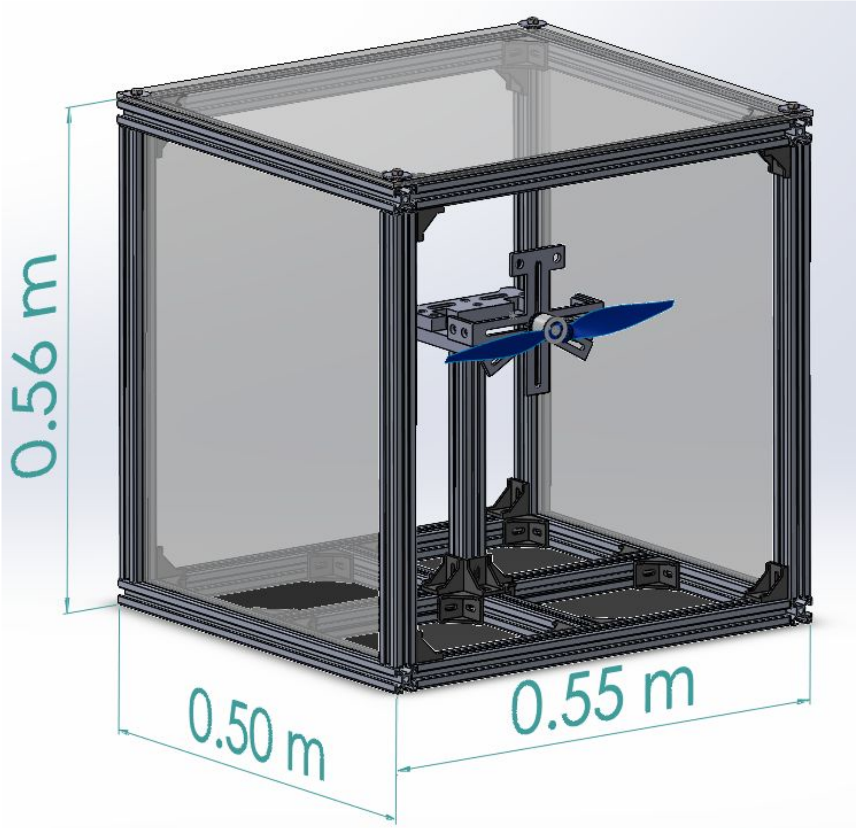


Aerodynamic Test Stand

Static Propulsion Test Stand

- Will be assembled by us
- Main Parts
  - Aluminum Extrusion
    - Cut to length/thread ourselves
  - 3 ¼” Acrylic Panels on sides
    - Cut to size ourselves
  - 1” wire screen for front/rear
  - Load Cell/Motor Mount Assembly
    - Lent by DBF

Cutting aluminum extrusion and assembling this week



Custom Battery Progress

Inventory

Still waiting for procurement on 1 major part

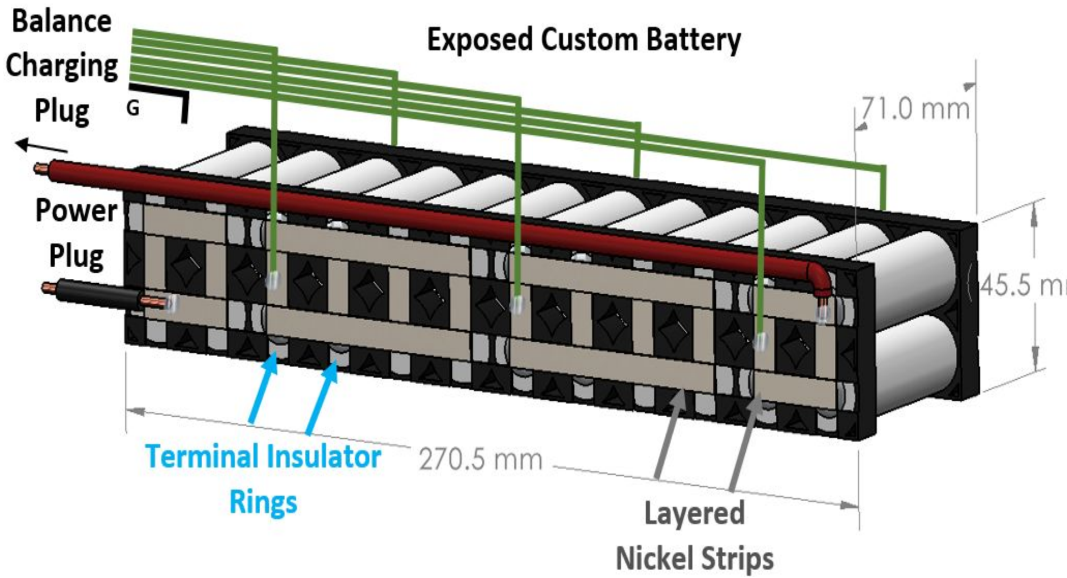
- Charging pin (delivery eta: **unknown**)

Deliverables

1. Single simple parallel cell testing (4 cells)
   Estimated time (1 hour)
2. 1st iteration full battery pack (24 cells)
   Estimated time (1 day)

Progress

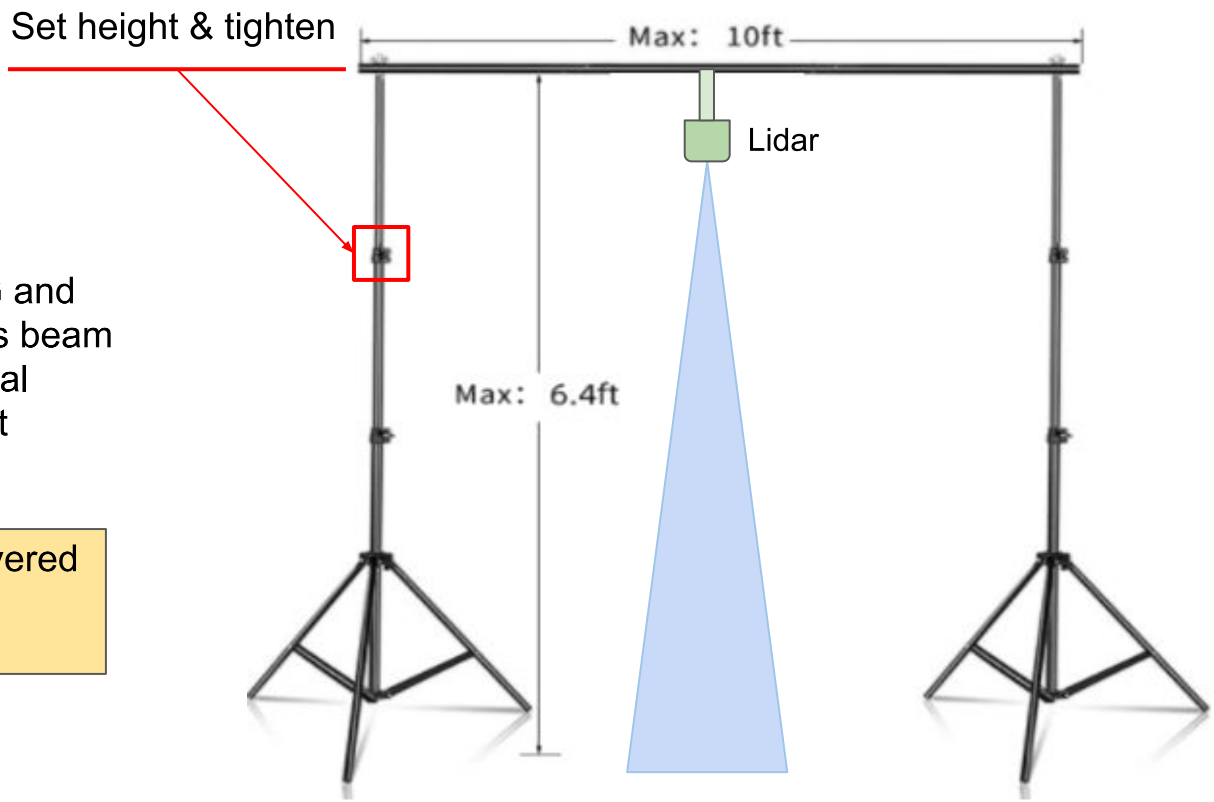
Waiting on R2R approval to begin manufacturing



LiDAR Test Stand

- Test stand has been purchased
  - Waiting on delivery
- Lidar Mount printed out of PETG and mounts to the center of the cross beam
  - Holds lidar sensor in vertical orientation at known height

Waiting on Test stand to be delivered
LiDAR mount printed
Assembled by Feb 5th

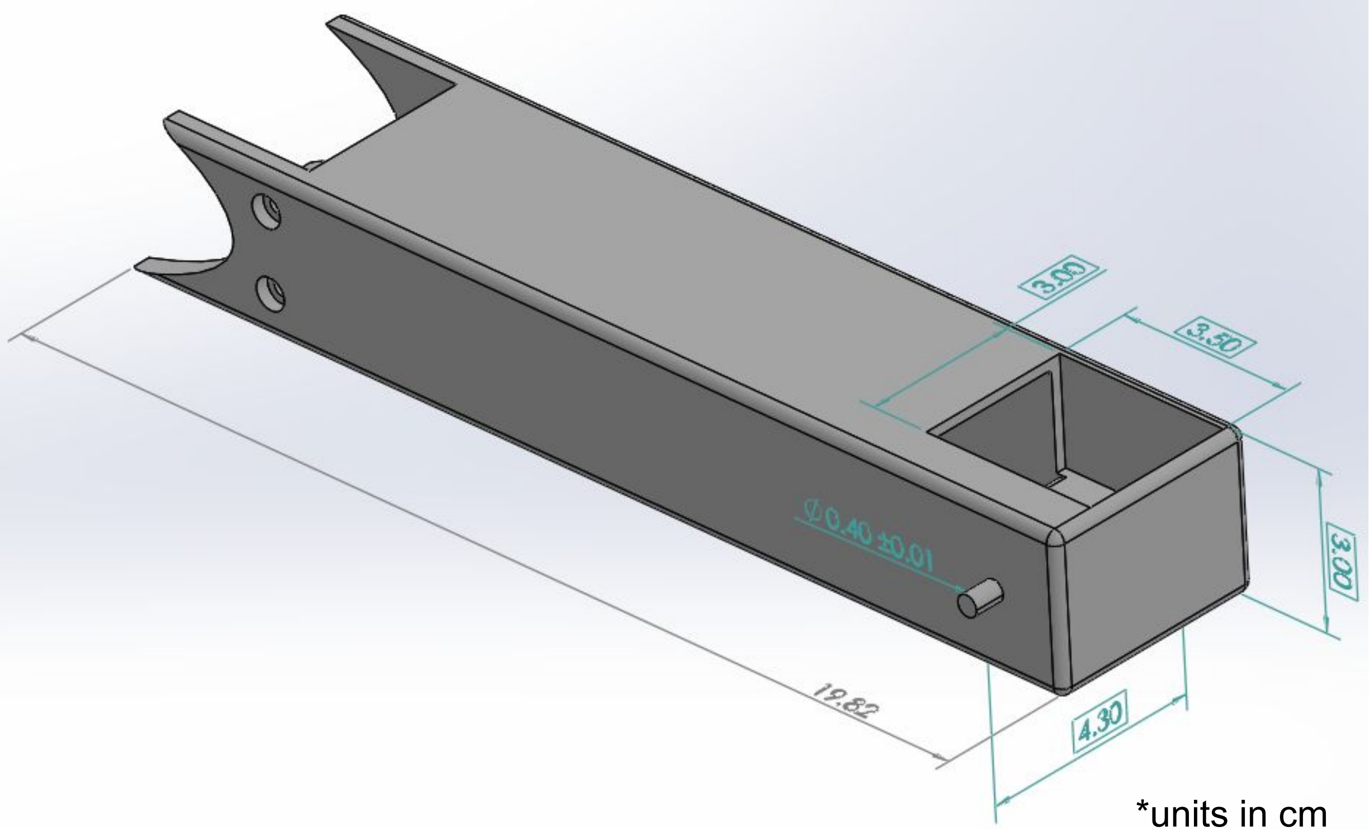


*Dimensions in mm

Motor Arm

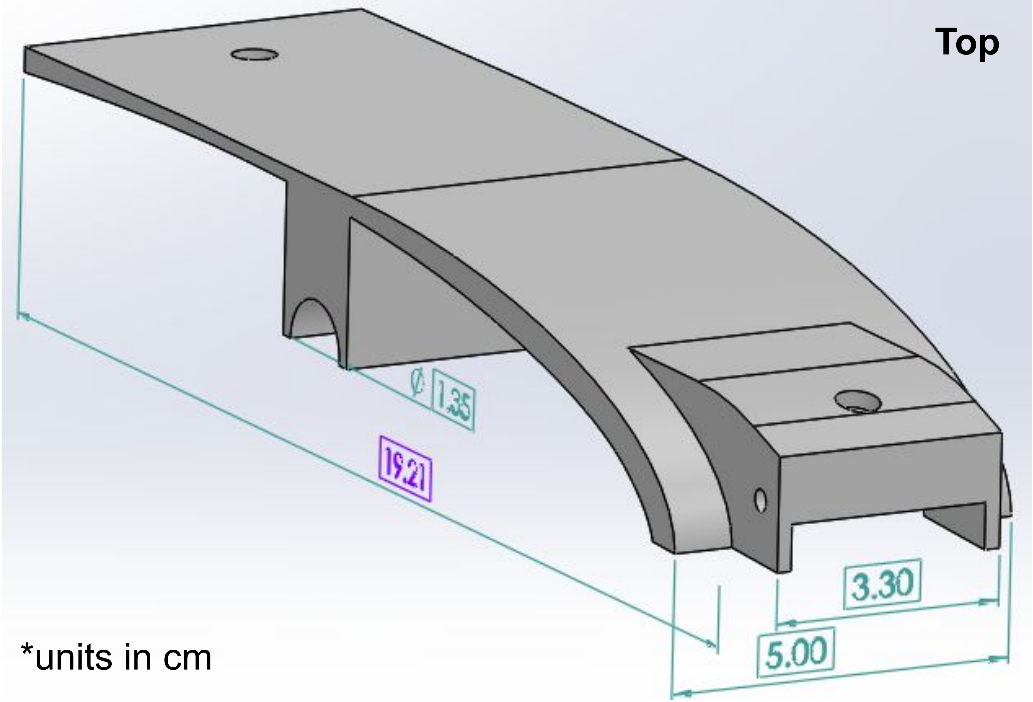
- Arm mounts printed out of PETG
  - ~10 hours each
  - Hollow to allow for wire channeling
- Motor arm attaches to wing mount by two horizontal 3mm bolts

To be 3D printed by Feb 5th



*units in cm

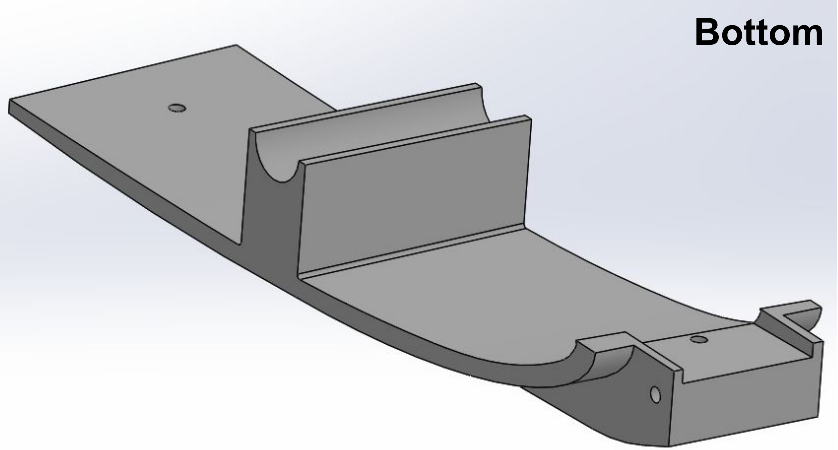
Wing Mounting



*units in cm

- Wing mounts printed out of PETG
  - ~12 hours total
- Wing mounts held together by glue and forward & rear 3mm bolts in the wing

One set is printed and ready to begin wing load testing



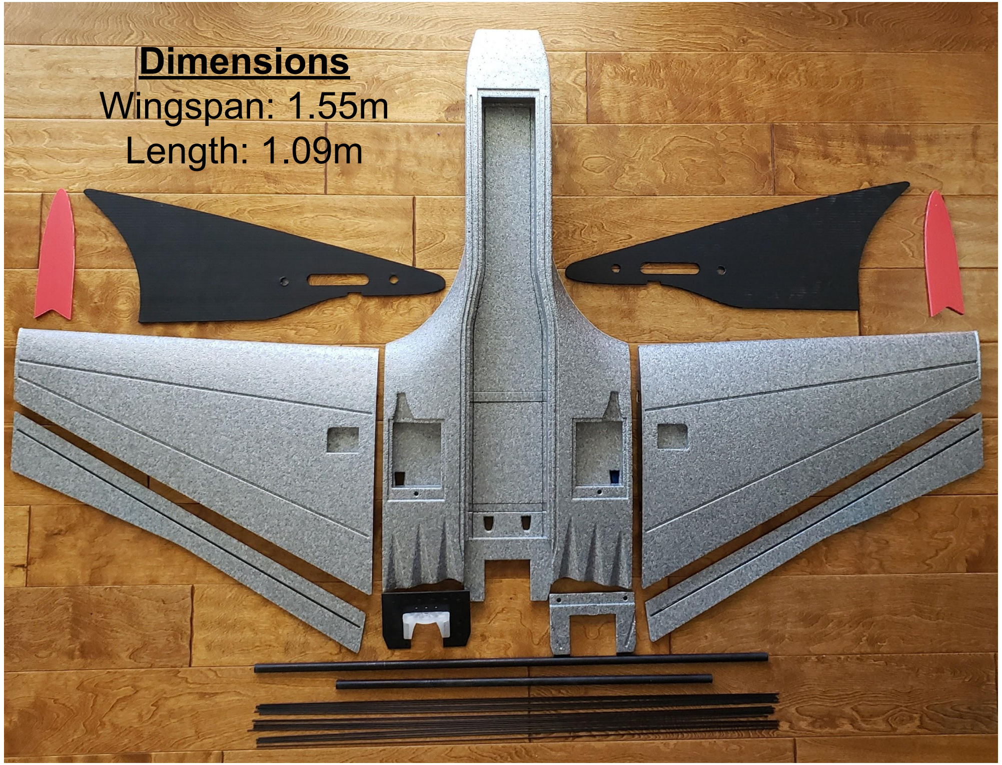
Overview and Scope

Component	Purchased or Manufactured	Manufacture Time	Completion Date	Status
Drak Wing Kit	Purchased/Assembled	~ 3 days	Feb 5th-8th	Waiting on Adhesive
Wing & Motor Mounts	Manufactured/Printed	12 hours	Jan 30th	Printed
Lidar Test Stand	Purchased/Printed	1 hour	Feb 5th	Printed, Waiting on Delivery
Custom Battery	Manufactured	6 hours	Feb 3rd	Waiting on R2R
Static Test Stand	Manufactured	3 hours	Feb 4th	Waiting on R2R
Dynamic Test Stand	Manufactured	4 hours	Feb 3rd	Waiting on Delivery

Drak

- Three Drak kits purchased and in our possession
  - Backups in case of damage during testing
- Extra wing set
  - Test wing mount loading
- Kit includes EPP foam body, coro-plast stabilizers, carbon fiber rods and spars
- Additional assembly tools
  - Adhesive
  - Tape for control surfaces

All Drak kits procured, waiting on adhesive to be delivered
To be assembled by Feb 5th-8th



Manufacturing/Testing Concerns

Category	Concern	Notes
Dynamic Test Stand	High	Primarily safety, Milling and cutting metal, Organizing testing space, Intense data processing
Static Test Stand	Medium	Safety, Experience with DBF propulsion testing, Shop work
Custom Battery Packs	Medium	Shipping parts. Battery pack performance after manufacturing. Safety
Motor Mounts, and Loading Test	Low	Uncertainty in FEM causing failure before the required loading.
Extra Control Surface	Low	Tail booms approx. 40 in, Hot wire foam cutting, Optimization Sizing, Ardupilot parameters