Solar Surfer

Demonstrating Net-Positive Energy Flight with Solar-Electric Seaplane

16.821 Spring 2023

2023/05/11

Picture by Matthew McGilllick

Part 1 - Aircraft Performance Review

- **Project Overview**
  - Context
  - Objectives
- System Overview
- Flight Test Overview
- Flight Analysis
- Conclusions

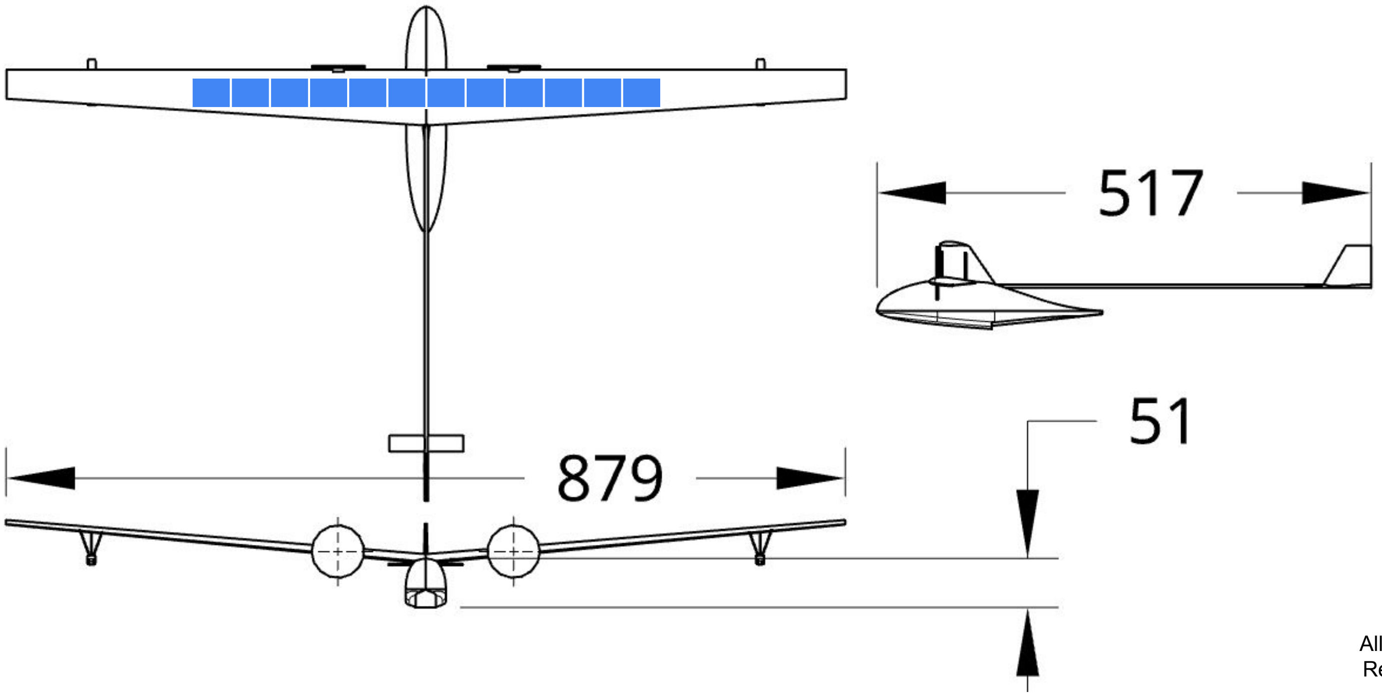
16.82 Ultralight Seaplane - SEAWAY

<u>Net-energy positive flight:</u>

- Large Wing Area
- Efficiency-first Wing
- Solar Panels Mounted on Wing Surface

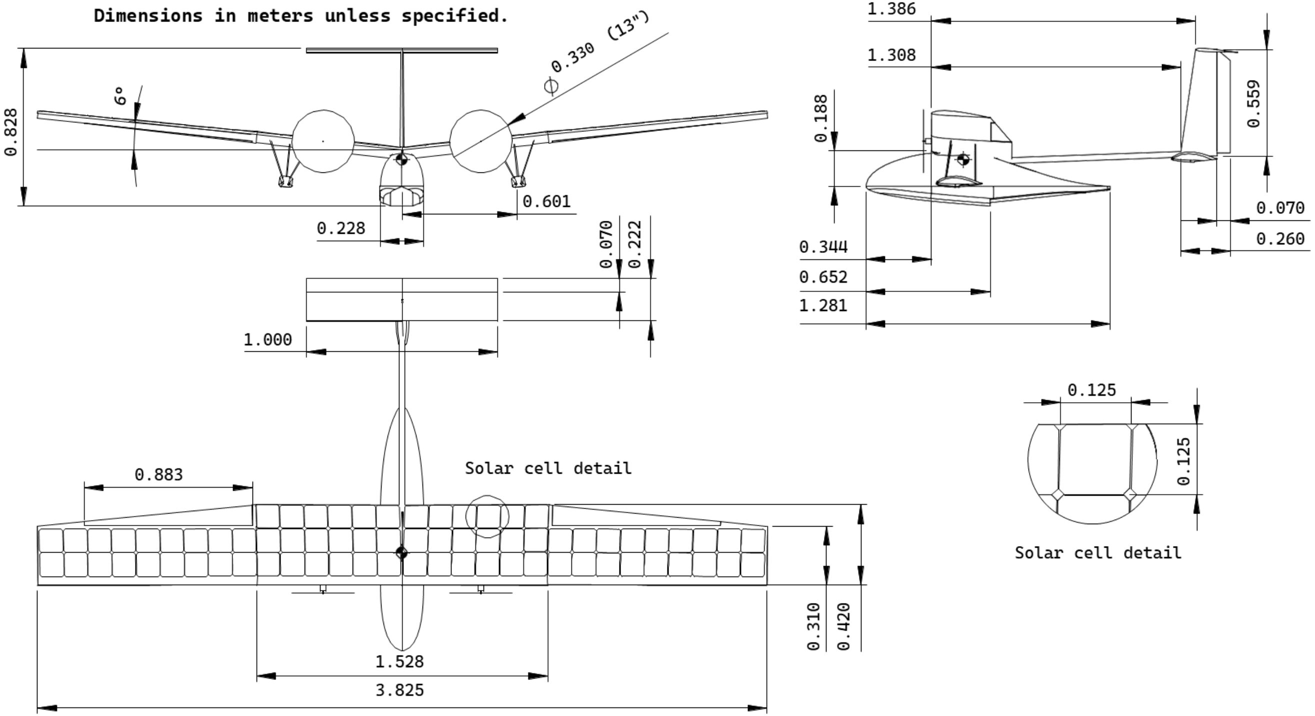
<u>Water takeoff and landing</u>

- Planing Hull
- Wing Floats
- Lifted Tail



All in inches
Rev. 9 12/8

Solar Surfer Point of Departure



Solar Surfer Mission Performance

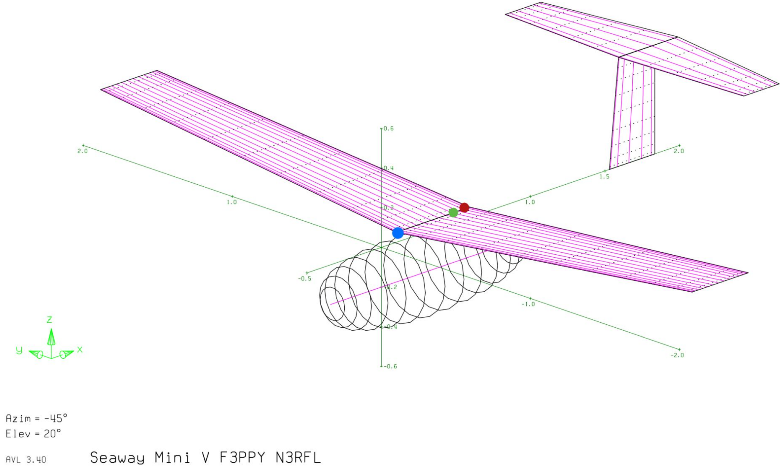
Mission Requirement	Requirement Met?
20% scale of SEAWAY design	Yes
Remote Control	Yes
MTOW less than 54 lbs	Yes
Water takeoff	Yes
Complete 360 degree turn in flight	Yes
Document takeoff, landing, and cruise performance	Yes
Document air and water handling	Yes
Demonstrate mission with no loss of net battery energy	Demonstrated in data

Part 1 - Program Review

- Project Overview
- **System Overview**
  - 3-View
  - Wiring Diagram
  - Build Documentation
- Flight Test Overview
- Flight Analysis
- Conclusions

Presenter: Joseph Ward

Visualization of Solar Surfer

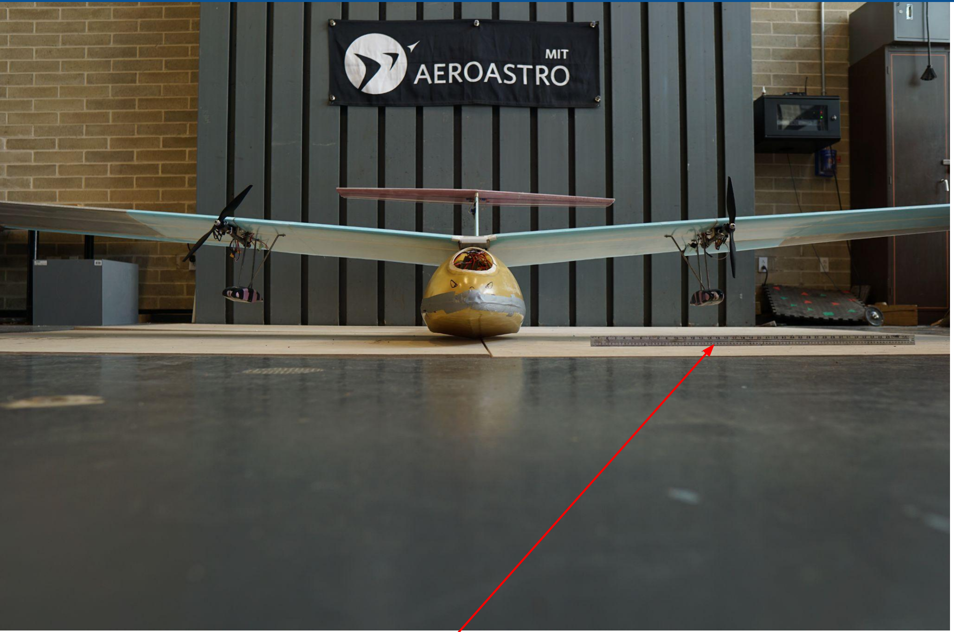


Modelled in AVL;
Origin: Blue
CG: Green - 41.1cm
NP: Yellow - 46.1cm

As-flown Statistics (May 3rd, 2023):

- Total Mass: 9.581kg
- Static Margin: 5cm ~ 11%
- Cruise Speed: ~27 mph
- Peak Speed: ~45 mph
- Takeoff Speed: ~20 mph

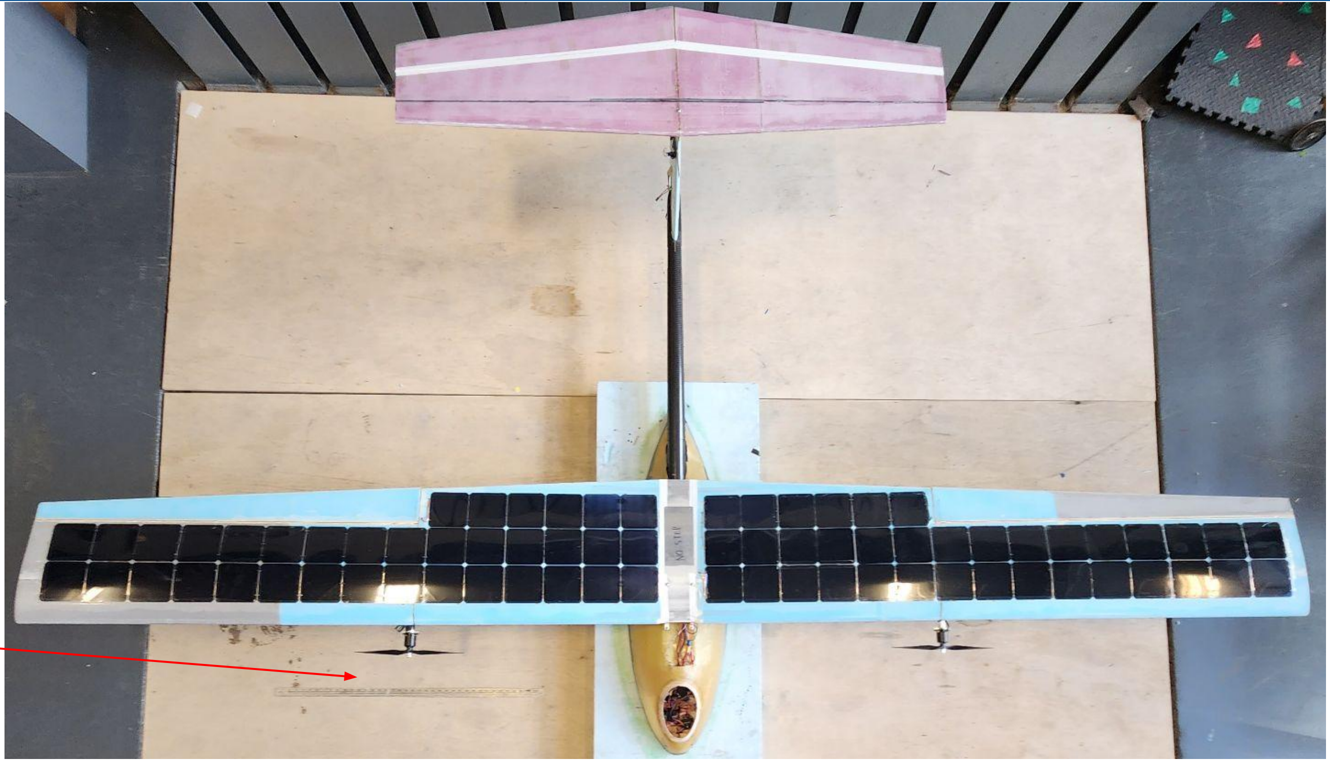
Threeview



Front View; Meter Rule for Scale

Side View ft. Cameron; Meter Rule for Scale

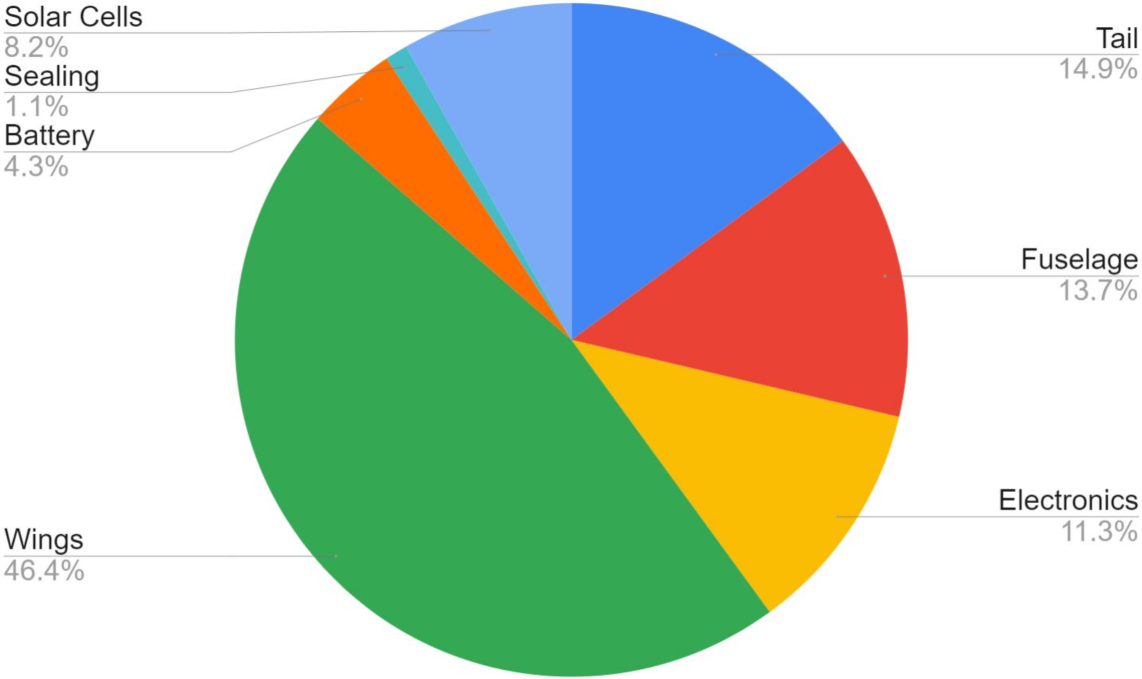
Threeview



Meter Rule
for Scale

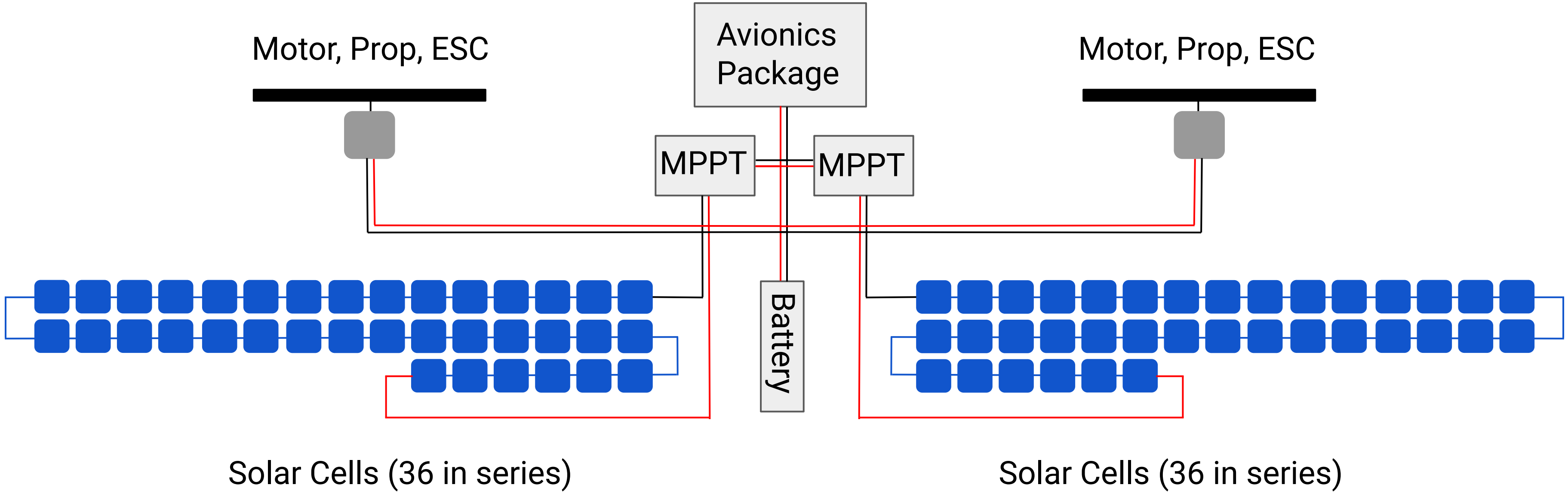
Mass Properties

Presenter: Joseph Ward



Component	Mass (kg)
Wings	4.3
Tail	1.4
Fuselage	1.3
Electronics	1.1
Solar Cells	0.8
Battery	0.4
Sealing	0.1
Total	**9.4**

Electrical Systems Overview



Part 1 - Program Review

- Project Overview
- System Overview
- **Flight Test**
- Flight Analysis
- Conclusions

Flight Test Plan Overview

Test 1: Performance & Flying Qualities (P&FQ)

- **How stable is our airplane?**
- **How controllable is our airplane?**

Test 2: Demonstrate Net Positive Energy Flight (NPEF)

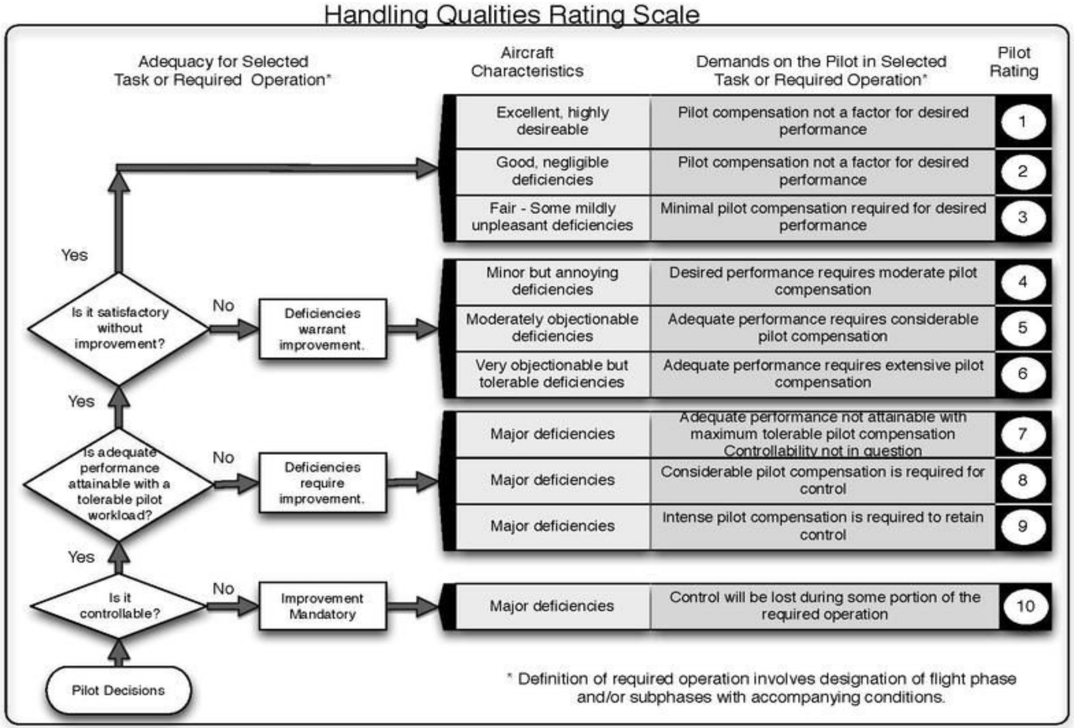
- **Can we, over a flight, generate more power than we use?**

Flight Test Execution Overview

1. Attempted **Water Handling**
    a. Failure, needed improvement
2. **Water Handling, P&FQ**
    a. Success!
3. Attempted **P&FQ**
    a. Failure, needed improvement
4. Attempted **P&FQ**
    a. Failure, needed improvement
5. **P&FQ**, Attempted **NPEF**
    a. P&FQ Success!
    b. NPEF Failure, will re-test in different weather conditions

Cooper-Harper Scale Analysis

- The four criteria we analyzed were handling for taxi, takeoff, in flight maneuvering, and landing



Test 1

Cooper-Harper Scale Analysis

Test 1

- Taxi : 10 (major deficiencies)
  - Poor roll control
  - Low airspeed
  - Nose dug into water
  - Steering with differential throttle
- Takeoff : N/A
- Flight : N/A
- Landing : N/A
- Comments
  - Would help if had yaw control without throttle

Modifications for Test 2

Nose digs into water due to mismatch of aero- and hydrodynamic design

The CG is forward of the center of buoyancy, digging the nose in

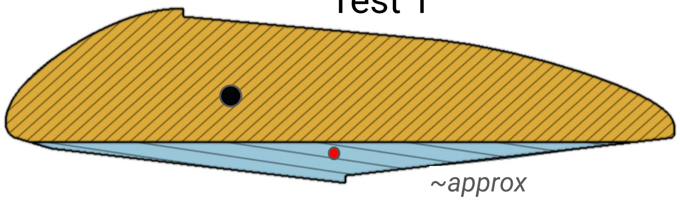
Fix: move the CG and neutral point back

→ Shift wing back, make the h-tail larger

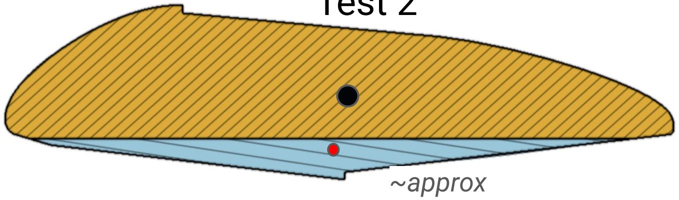
More context is found in the Fuselage build section

- Above waterline
- Below Waterline
- Center of Buoyancy
- Center of Gravity

Test 1



Test 2



Test 2

Cooper-Harper Scale Analysis

Test 2

- Taxi : 8 (major deficiencies)
  - Wobbly
  - High inertia, low power
  - Poor control power
- Takeoff : 4 (minor deficiencies)
  - Massively out of trim
  - 80% nose down and sensitive
- Flight : 3 (fair)
  - Overly sensitive in pitch
  - Roll is beautiful
- Landing : 2.5 (fair)
- Comments
  - “It’s like trying to steer around big mass with low force” - Mark Drela

Test 2 Modifications for Test 3

No airframe modifications were done.

Takeaways from Test 2 revolve around modifying the radio controller values of the aircraft. Specifically:

- Elevator trim set by pilot
- Elevator gain reduced (100 -> 70), expo added (0 -> 40)
- Aileron expo added (0 -> 20)
- Added more differential thrust authority, less expo (100 -> 70)

Expo = exponential control curve between stick position & PWM command (e.g. 2 units of moving the radio stick is 2^x units of PWM command)

Test 3

Cooper-Harper Scale Analysis

Test 3

- Taxi : 7 (major deficiencies)
  - Poor roll control because low speed
- Takeoff : 7 (major deficiencies)
  - Lack of roll control due to low power
- Flight : N/A
- Landing : N/A

Test 3 Modifications for Test 4

The low power on this takeoff run was due to lack of thrust.

Lack of thrust was inspected to be caused by the Left & Right motor “jittering” and not smoothly rotating or in some cases not rotating at all.

Cause of jittering: the power system was exposed to water despite not being waterproof, and so due to water ingestion some time before test 3 started, the ESCs needed to be replaced.

After replacing the ESCs and waterproofing the exposed power system, test 4 was ready

Test 4

Cooper-Harper Scale Analysis

Test 4

- Taxi : 5 (moderate deficiencies)
  - Keep wings level for roll control
- Takeoff : 2 (good)
  - In trim
  - Throws are good
- Flight : 2.5 (fair)
  - Lost control during flight
- Landing : 2.5 (fair)
  - Landed at a crosswind due to emergency landing
- Comments
  - Radio was glitchy
  - Control was bad when signal was lost

Test 4 Modifications for Test 5

This is the radio failsafe error, which will be expanded upon in the Avionics build section and backup slides.

Radio signal was attenuated due to improper mounting of the receiver when power components were being moved and fixed following test 2 and test 3 modifications.

The solution for the radio signal being attenuated was modifying the radio receiver mount to not include material that attenuates radio signal (kapton tape)

Test 5

Test 5

Cooper-Harper Scale Analysis

Test 5

- Taxi : 2 (good)
- Takeoff : 2 (good)
  - Prefers a bit more roll control
- Flight : 1 (excellent)
- Landing : 2 (good)
  - More roll control
- Comments
  - Flawless in control
  - Well damped
  - Handles nicely
  - Fully controllable

Test 5 Takeaways

Solar Surfer, as an airframe and unmanned aerial system, is ready for a demonstration of NPEF (net positive energy flight).

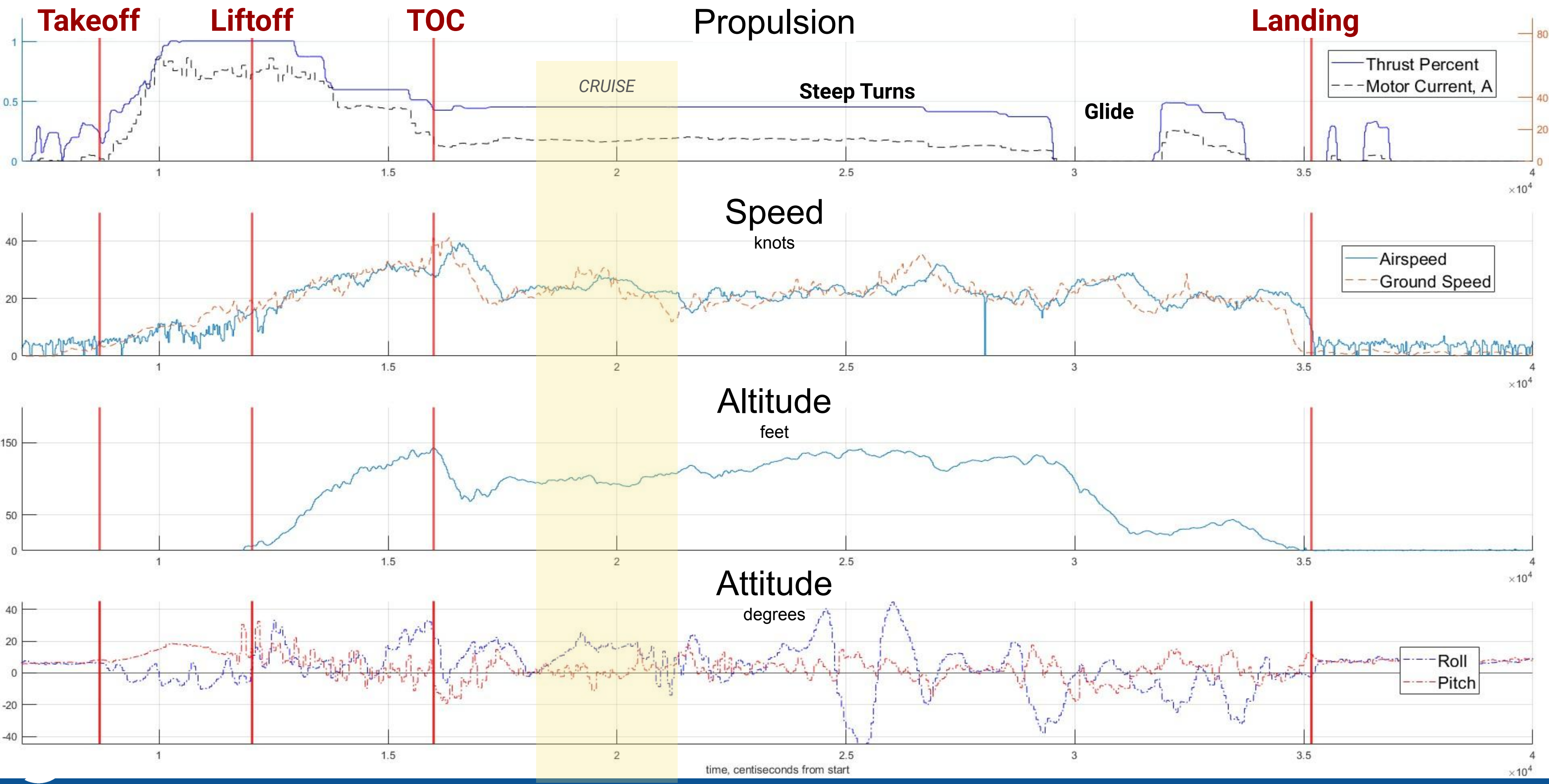
The demonstration itself being successful (ie showing NPEF flight) is dependent on if the data proves that NPEF is possible.

Part 1 - Aircraft Performance Review

- Project Overview
- System Overview
- Flight Test
- **Flight Analysis**
- Conclusions

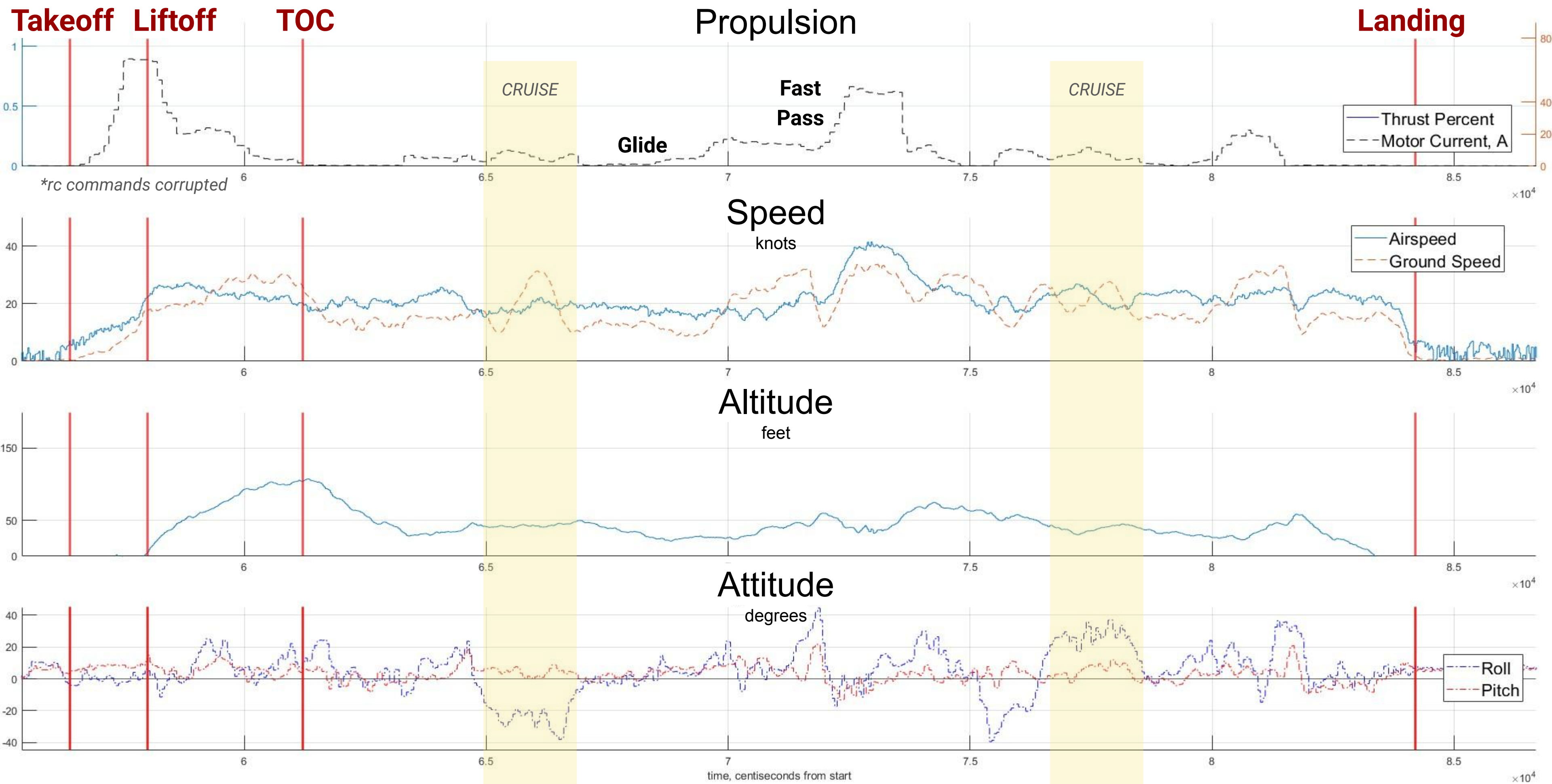
Contributor: Amira Malik

Test 2: Flight 1 Overview



Contributor: Amira Malik

Test 5: Flight 3 Overview



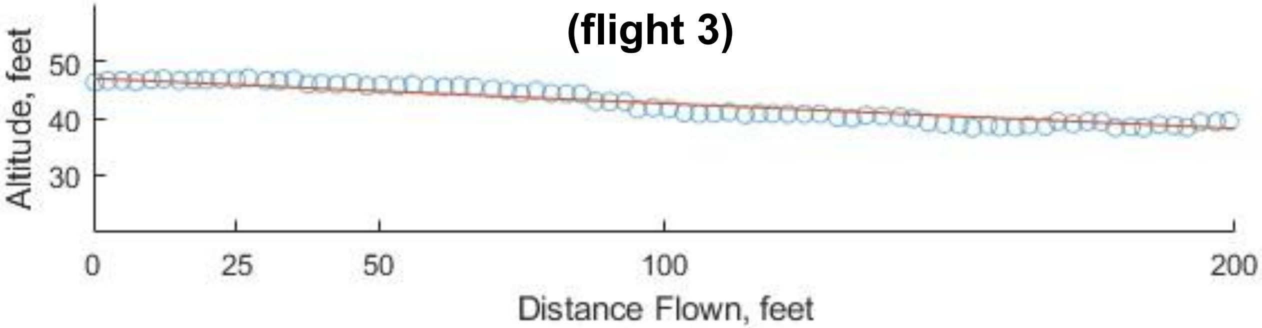
Meeting & Exceeding Aero Performance

	Design	Data Estimate
L/D	15-19	17-21
Drag Power	67 W	45 W
Total Power	75 W	80 W

Weather Conditions

Poor Solar Quality	Medium Solar Altitude 20% cloud cover 4000' 75% cover 6000' - 9000'
Light Head Wind	8 knots ENE
Few Thermals	10AM flight over water

Glide Profile (flight 3)

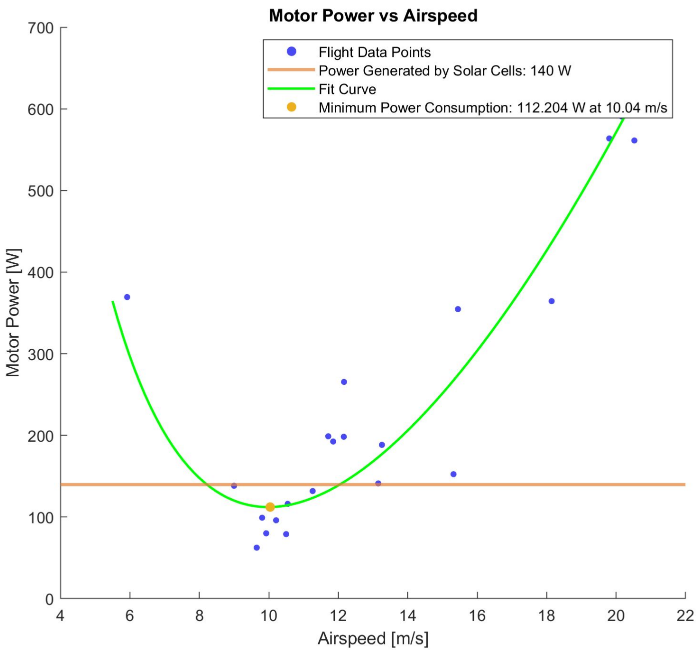


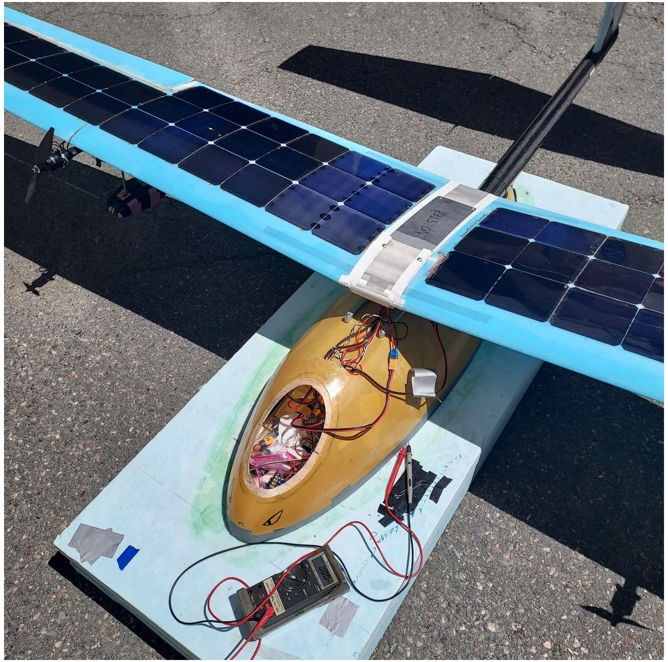
*Zero power

*Minimal stick input

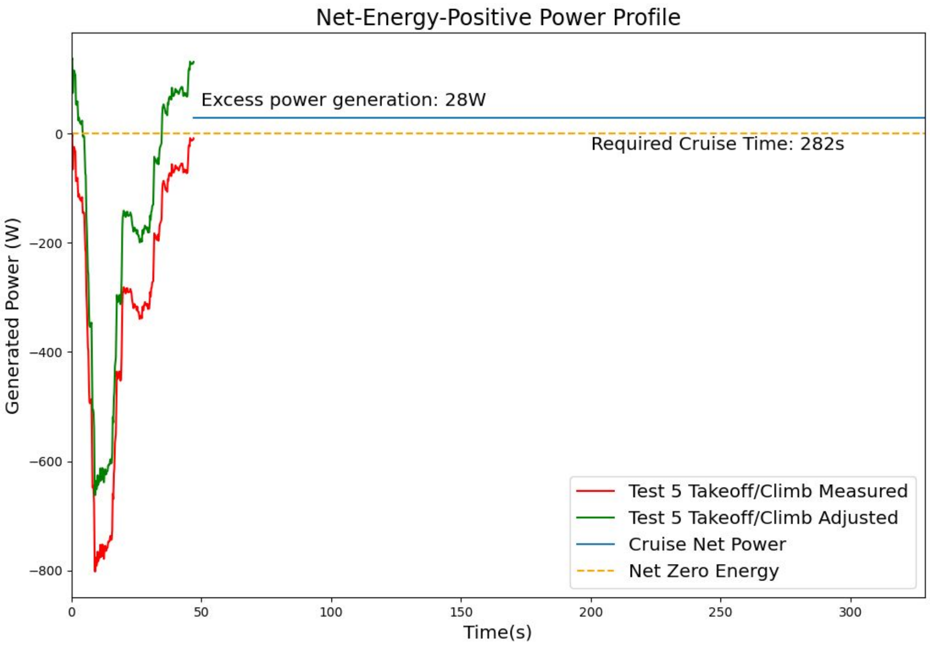
~670 to 680 seconds

Measured Power Generation and Consumption





Net-Energy-Positive Flight



Part 1 - Aircraft Performance Review

- Project Overview
- System Overview
- Flight Test
- Flight Analysis
- **Conclusions**

Conclusion

Solar Surfer the feasibility of the full-scale SEAWAY design including:

- Configuration flight performance and handling characteristics
- Ability to takeoff from and land on calm water
- **Potential for net-energy positive long distance flight**

Lessons learned and areas for future work

Potential to better characterize the Solar Surfer demonstrator:

- Need more test flights in varying weather and water conditions, takeoff and climb performance varied widely
- Need more handling quality and glide tests to better model aerodynamic characteristics
- Need flights in better solar conditions to demonstrate net-energy positive flight

Program-level improvements on schedule risk and critical path analysis

Number of systems-level improvements identified in the following build briefing

Presenter: Joseph Ward

Overall Brief Outline

Part 1 - Aircraft Performance Review

- Project Overview
- System Overview
- Flight Test Overview
- Flight Analysis
- Conclusions

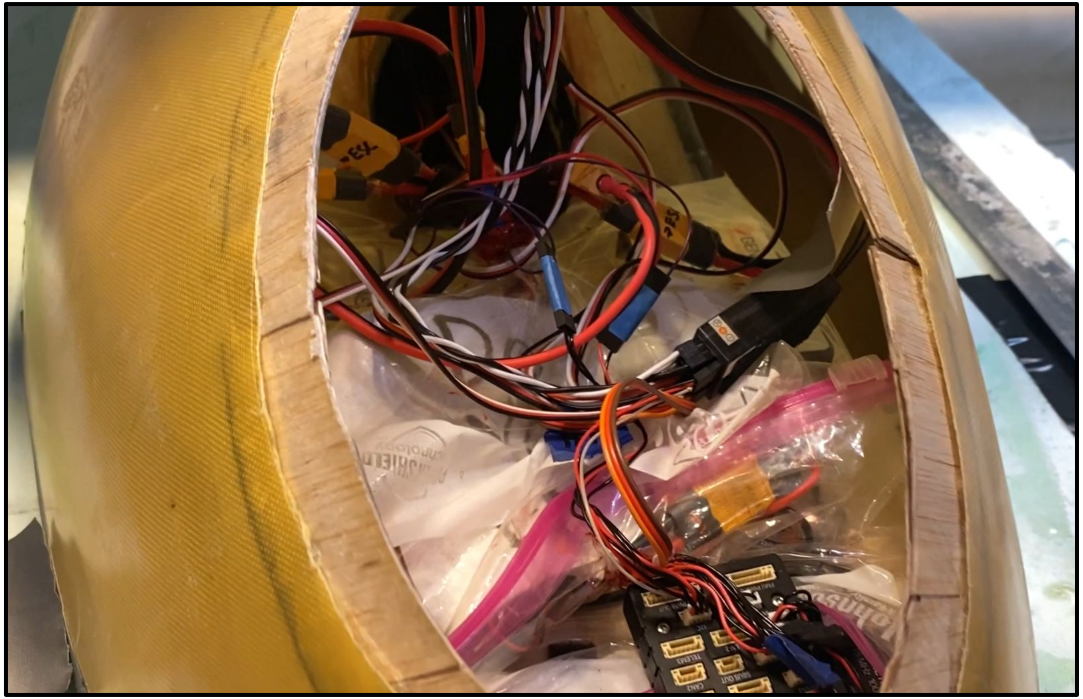
Part 2 - Build Review

- Avionics details
- Power details
- Wing details
- Tail + boom details
- Fuselage details

BUILD REVIEW

AVIONICS

Avionics: “The Brain”



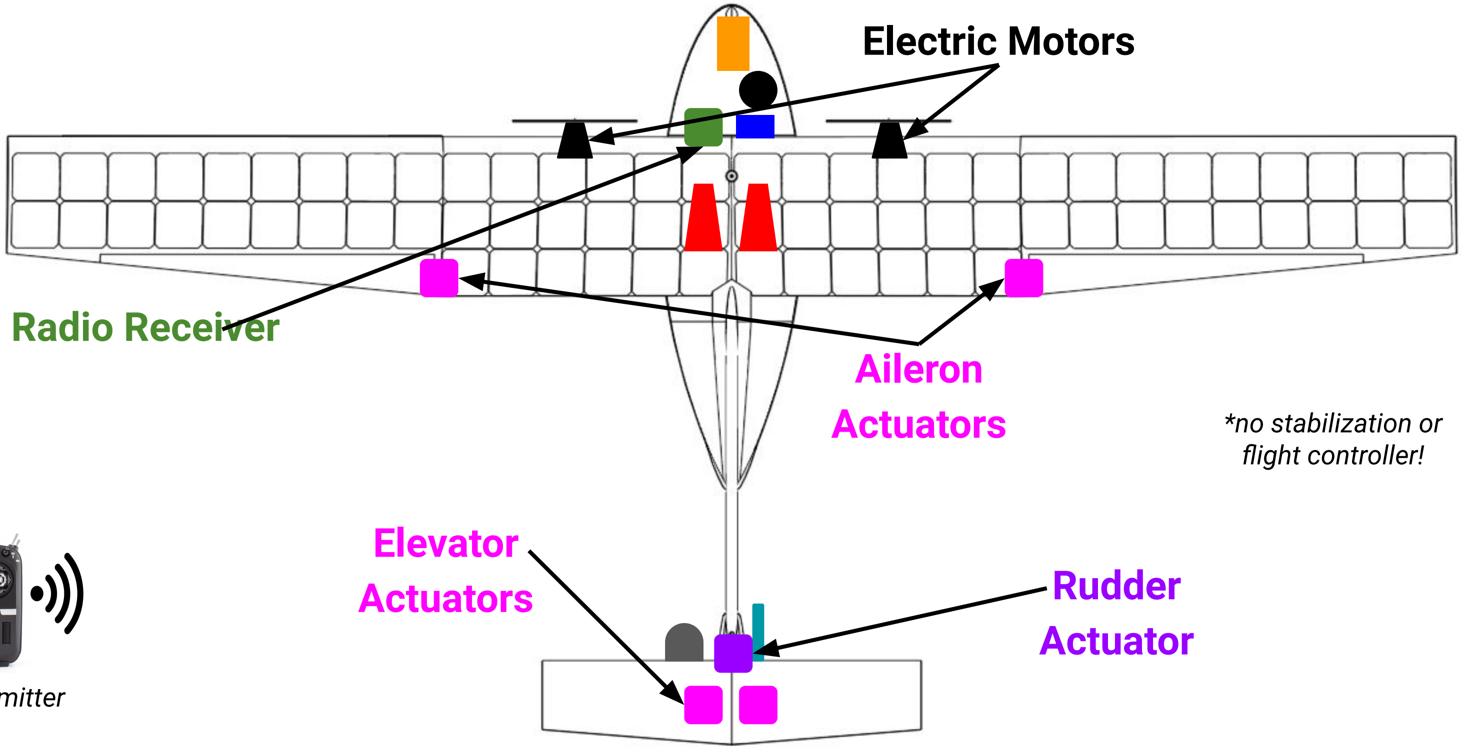
Control the Airplane
with pilot commands

↓

Collect & Send Data
from sensors

Photo by Matthew McGillick

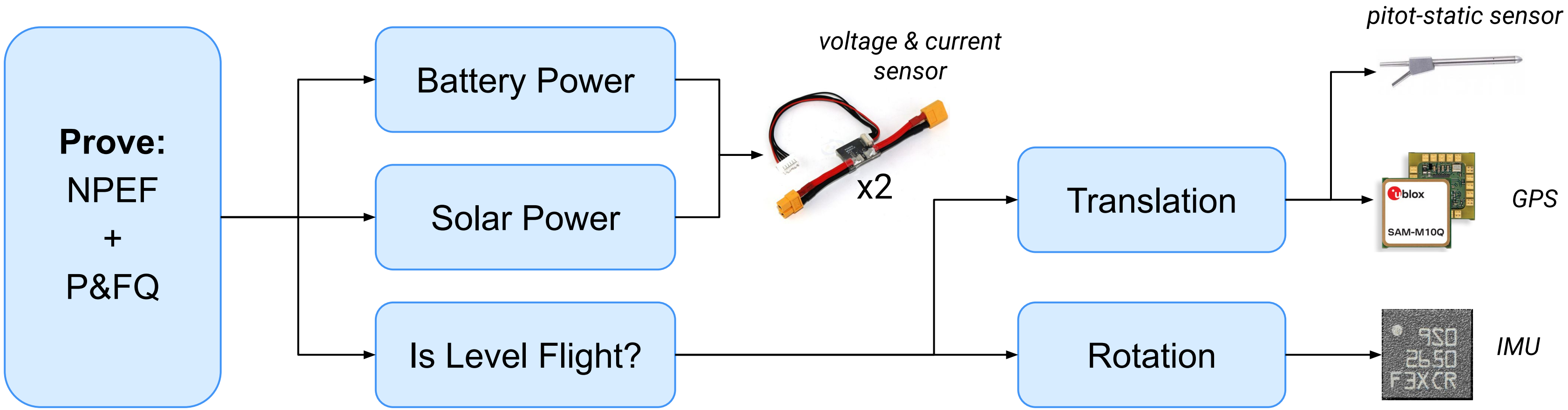
Control the Airplane



no stabilization or flight controller!

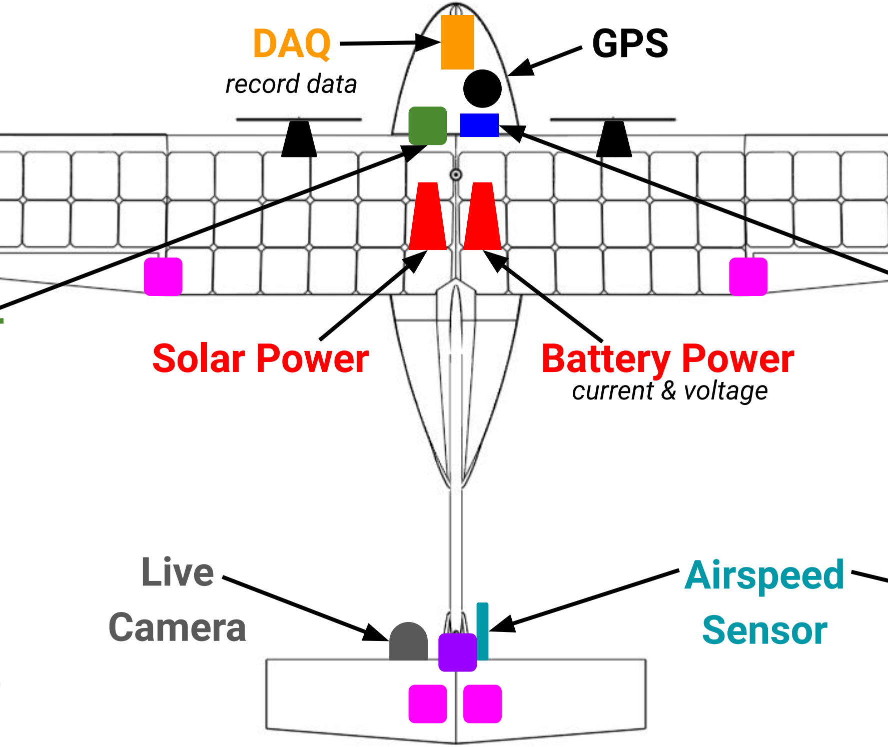
Radio Transmitter

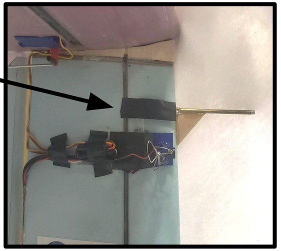
Analysis Requirements drove Instrumentation



All images from HolyBro and Adafruit

Collect, Store, & Send Data

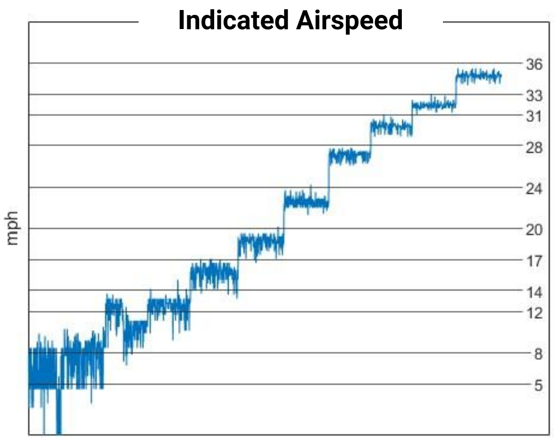


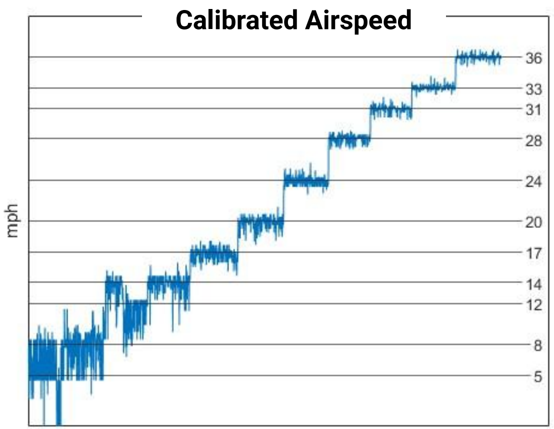


Camera Feed

Telemetry Station

Sensors Calibration: Pitot-Static System





- Low sensor accuracy under 12 mph
  - 18 mph stall speed, so this is acceptable
- Less sensor noise at higher speeds

Performance meets Expectations

Verification

Smoke Test

Confirm:
- Proper wiring
- Current & Voltage

Mock Flight

Confirm:
- Sensors working
- Data is logging

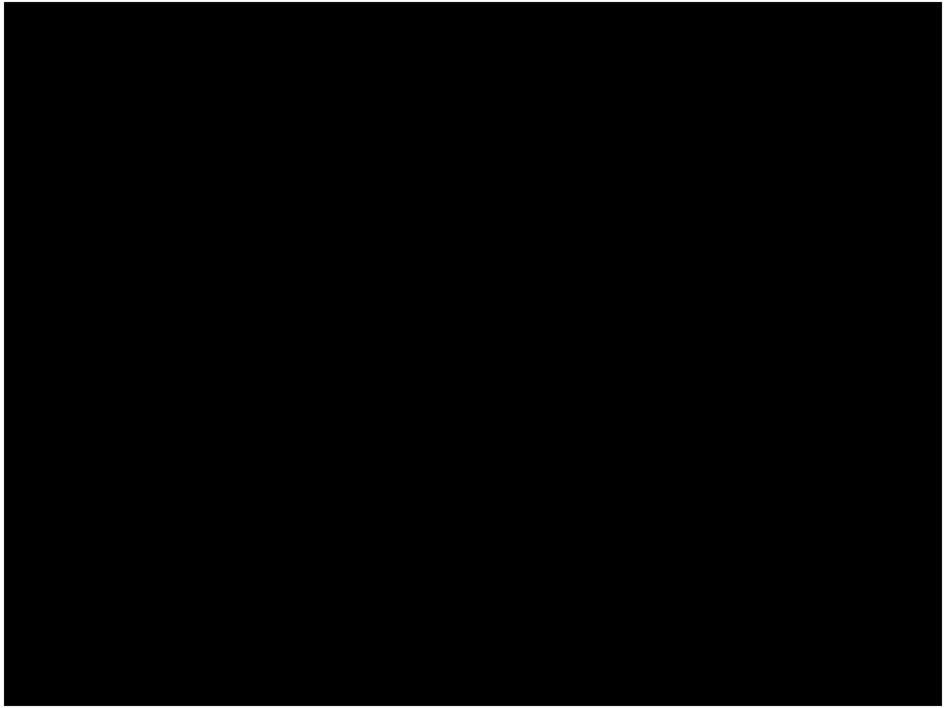
Range Test

Confirm:
- Radio signal range
- Sensor calibration

Validation

Confirm:
- Airplane is controlled
- Data is collected
- Analysis is possible

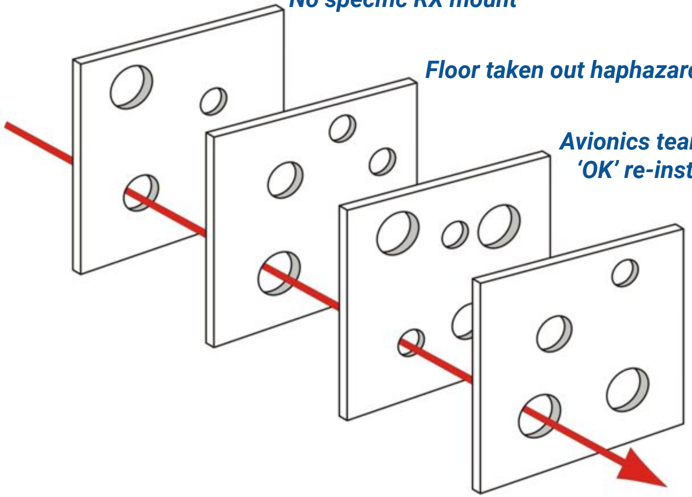
Test 4 Flight 2 Mishap: Partial Radio Signal Loss



Videos & Narration by Olivia Tobin and onboard camera; Edited by Amira

Test 4 Flight 2 Mishap: Partial Radio Signal Loss

cause: **Radio Signal attenuated by Kapton tape**



Other Problem:

- Radio "signal-loss" default values did not account for pilot trim

Solutions:

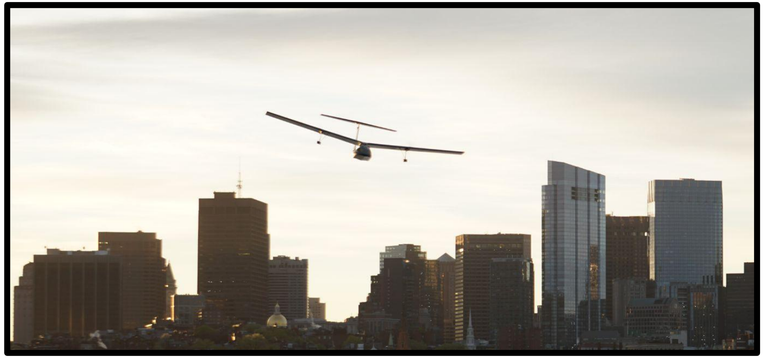
- **Make a specific** antenna mount
- **Require check from Avionics** upon reinstallation
- **Range check** after any modification

Crash averted due to luck that the signal loss was not total & continuous

Avionics Today & Tomorrow

These solutions ***were*** implemented because…

The plane flew!



The plane came back!

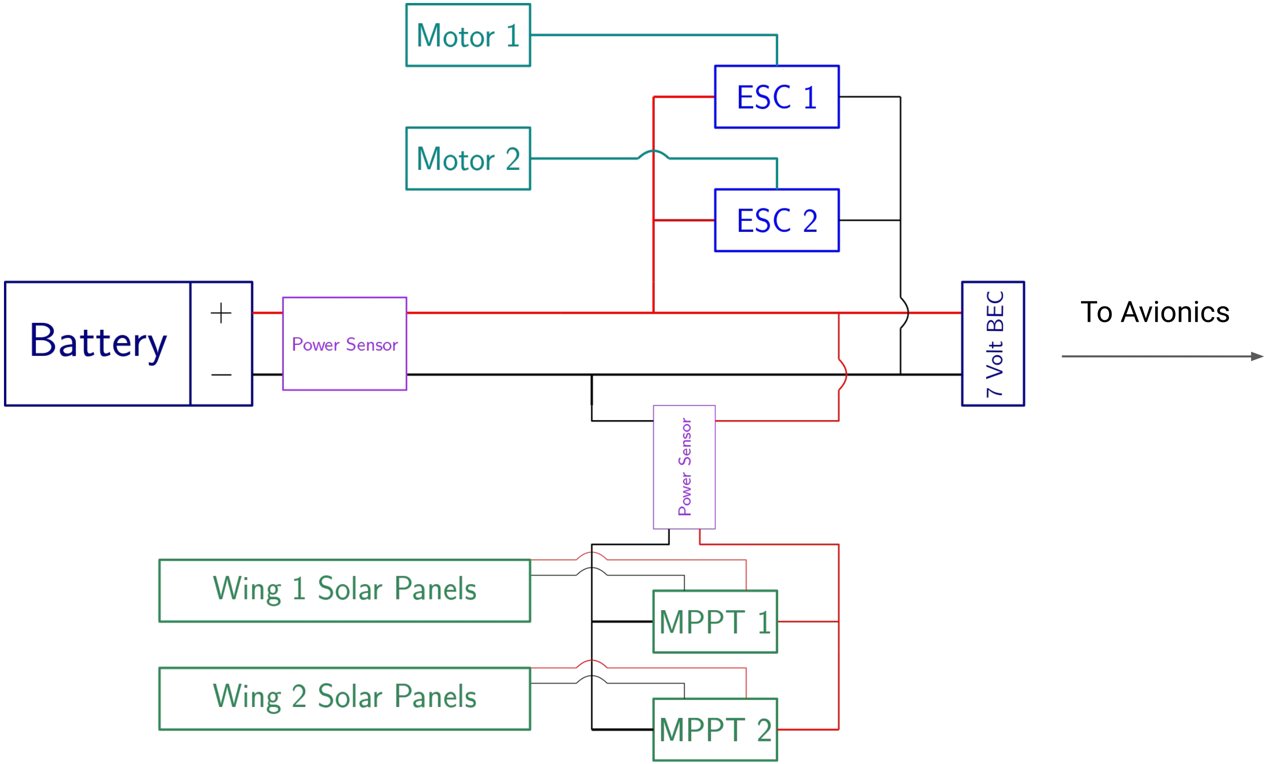
Avionics are ready for the next flight, and the next 100 flights

Photos by Matthew McGillick

POWER

Presenter: Madison Bronnimann

System Overview



Contributor: Will Kupiec

Presenter: Madison Bronnimann

Prop/Motor Selection

QMIL/QPROP Theoretical Analysis

↓

Candidate Propellers: 13” to 15”, Pitch 6-10
Candidate Motors: 550-800 Kv

↓

Wind Tunnel Testing

↓

Selected Propeller: 14”x8.5
Selected Motor: 700 Kv

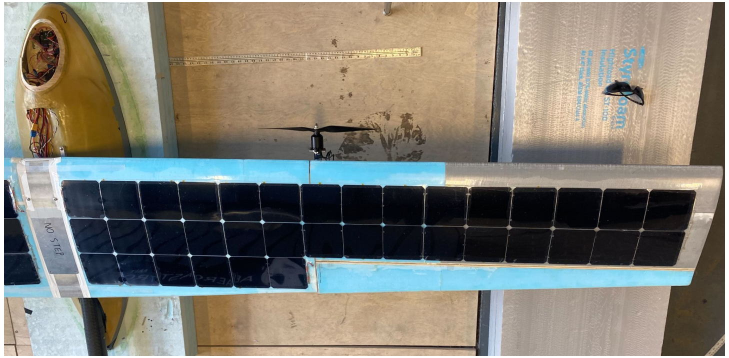
↓

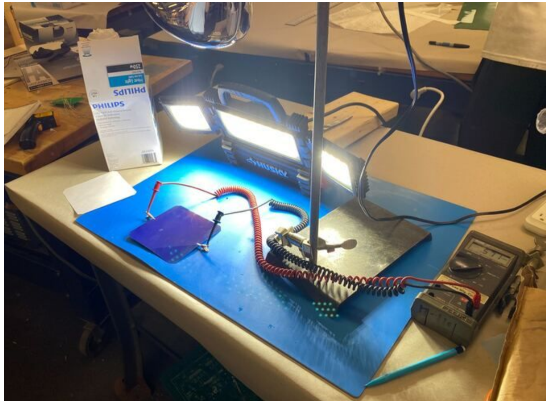
Flight-Proven

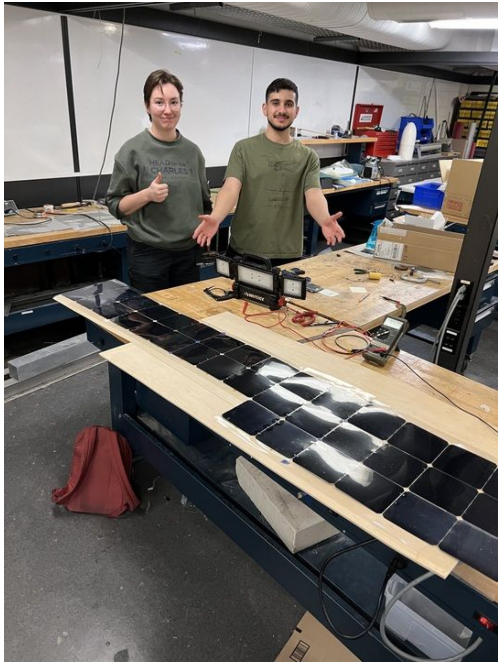
Motor & Propeller on Plane

Solar Cells Selection

- Aircraft powered by 72 Sunpower C60 Solar Cells
  - Lightweight, thin, and flexible (6.5g each)
- Each wing holds 36 solar cells connected in series
- Expected ~0.6 V each when in use
  - 21.6V total per wing







Presenter:

Battery Sizing & Selection

Pre-Flight: 20W for 15min --> 337.8 mAh

Takeoff: 900W for 10s --> 168.7 mAh

Climb (500ft): 415 mAh

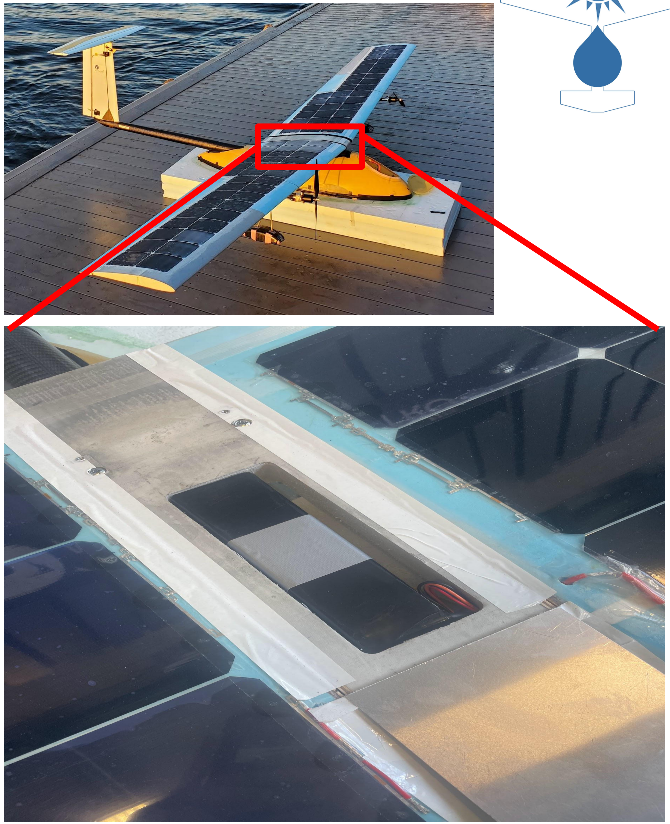
Cruise (Backup): 75W for 20min --> 1690 mAh

Approach Pattern: 75W for 5min --> 422.3 mAh

Go Around: 350 mAh

Approach Pattern: 75W for 5min --> 422.3 mAh
Total Capacity Required: **3806.1 mAh**

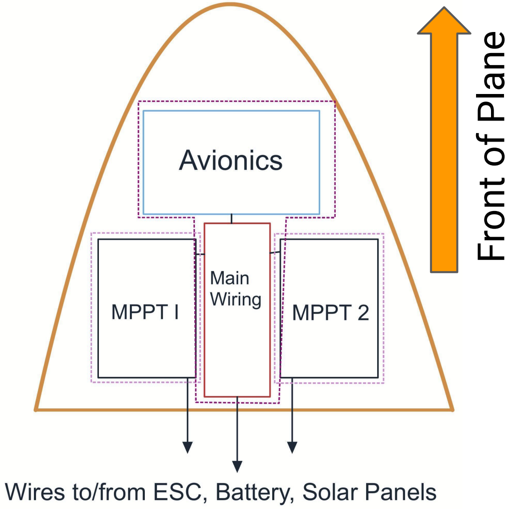
LiPo 4500mah 4S 14.8V - 400g



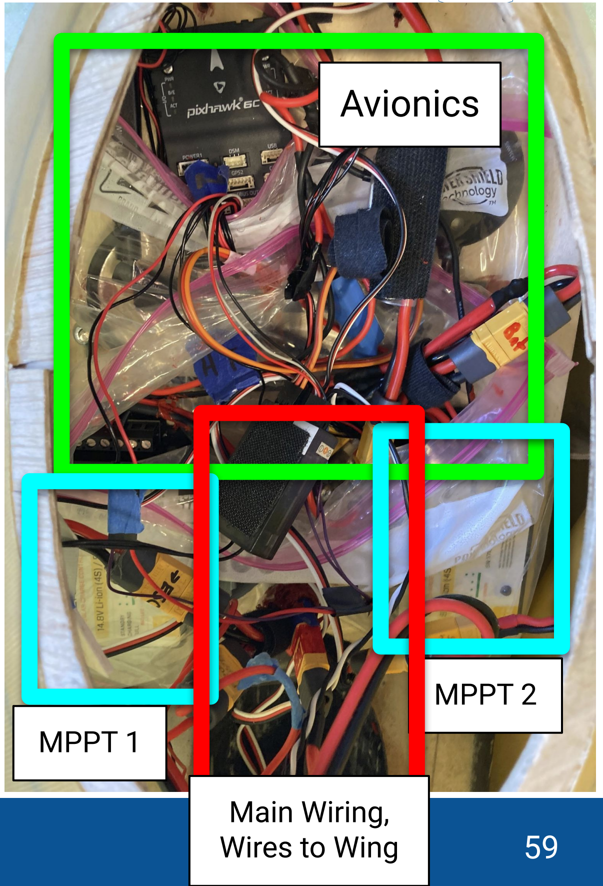
Presenter: Madison Bronnimann

Mounting of Main Power Bus and Avionics

- MPPTs, wiring, and avionics mounted on wood panel in nose.
- Splash-proofing used silicone sealant & plastic bags.
  - One bag for each MPPT, one bag for wiring & avionics
  - Used silicone to waterproof wiring connections between bags



Power Panel Layout
Bronnimann



Post-flight Power Output Measurement

996 W Solar Irradiance

↓

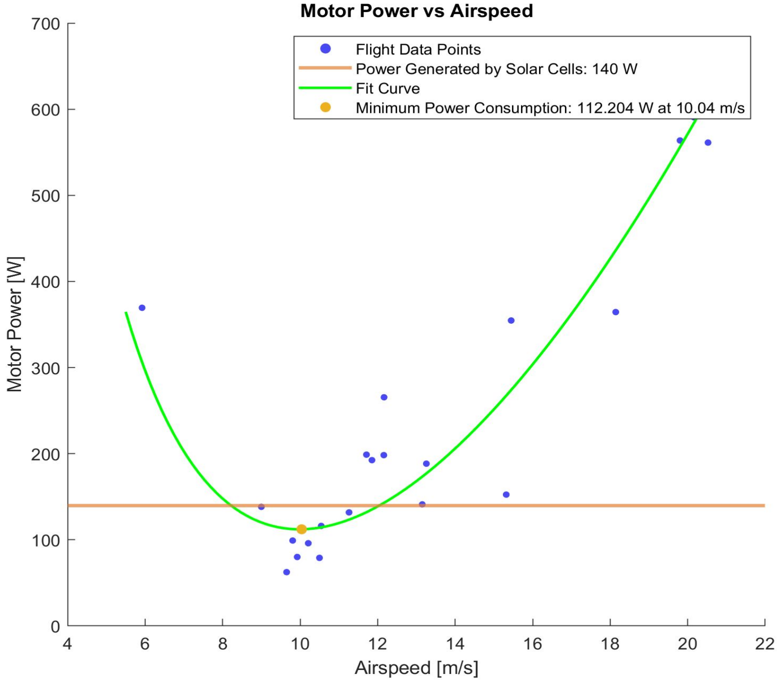
140W Generated
(14%)

Power generation test: 5/8/23 12:20 pm
Charlotte Gump

Presenter: Madison Bronnimann

Overall Performance

- Flights indicate net-positive possible using post-flight solar test data
  - Use 5.65 W-h on takeoff
  - Power Generated = 140W
  - 282s of cruise for net-positive
- Minimum-Power Airspeed: **10.04 m/s = 22.4 mph**



Motor Power Curve

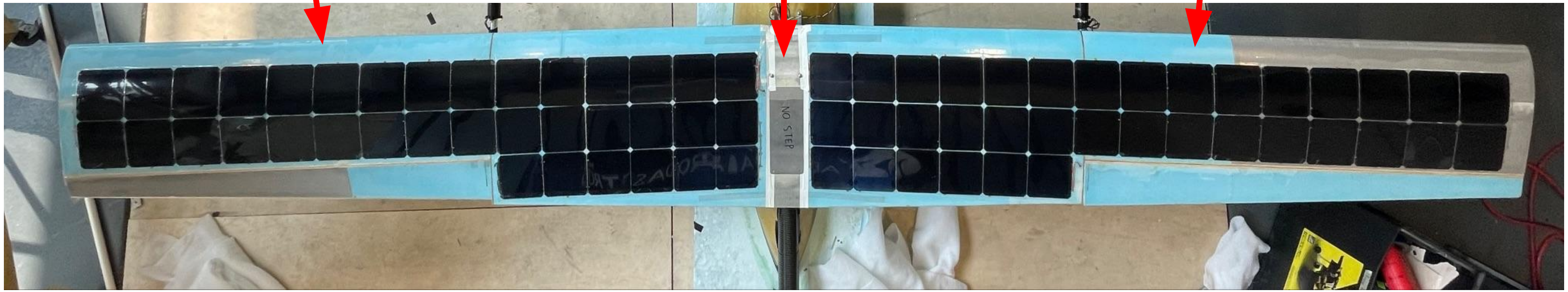
Bronnimann


WING
AEROASTRO

Wing - Overview

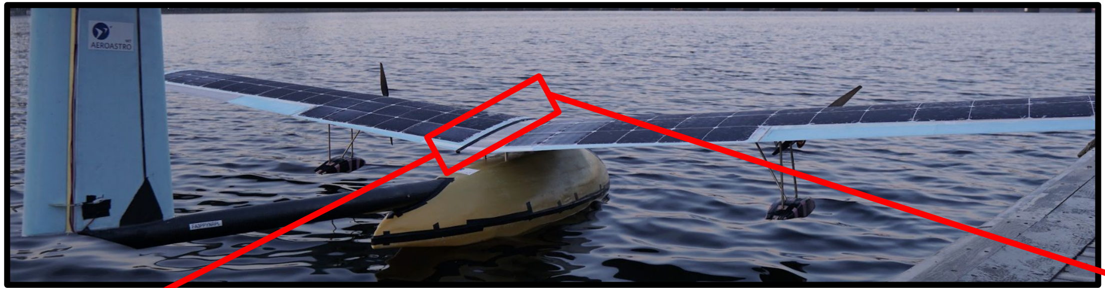
- Divided into 2 sections + center for:
  - Solar array compatibility
  - Manufacturability
- Foam core and fiberglass skin construction
- Vacuum bagged with prefab embedded spar

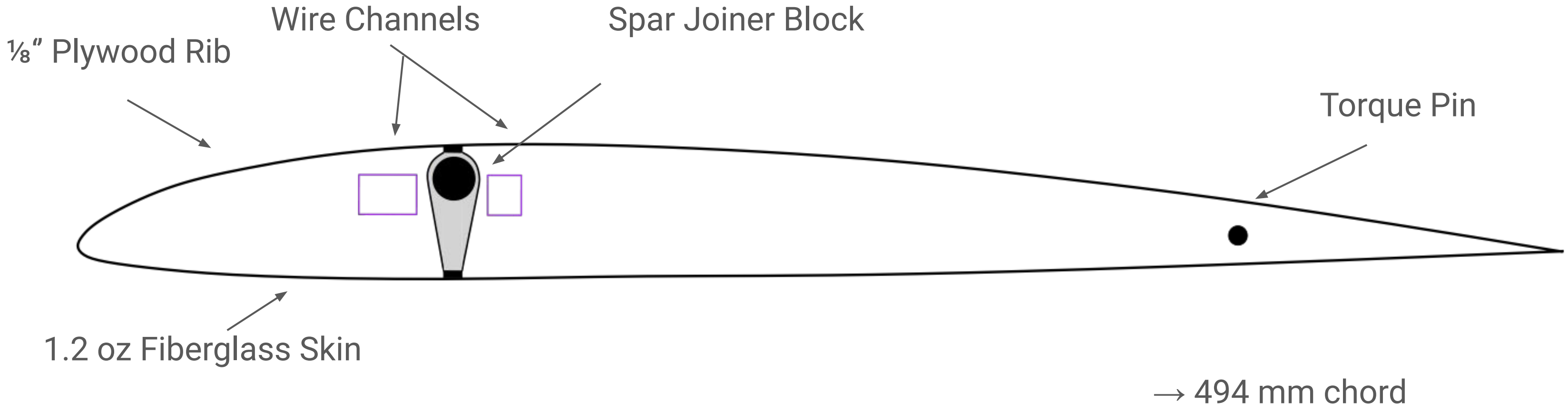
Left Wing　　Center　　Right Wing



Wing - Root Cross Section

Presenter: Cecilia Perez Gago

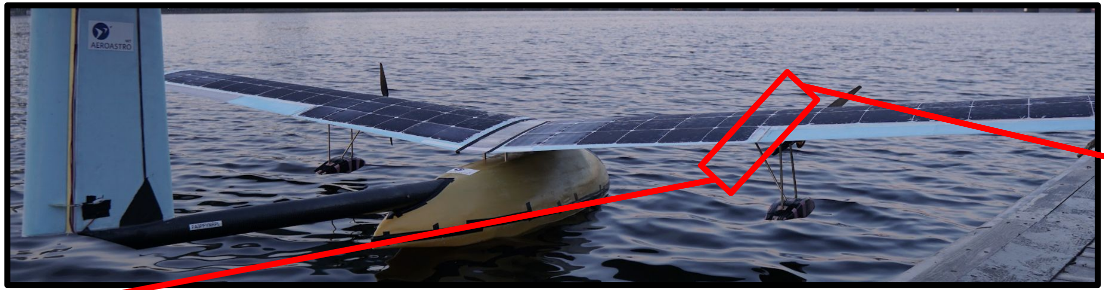


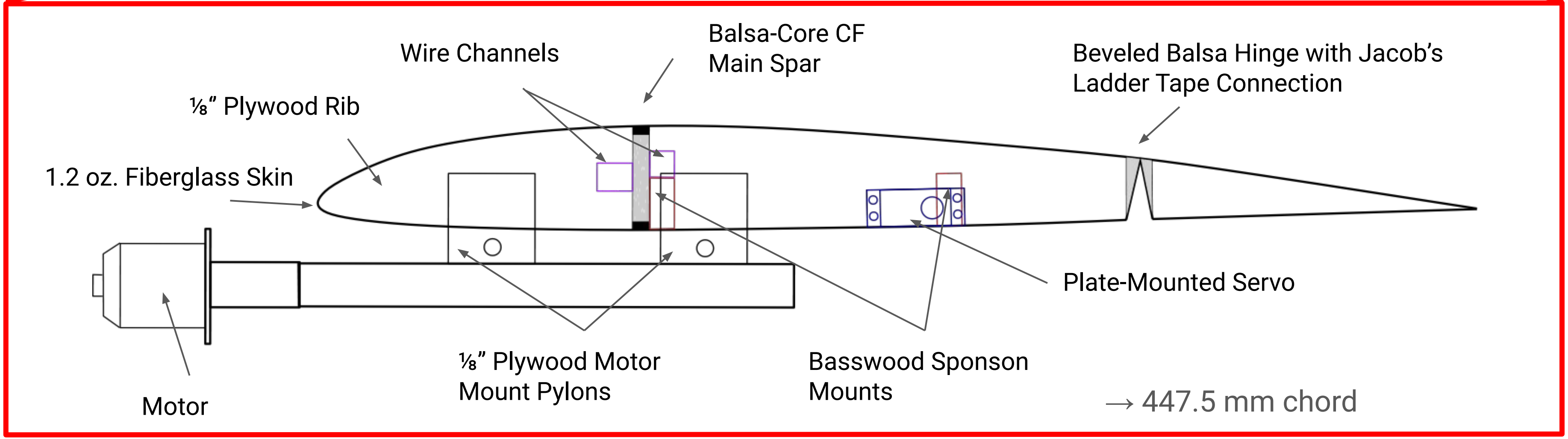


Contributor: Jake Sonandres, Erick Gonzalez, Cecilia Perez Gago

Wing - Rib Cross Section

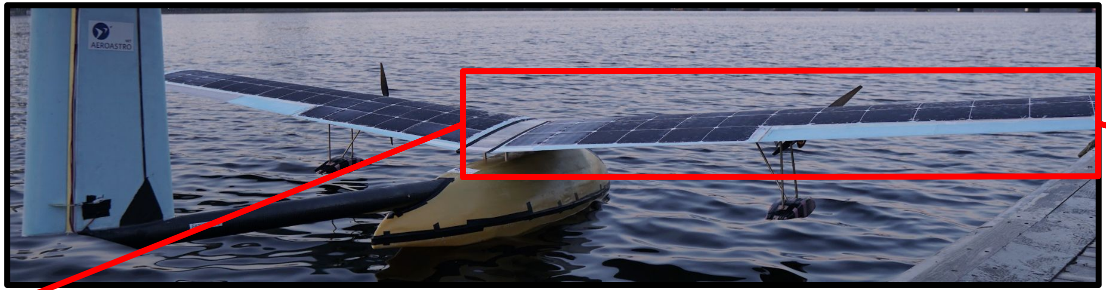
Presenter: Cecilia Perez Gago

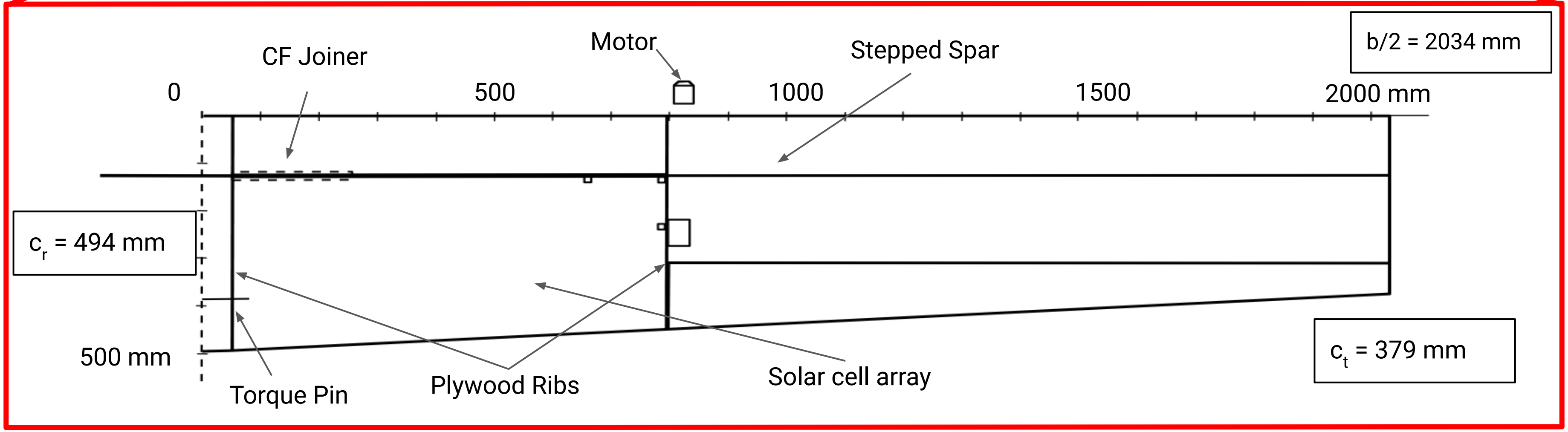




Wing - Half Span

Presenter: Cecilia Perez Gago





Wing Build - Rails and Raisers

- Wing - fuselage interphase built too far forward
- Clearance between prop and water
- Bring wing “up” and “back”

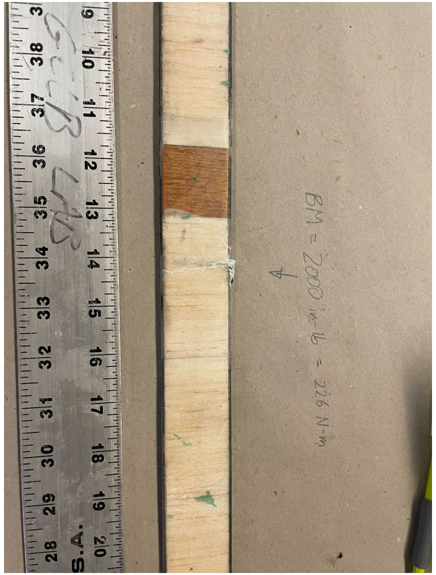
½” by ½” Aluminum rod with threaded bolt holes

Presenter: Morgan Ferguson

Testing and Validation: Spar 3-point bending test

Main idea: validate spar strength

- Built test section identical to final spar
- 13G equivalent load spar-cap compression failure

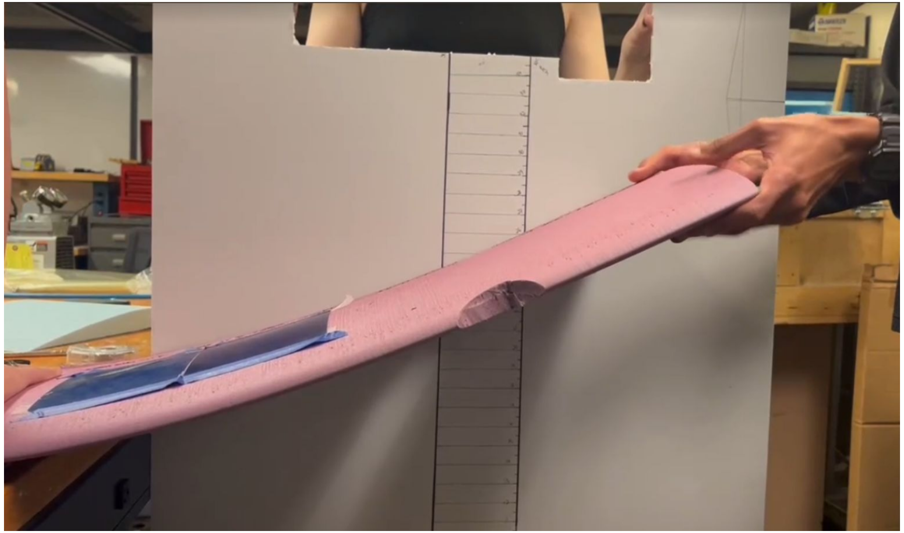


Contributor: Morgan Ferguson, Cecilia Perez Gago, Julian Powers

Testing and Validation: Solar Panel Bend

Main idea: validate solar array - wing interface

- Deflected wing with solar cells adhered
- No failure mode observed

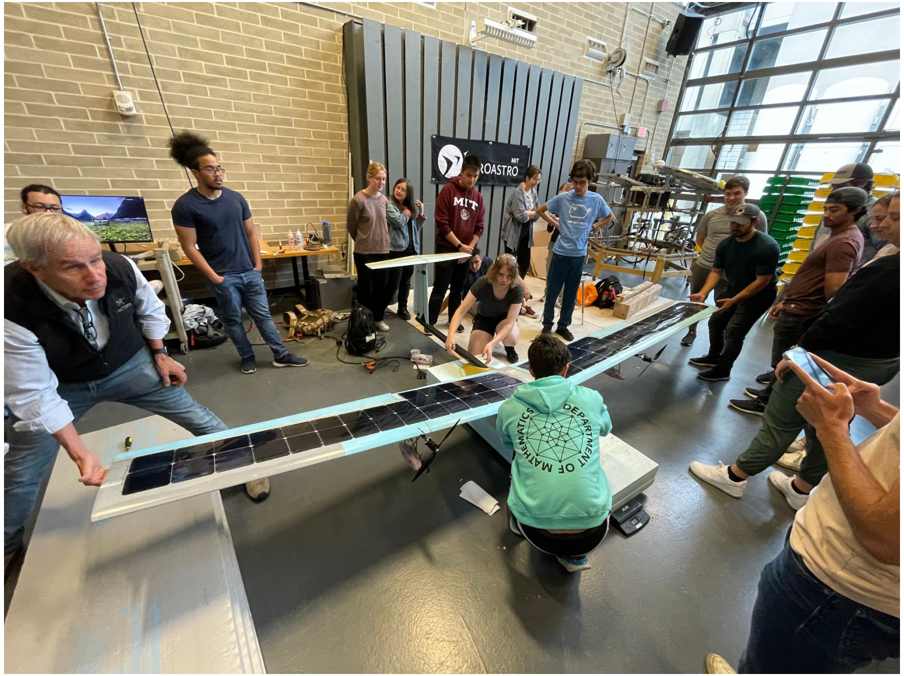


Testing and Validation:
Tip load

Presenter: Morgan Ferguson

Main idea: validate spar strength of final aircraft

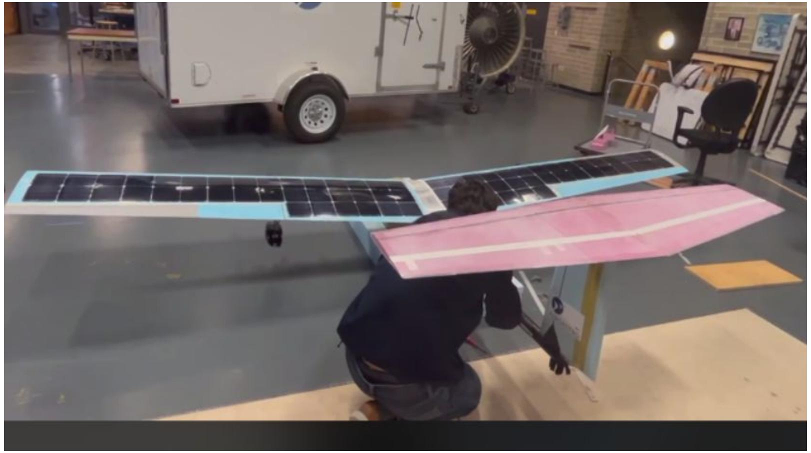
- 2.5G tip load applied to simulate load factor when maneuvering



Testing and Validation: Full Throttle

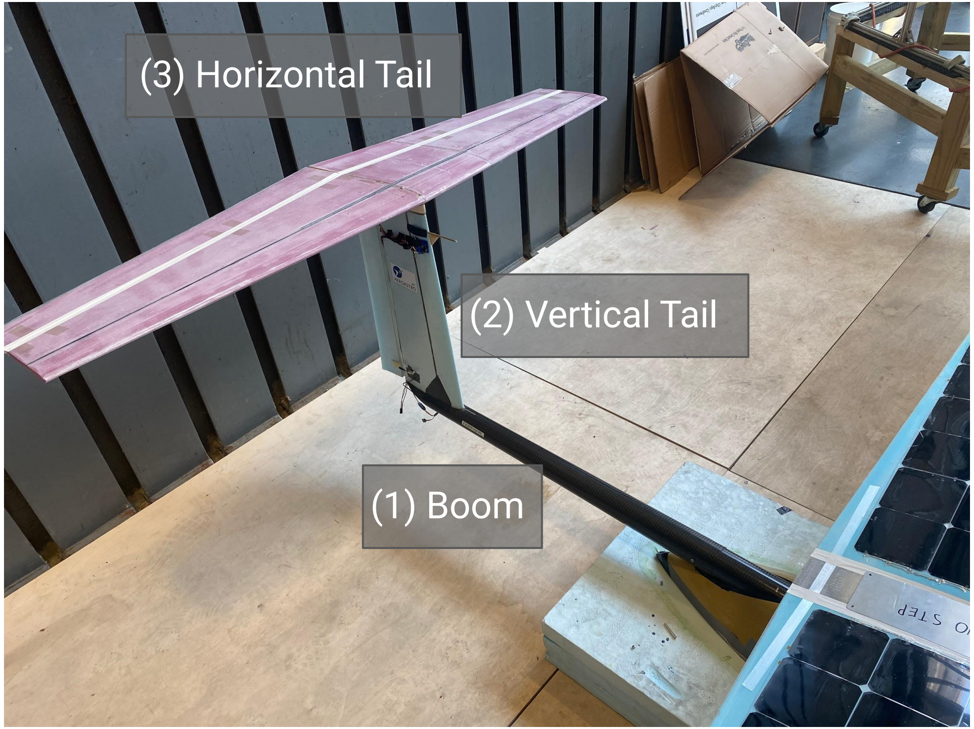
Main idea: ensure motor mount integrity and validate wing fuselage interface under prop loading

- Full throttle spin up and hold
- Slight vibration observed on aircraft while holding full throttle



BOOM & TAIL

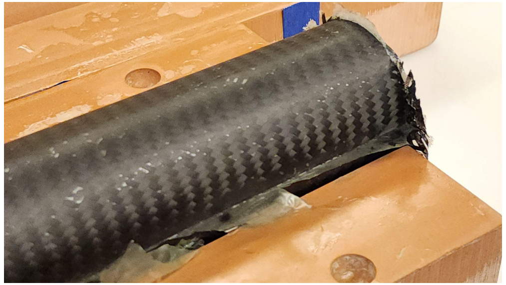
Boom/Tail Components



Boom Build Techniques

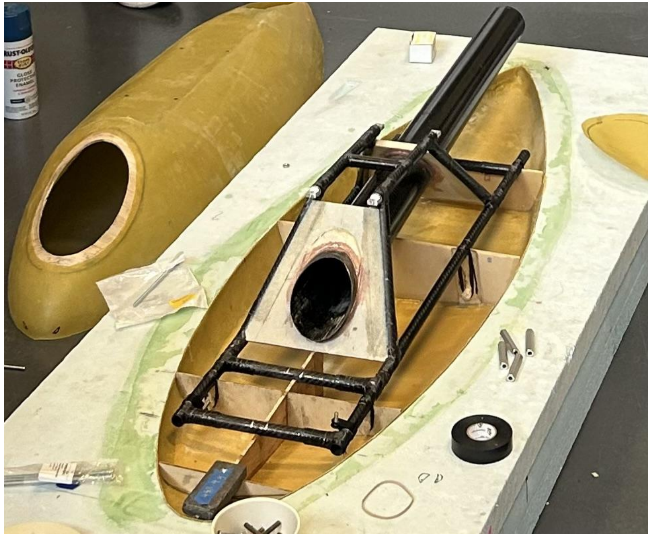
Split Mold Layup

Cure Under Vacuum

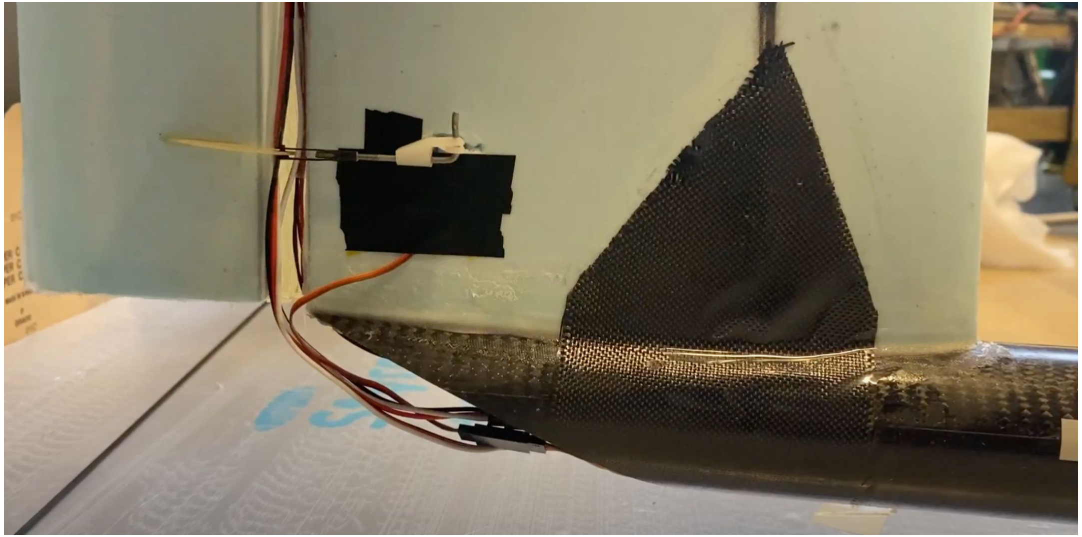


Celebration

Boom Interfaces



Boom-Fuselage: A permanent mount led by Fuselage team



VTail-Boom: Carbon fiber wrap with fiberglass around seam.
Wires run into VTail's Channel

Presenter: Ella Berrey

Vertical Tail Design & Build

Plywood rib glassed in

HT36 Airfoil

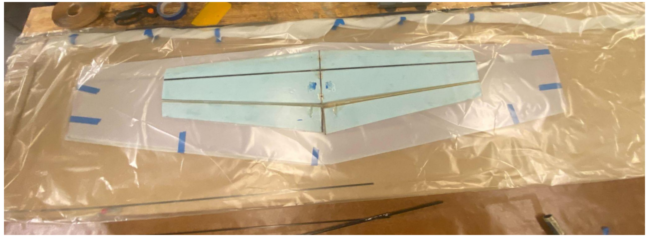
Kevlar hinge

Pultruded CF Spar Caps, dremeled in

Wire conduit down hinge

45/45 fiberglass skin, foam core

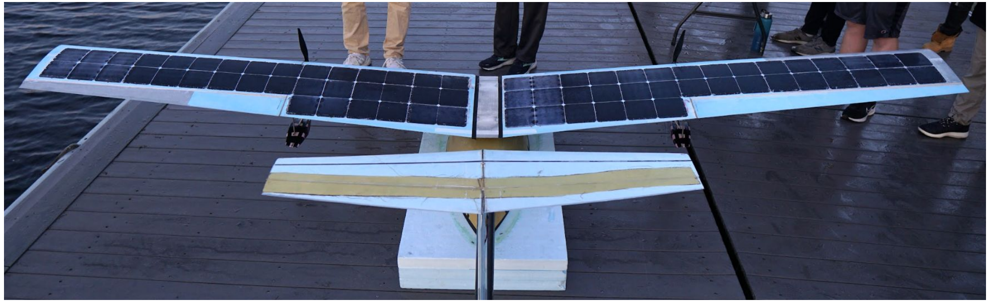
Layup in vacuum bag w/Mylar, surround with molds to keep shape



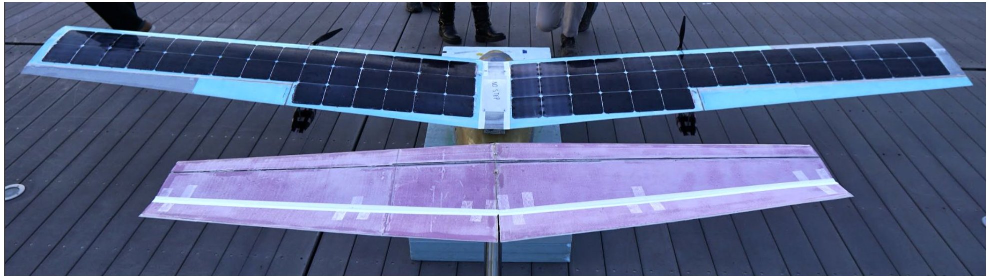
Horizontal Tail Redesign

Larger HTail → Shift Neutral Point Back → Shift CG Range Back → Water Takeoff!

Size Comparison of both Horizontal Tails

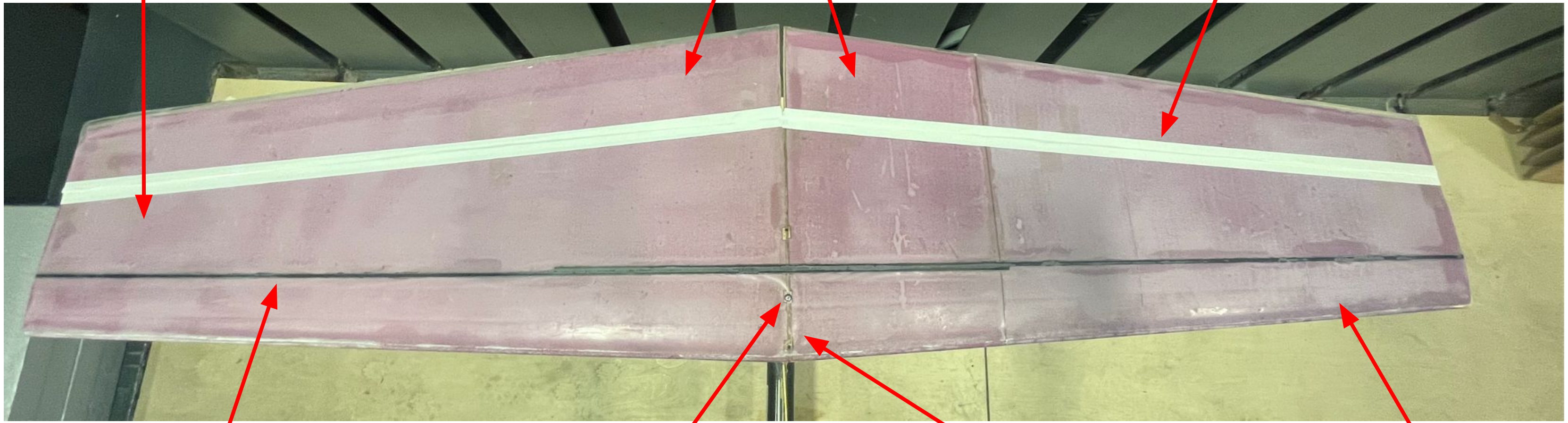


Horizontal Tail for the 1st Flight Attempt



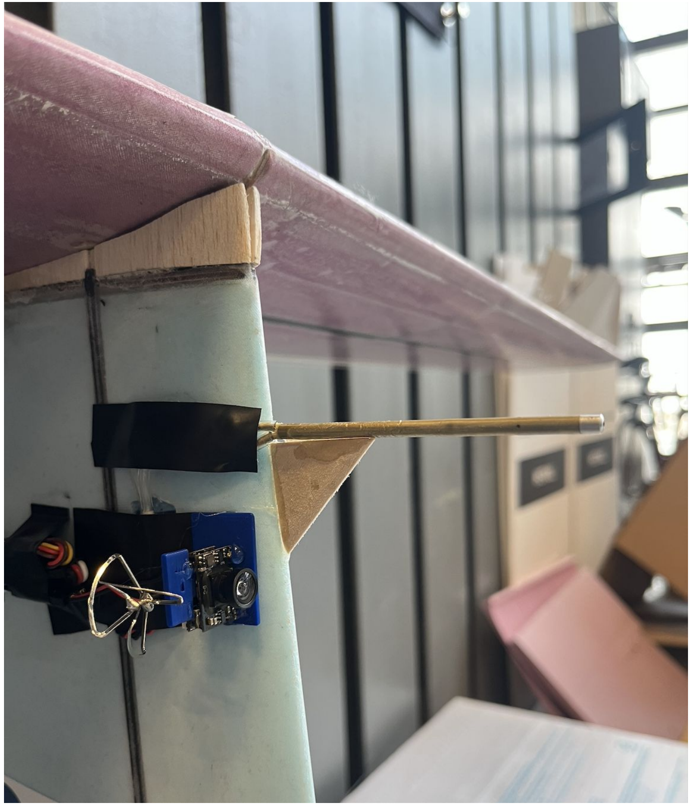
Redesigned Horizontal Tail

Final Horizontal Tail Design & Build



Avionics Mounting on VTail

- Pitot tube mounted away from tail flow on a basswood riser.
- FPV Camera mounted for in-air flight footage.
- Wires are routed down the hinge of the VTail.



Wet Components

Fuselage, Sponsons, and Truss

Design Drivers - Fuselage

Hull

- Planing Dynamics
- Slam Loads

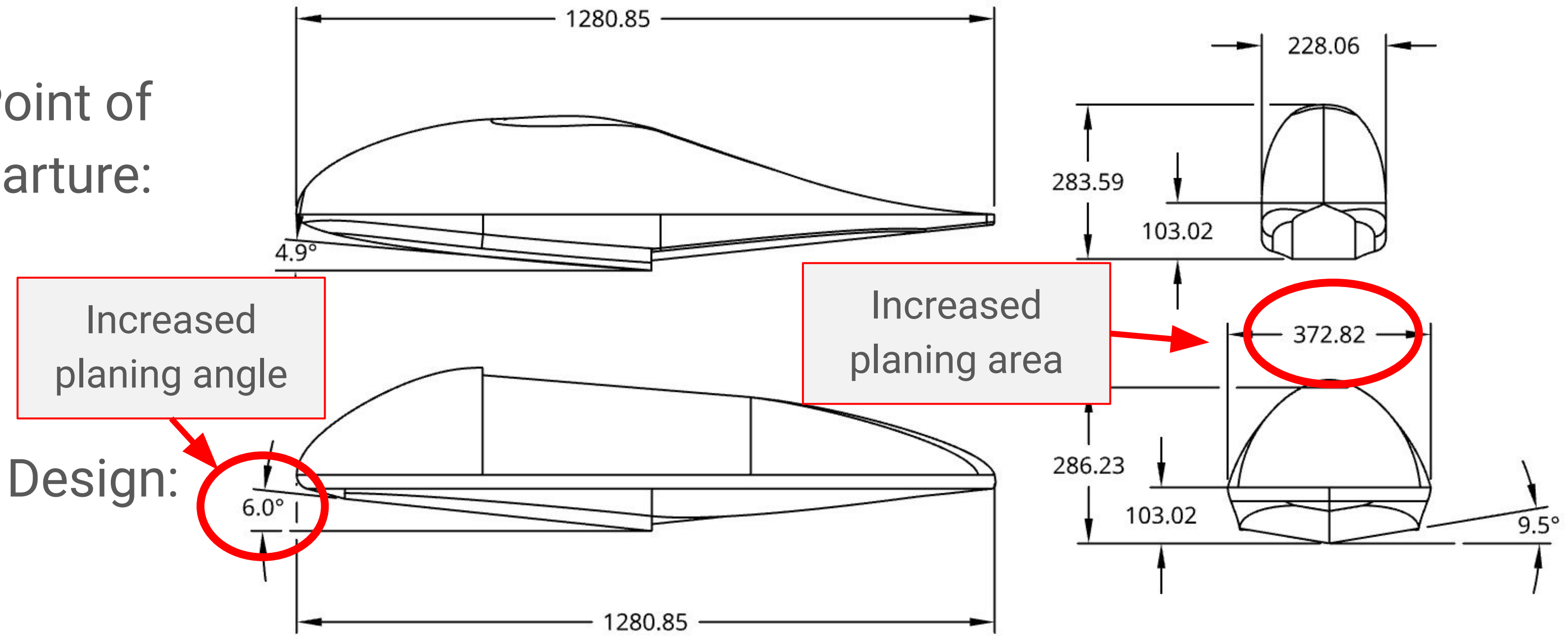
Aeroshell

- Wing Interface
- Minimize Drag

Planing Dynamics

Point of Departure:

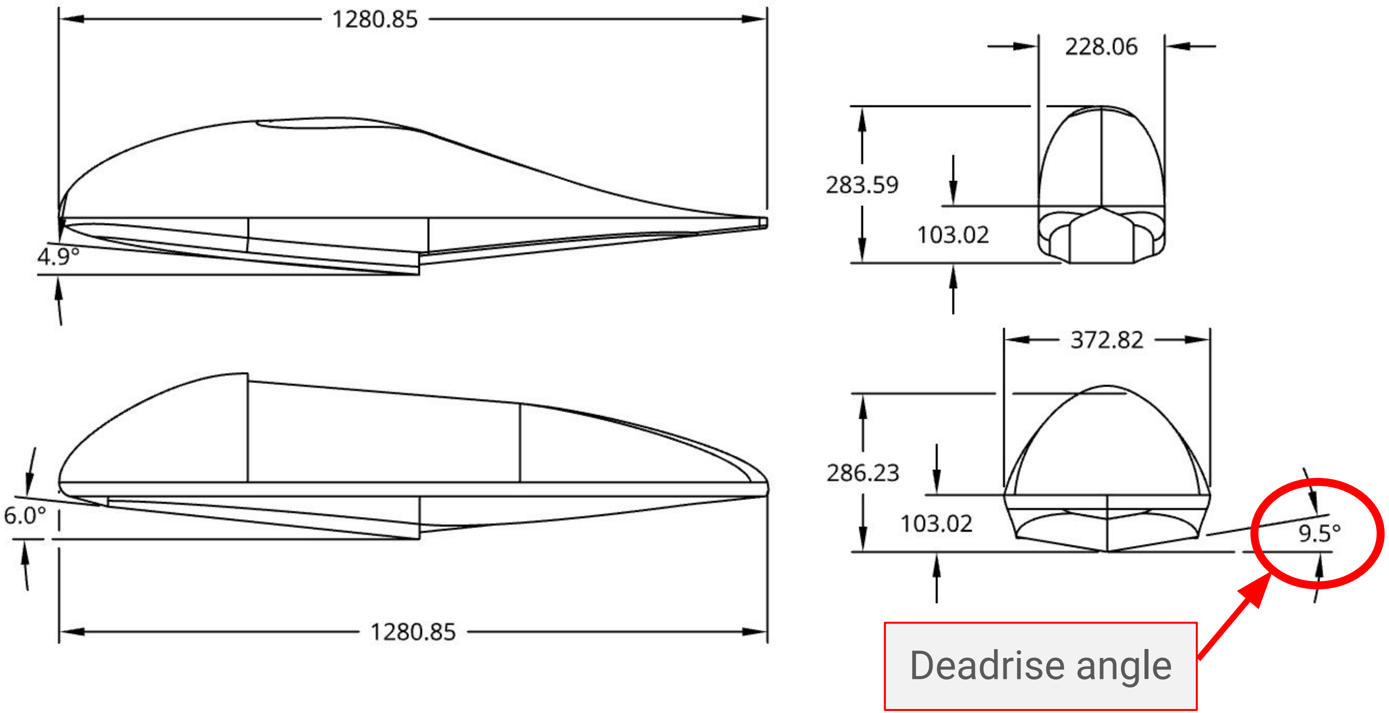
Final Design:



Slam Loads

Point of Departure:

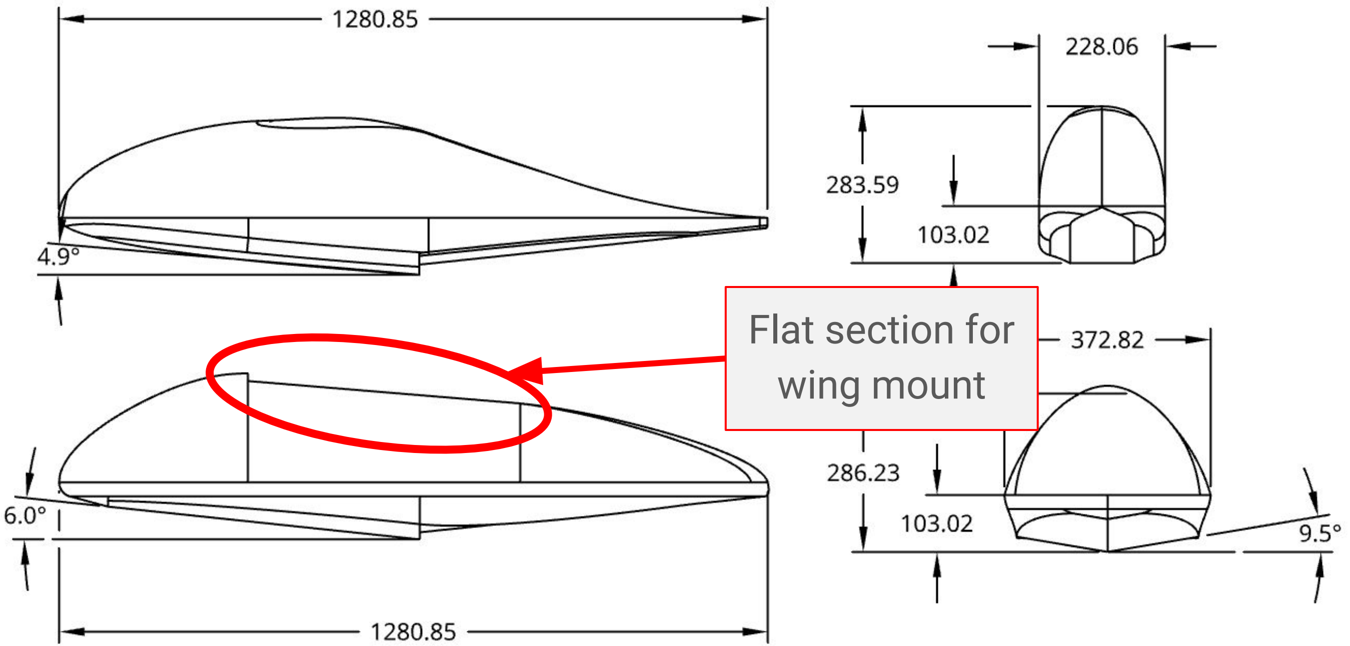
Final Design:



Wing Interface

Point of Departure:

Final Design:



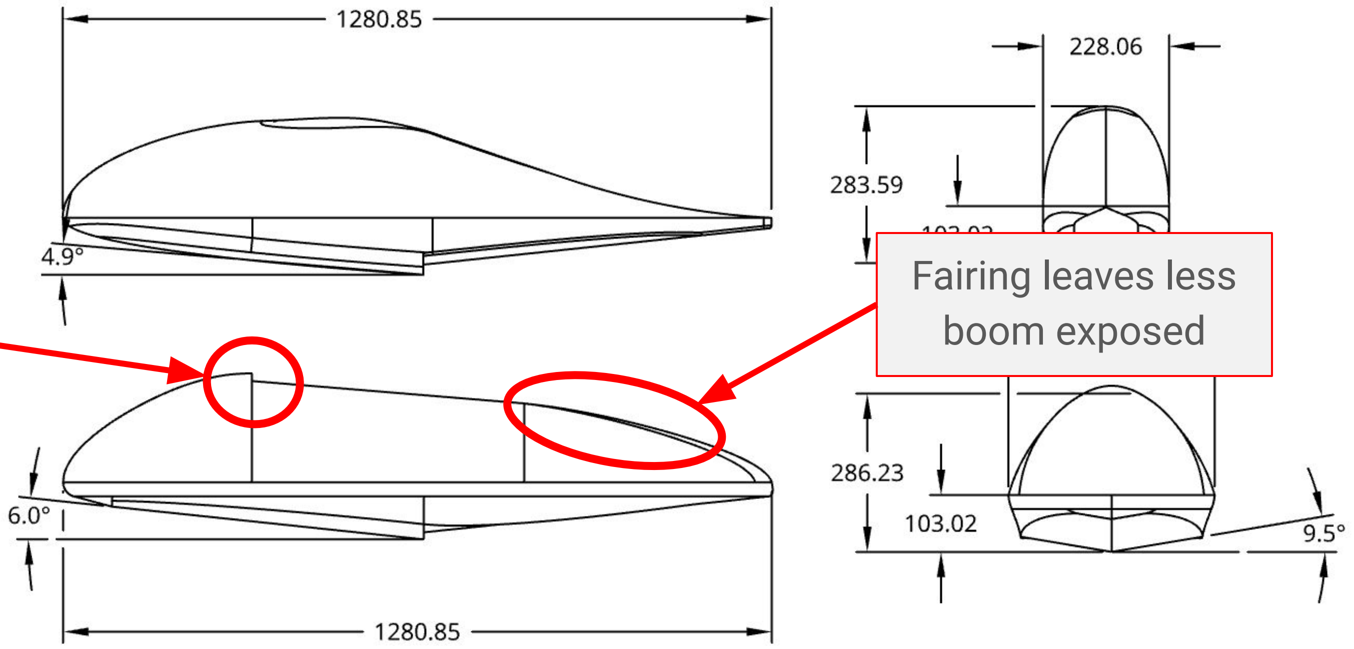
Drag Minimization

Point of Departure:

Step to cover flat leading edge

Final Design:

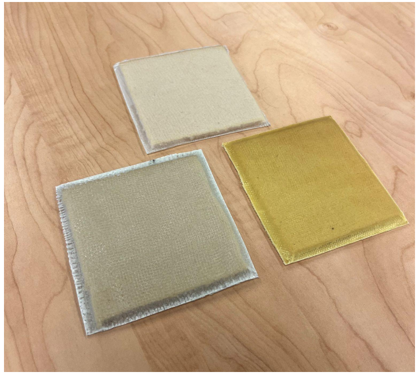
Fairing leaves less boom exposed

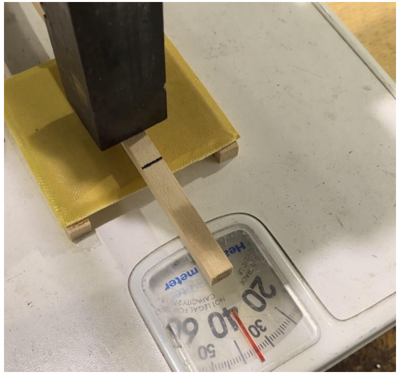


Material Selection

- Tested strength of various composite sandwiches
- 4 total layers, 2 above and 2 below core
- ⅛” Divinycell sandwich core
- Carbon fiber not considered
    - Radio opacity

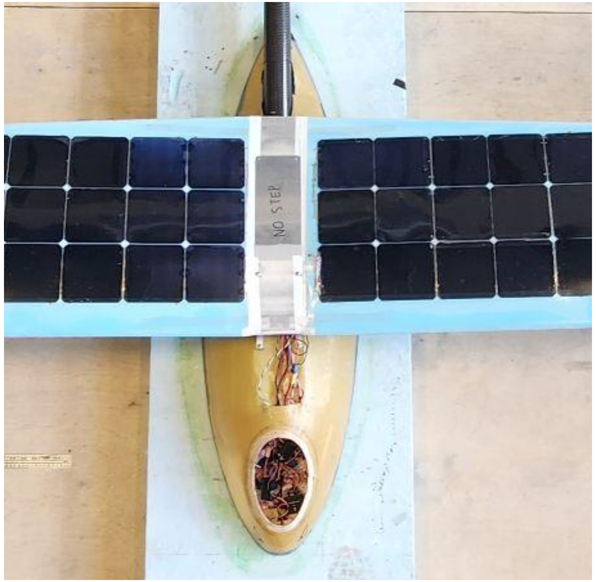
Material	M_{max} per span (N)	Density (kg/m^2)
3.4oz Fiberglass	58.8	1.30
1.6oz Fiberglass	22.2	0.49
1.6oz Kevlar	44.8	0.65





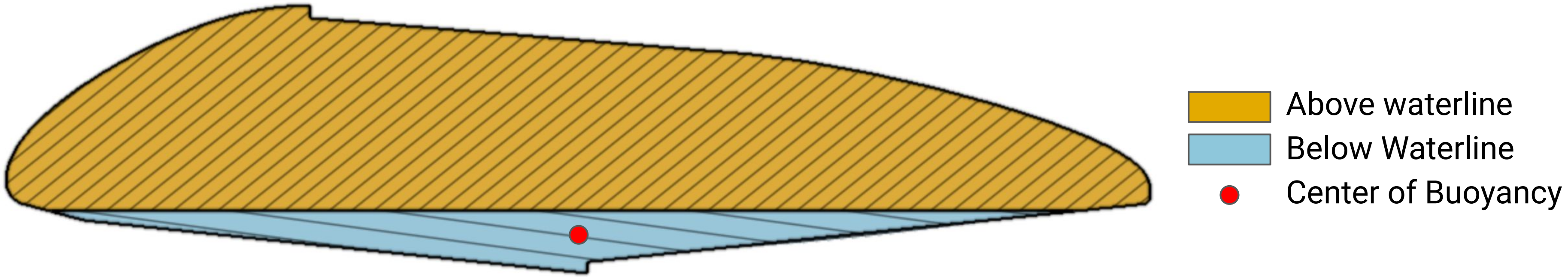
Fuselage Assembly

- Seam between hull and aeroshell sealed with Gaffer's tape
- Access hatch strengthened with balsa ring



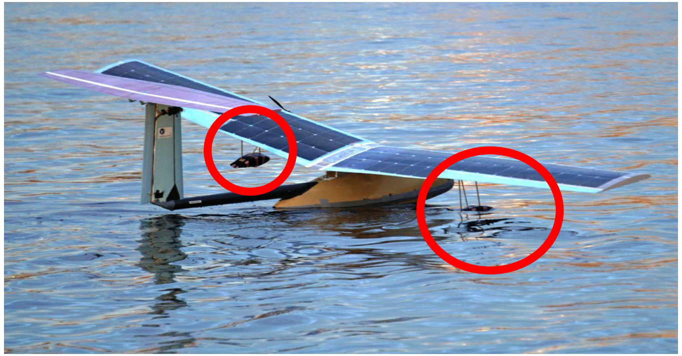
Center of Buoyancy

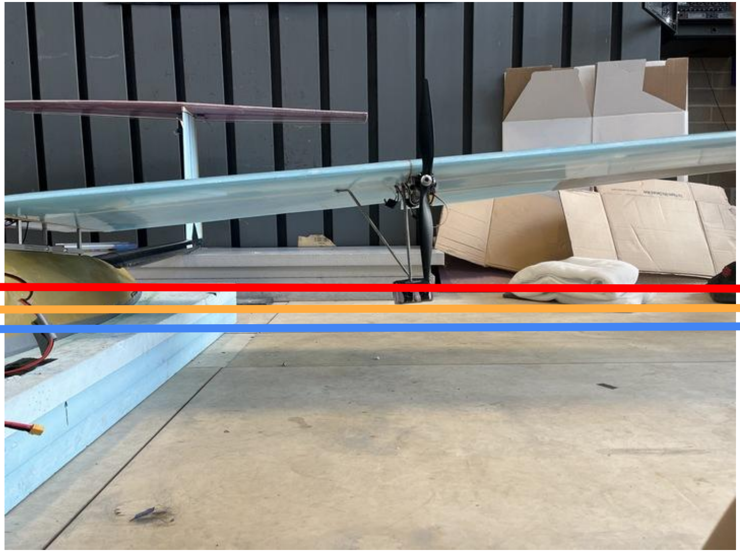
- **Led to failure in flight test #1** (as discussed in part 1)
  - Mismatch in aerodynamic vs. hydrodynamic stability
  - Error in mounting point of the truss/design of aero shell
- Key takeaway: *should have been considered before it was too late to change in design*



Sponsons - Design Drivers

- Enough **buoyant force** to support the wing during water taxi
- **Low drag** to minimize effect on flight efficiency
- Above water height at wings level

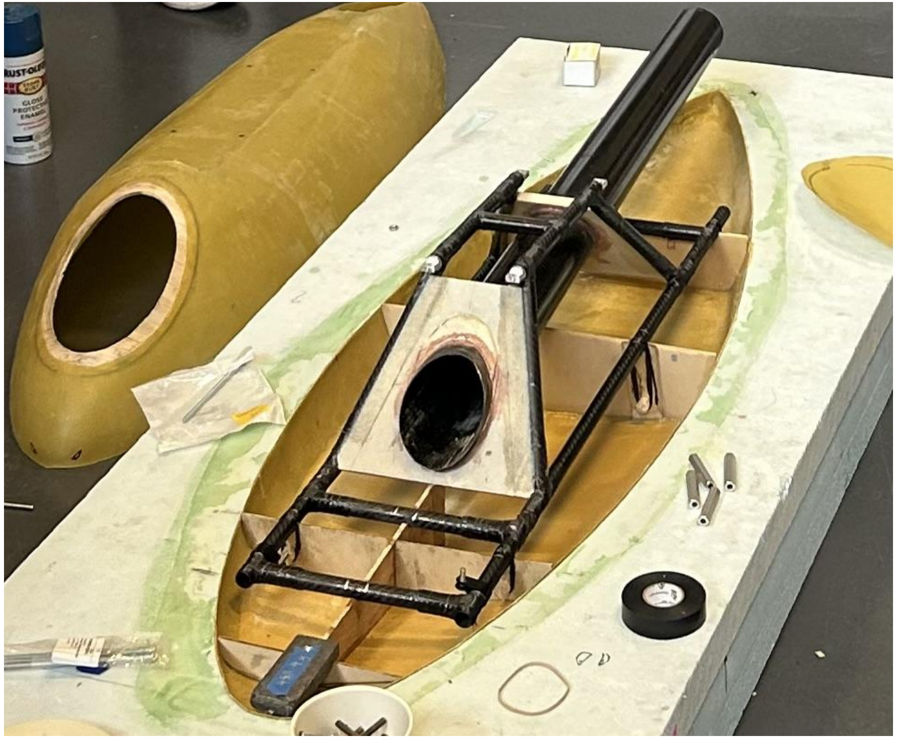




Internal Structure - Purpose

Hull-Wing Load Path

- Wing Saddle
- ↕
- Truss
- ↕
- Bulkheads
- ↕
- Hull

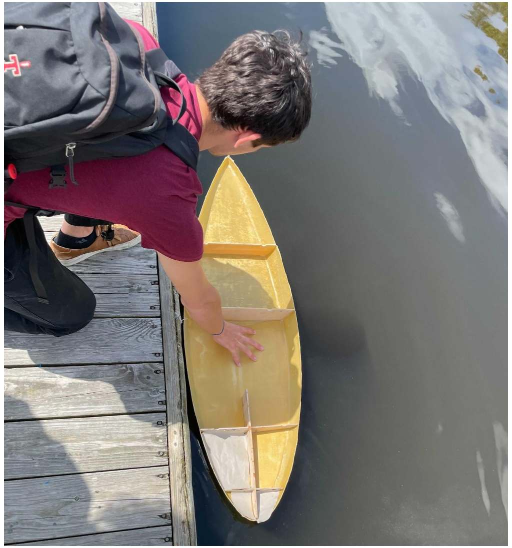


Boom-Truss Load Path

- Truss
- ↕
- Boom Plates
- ↕
- Forward Boom

Fuselage and IS Tests

- Waterproof test on hull and sponsons
- Truss loading test (can withstand 1 Drela unit of compressive loading)

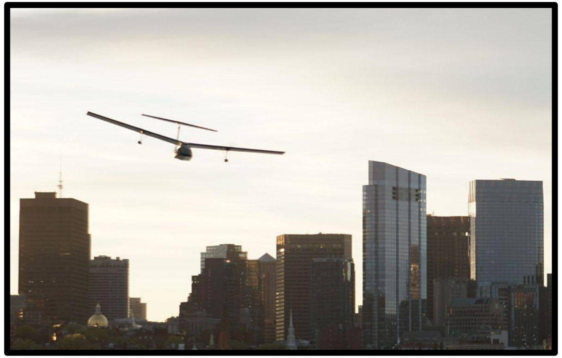


Today, Tomorrow, & Beyond

Our lessons & work *can continue* because…

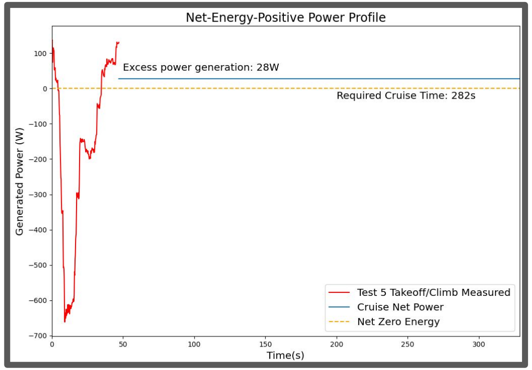
The plane flew!

The plane came back!

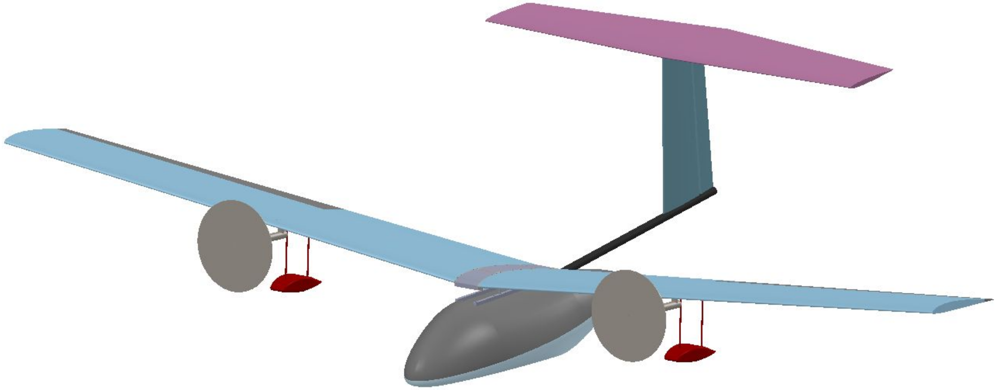


possibly

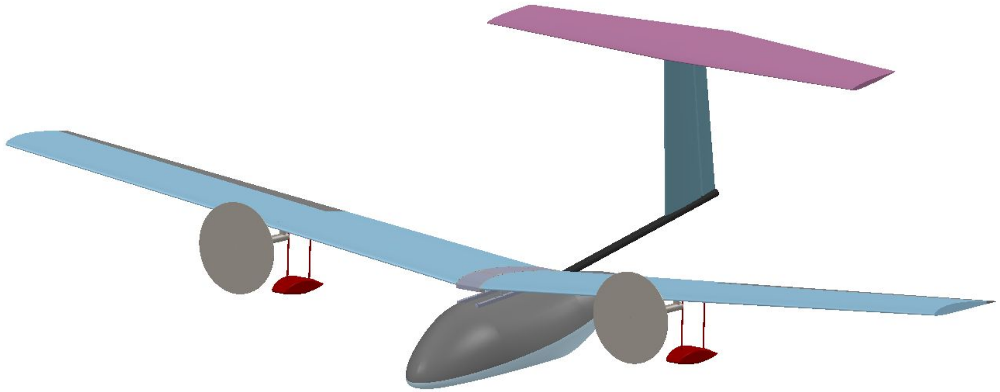
Net Positive Energy!



We hope to fly again!

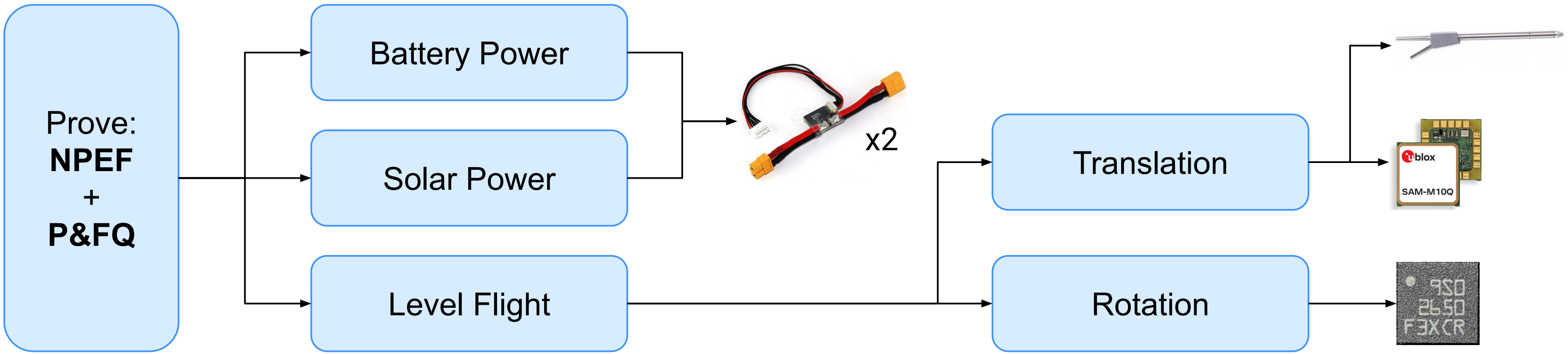


Solar Surfer - Appendix



Avionics Appendix

Sensors chosen based on Variable Requirements



SENSOR	VARIABLES	
Power	Voltage	Current
GPS	XYZ Position	XYZ Speed
IMU	XYZ Accels	XYZ Angular Rate
Pitot-Static	Airspeed	Altitude

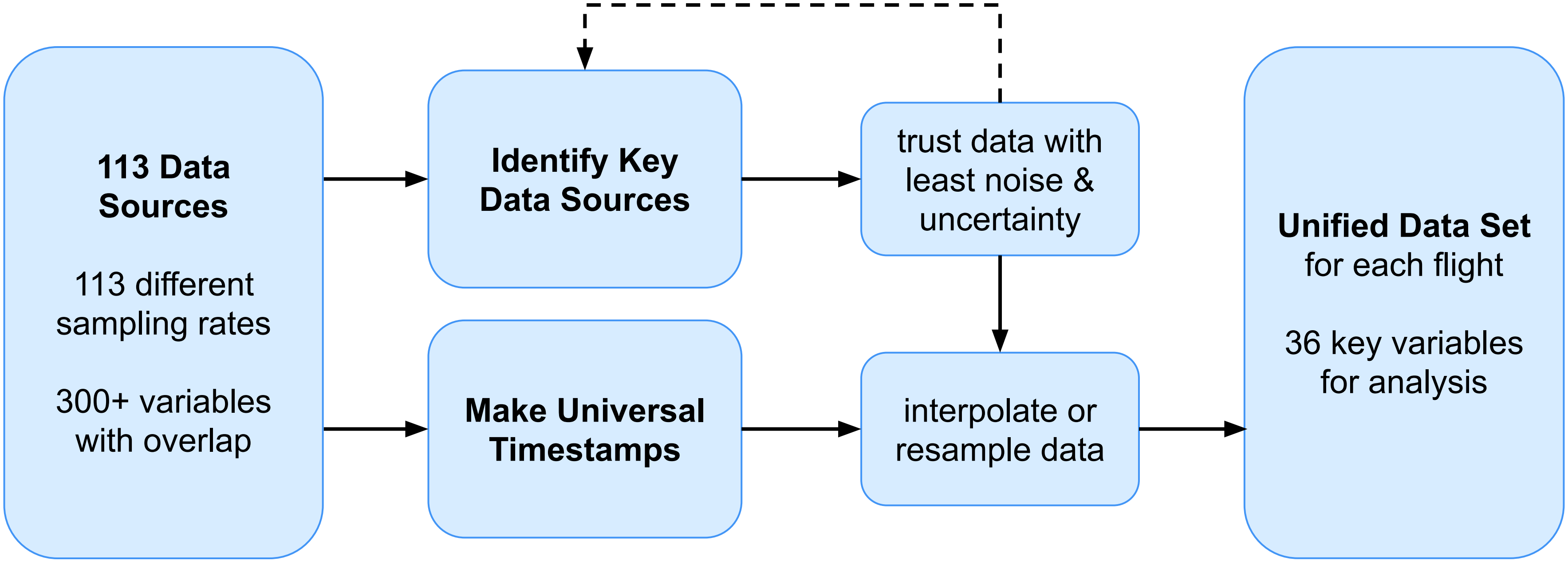
Additional Component: Telemetry Transmitter

- Live airspeed and battery voltage
- Data recording in case of unrecoverable crash

All images from HolyBro and Adafruit

Presenter: Amira Malik

Processing Data from Raw to Easy-Use



This flowchart explains how csv_converter.py was made, on github (next slide)

Presenter: Amira Malik

End User Guide to Data Processing

1. For each log, **download** .ulg file from Pixhawk
2. Use **pyulog library** to run ulog2csv
3. Change in **csv_converter.py** the filename variable to the file prefix of the 100+ csv files
4. Run **csv_converter.py** to consolidate all data into one csv
5. **"AABV_filename" is created!**

Github link: https://github.com/amiramalik33/1682X/tree/main/16.821/Data

README link for starting data analysis:
https://docs.google.com/document/d/1m3ldarUdi4AzhYiZVtuyyFsvVfA2kI1WpaGLP2vG5bs/edit?usp=sharing

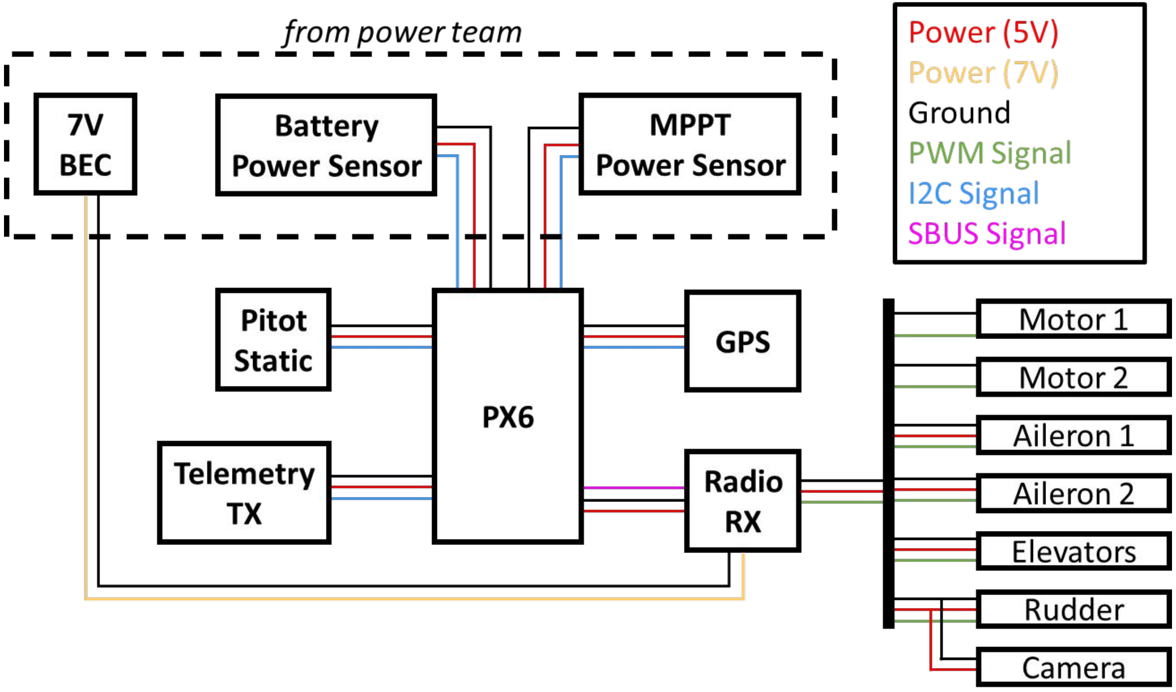
End User Guide to Data Sources in AABV file

source	variable
IMU	Quaternion Angles
	Angular Rates
GPS (check GPS uncertainty, may be high in some time periods)	Latitude & Longitude
	GPS Altitude (MSL)
	Ground Speed
	Heading
	XYZ Position, XYZ Speed, XYZ Accel

End User Guide to Data Sources in AABV file

MPPT Current Sensor	MPPT Voltage
	MPPT Current
Battery Current Sensor	Battery Voltage
	Battery Current
PX6C Barometer + Static Port Fusion, minus the density altitude of the test (validated against on water altitude being 0)	Barometer Altitude, AGL
Pitot-Static with wind tunnel calibrated applied	Calibrated Airspeed
Receiver	Servos & Motors commands

Avionics Wiring & Signal Diagram



Presenter: Amira Malik

Avionics Literal Components

Onboard	
Flight Data Recorder	Holybro PX6C
Current/Voltage Sensors x2	Holybro PM04
GPS	M8N Pixhawk GPS
Radio Receiver	FrSky R8 Pro
Pitot-Static Sensor	Holybro 19003 Digital AS
Telemetry Transceiver Pair	SiK Radio V3
FPV Camera	GTO2 AIO 200mw FPV
Aileron & Elevator Servos	KST MS589
Rudder Servo	KST X08 V6

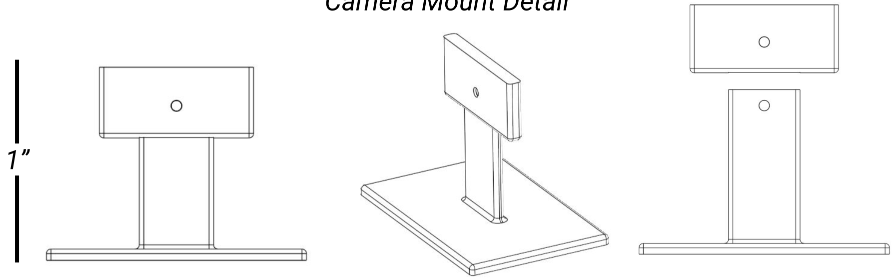
Ground Station	
Pilot Radio	FrSky Taranis X-Lite
Telemetry Transceiver Pair	SiK Radio V3
FPV Receiver x2	Lumenier DX800
Software	QGroundControl

Custom Mounts	
Avionics Floor	Power team + Amira
Dynamic & Static Port Mount	Tail team + Amira
FPV Camera Mount	Amira + Tail team
Servo Mounts	Wing & Tail teams

Avionics Custom Mounts

Custom Mounts	
Avionics Floor	Power team + Amira
Dynamic & Static Port Mount	Tail team + Amira
FPV Camera Mount	Amira + Tail team

Camera Mount Detail



Camera is two circuit boards connected by headers on the edges. The tall skinny mount is the thickness of the gap of the camera between the headers

Avionics Floor & Waterproofing

- More info on power teams slides

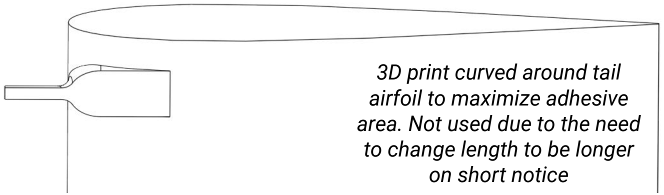
FPV Camera Mount

- 3D printed piece, slots inside camera, glued onto flat surface

D/S Port Mount

- Various designed; ADC embedded into foam

Pitot-Static Sensor Mount



ADC = Air Data Computer

Presenter: Amira Malik

Sensors Calibration: Pitot-Static System (Detailed)

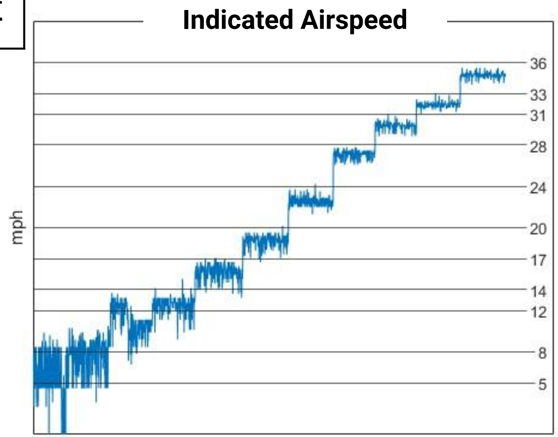
Sensor	Calibration Method
Pitot-Static	Wind Tunnel
Power	compare to real V & I
GPS + IMU	axes rotation + alignment

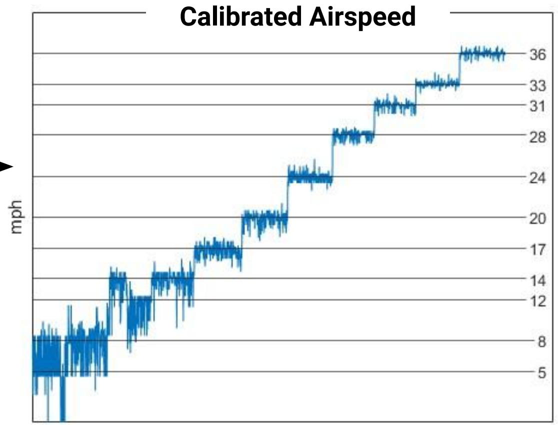
Test Limitations

- ***Approx. -2° angle of tail***
  - *only/best way plane fits without removing tail*
- ***Human error in pressure accuracy***
  - *hard to precisely control Tor*

- Low sensor accuracy under 12 mph
  - 18 mph stall speed, so this is acceptable
- Less sensor noise at higher speeds

Calibration applied to data





Contributor: Amira Malik

Photos & Graphs made by Amira

Sensors Calibration: Others

Sensor	Calibration Method
Pitot-Static	Wind Tunnel
Power	compare to real V & I
GPS + IMU	axes rotation + alignment

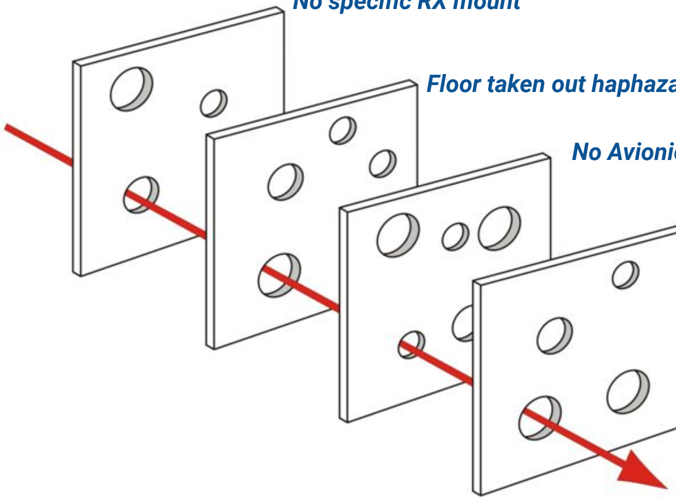
Power → Details in Power Slides; calibration factor applied to voltage & current data

GPS + IMU → Done in QGroundControl software

Avionics Verified by Ground Tests

	Test	Method	Pass Criteria
Ground Tests	Smoke Test	Check: Continuity, Voltage, & Current	Measurements as expected
	Mock Flight	Mount sensors, rotate & translate	Sensors read as expected Data logging correctly
Integration Tests	Smoke Test	Plug everything in	No Smoke
	Sensor Calibration	various	Sensor readings as expected
	Radio Signal	Range Check	RSSI stable and high 2000'+ away
Move to Validation (flight)			

Partial Radio Signal Loss: Slice Details



No specific RX mount was designed in the electronics floor for the antennas (the RX itself was taped down like other avionics components)

Floor taken out haphazardly (wires and antennas were cut) and so fixes to broken components took precedence over checking re-installation was identical to initial installation

No Avionics sign-off on floor re-installation

No range check upon re-installation of the floor & antenna mounting at the field (one was apparently done, but Avionics can not confirm)

Future Project Recommendations

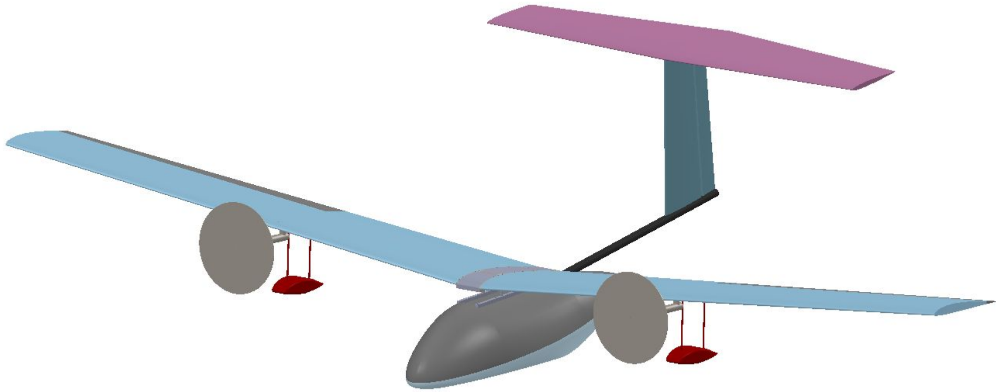
Waterproofing is nontrivial

Make sure signal wire lengths do not risk EMI!

Long wires may increase weight, but also allow for better rigid and fixed mounting of components

Work continuously with teams on sensor (& camera!) integration to ensure those teams have a plan for them

Whenever anything new happens to avionics, double check everything, including a range check!

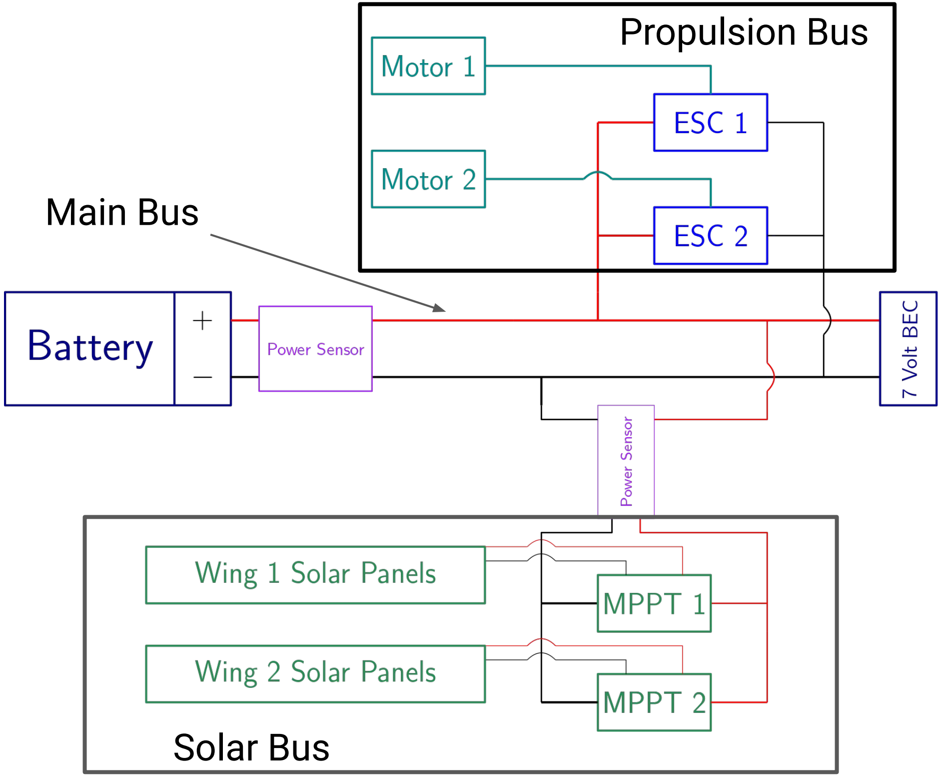


Power Appendix

Presenter:

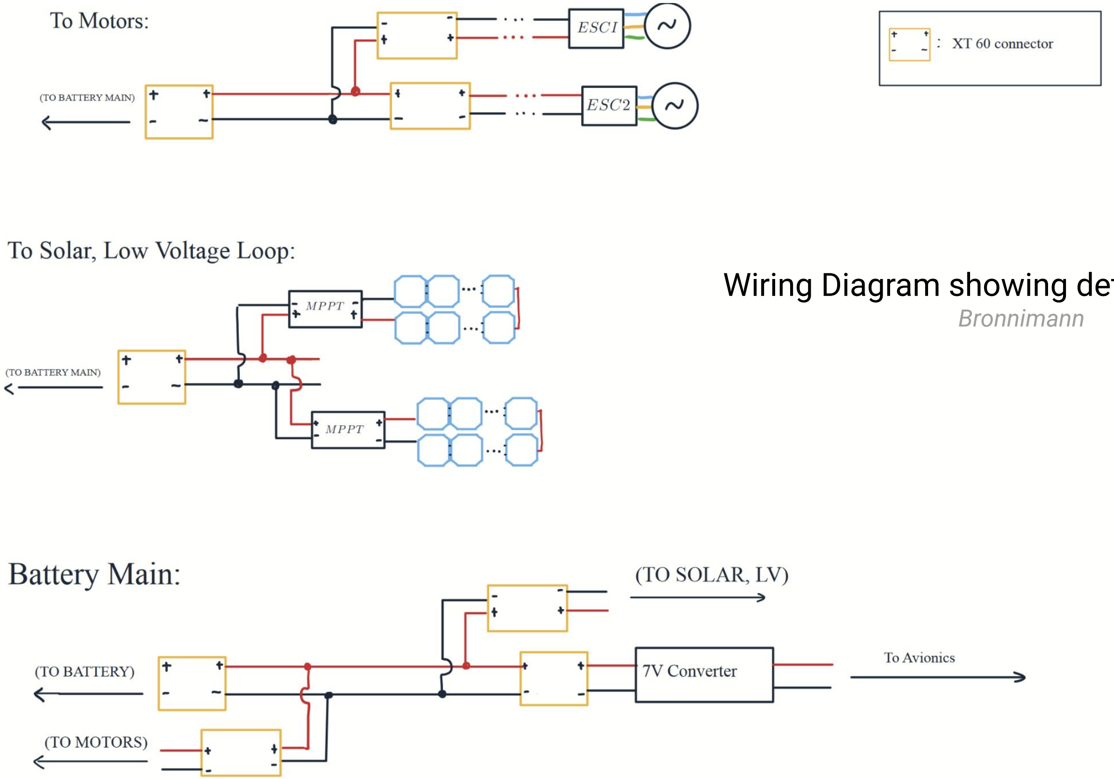
Electronics Bus Design & Manufacture

- Power sensors located on battery and solar panel connections. Enables tracking current inflow and total power across the battery.
  - Allows for subtractive measurement of flight control & propulsion
- Bus Manufactured with splices connecting components to the main bus.
- Wire gauges reduced on the solar panel bus and on wires connecting to individual ESC's. This is to correspond match gauge with current.
- Each bus is connected via XT-60 for ease of disassembly.
  - Labels on connectors was helpful



Presenter:

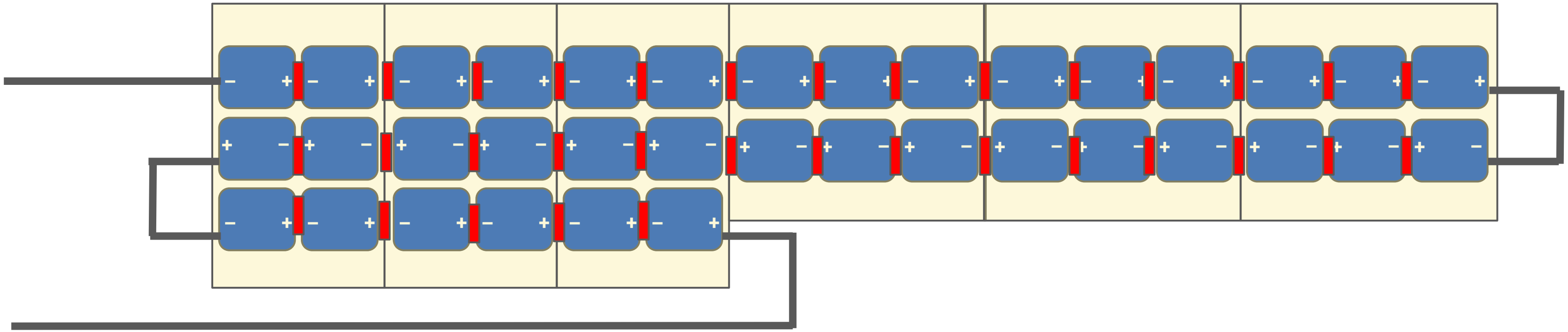
Electronics Ease of Assembly 2 - Detailed Build



Wiring Diagram showing detachable areas

Bronnimann

Solar Cells – Cell Layout/Polarity Diagram

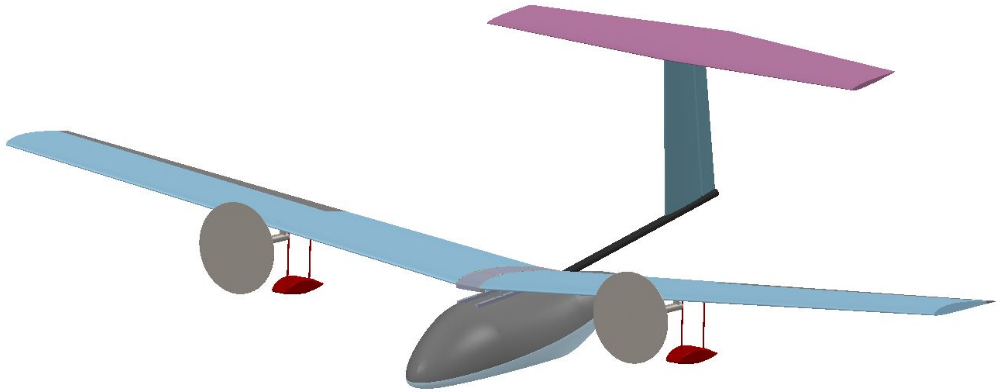


Solar cell

Laminated set

Dogbone connector

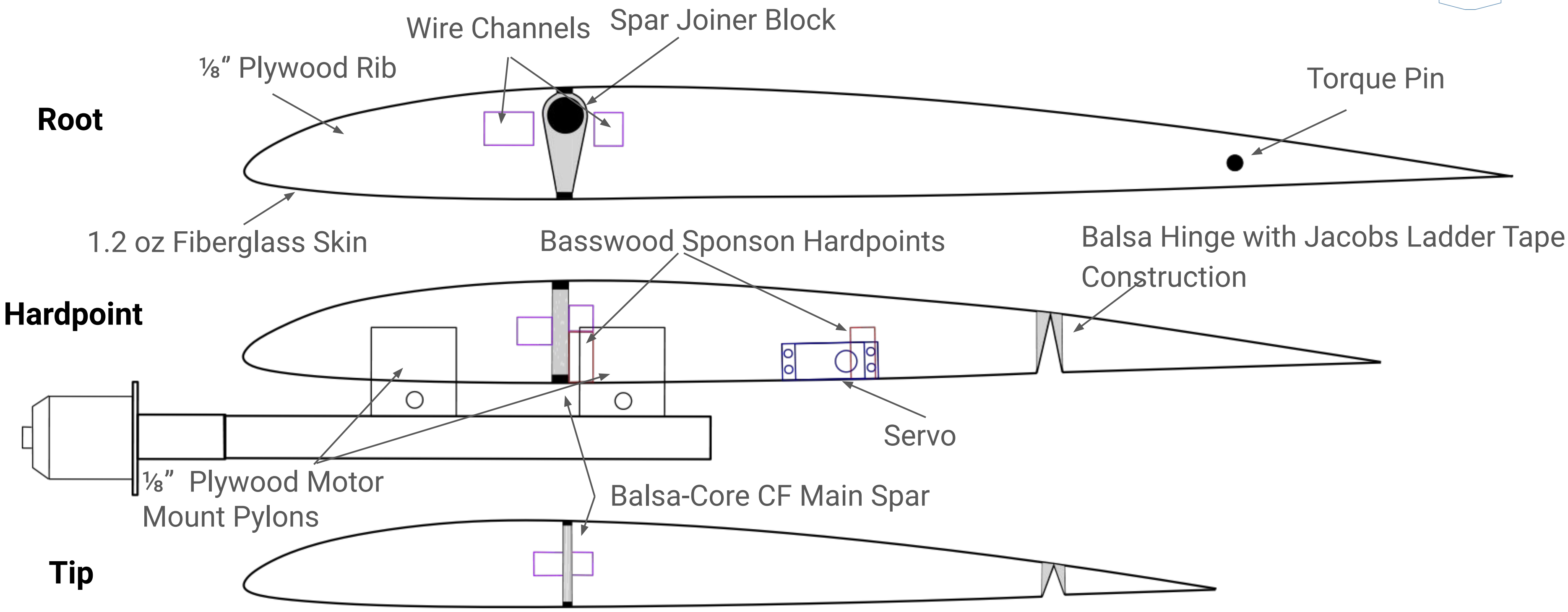
*other wing is the mirror image of this



Wing Appendix

Presenter:

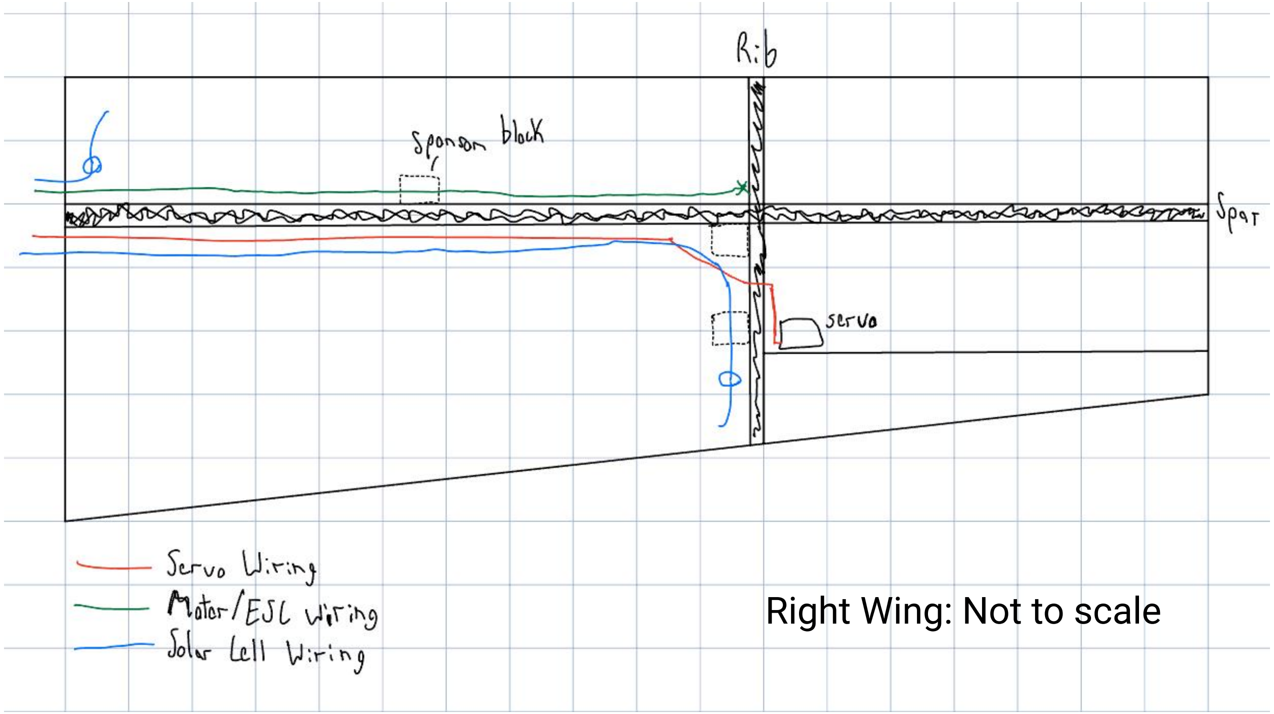
In Depth Cross Sections



Detailed Build: Wire Routing Plan

Presenter:

- Three main wiring channels sanded in: one on LE side of spar, one on TE side of spar, and one on tip side of rib
- Original wiring plan didn't include any hardpoints which became a problem when working with the real wing (see next slide)

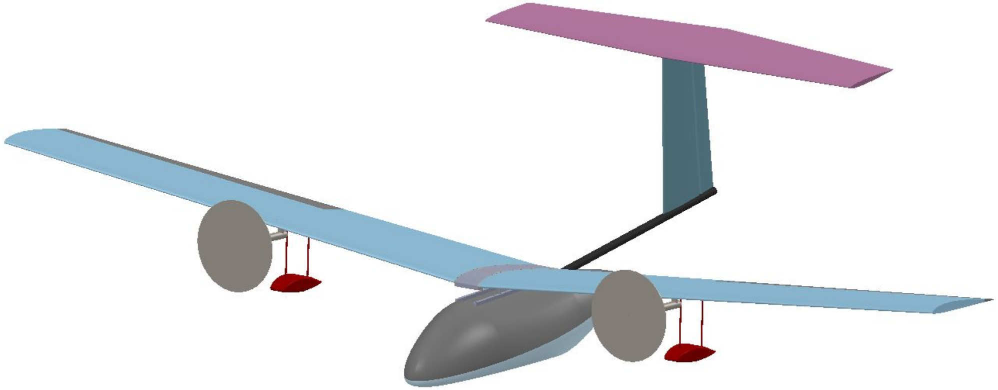


Right Wing: Not to scale

Detailed Build:
Mass Breakdown

Presenter: Morgan Ferguson

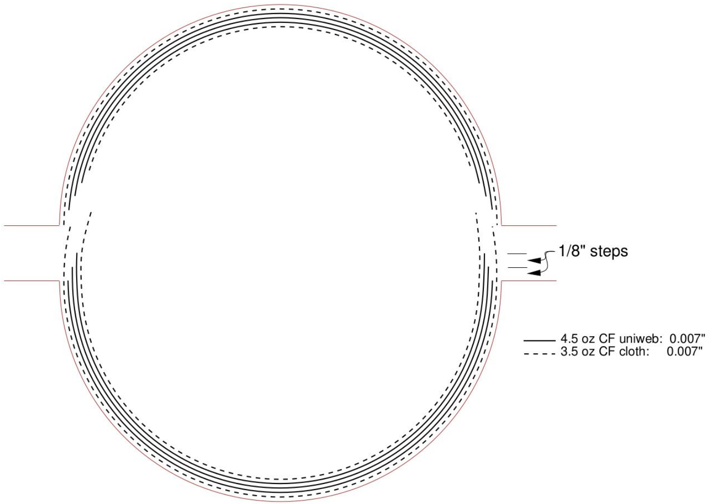
	Mass (g)	Xcg (cm from LE)
Spar	366	13.8
Center Piece	350	17.6
Hardpoints & mounts	399	18.9
Foam core	1671	18.2
Skin (& epoxy resin)	346	21.8
glue, misc.	151	13.8
	Total = 3,203 g	**Xcg,wing = 18.2 cm**



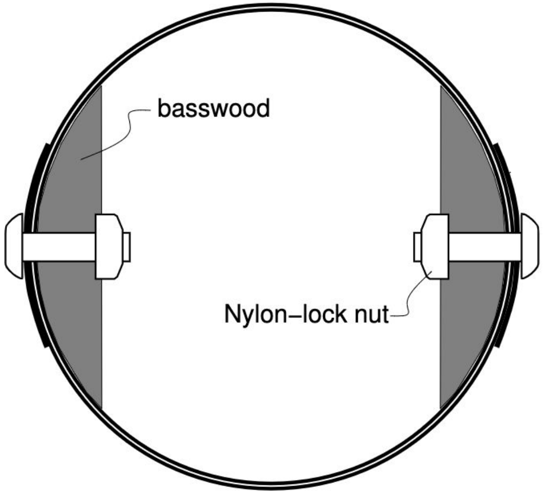
BoomBoom Appendix

Presenter: Josh Malone

Boom Design



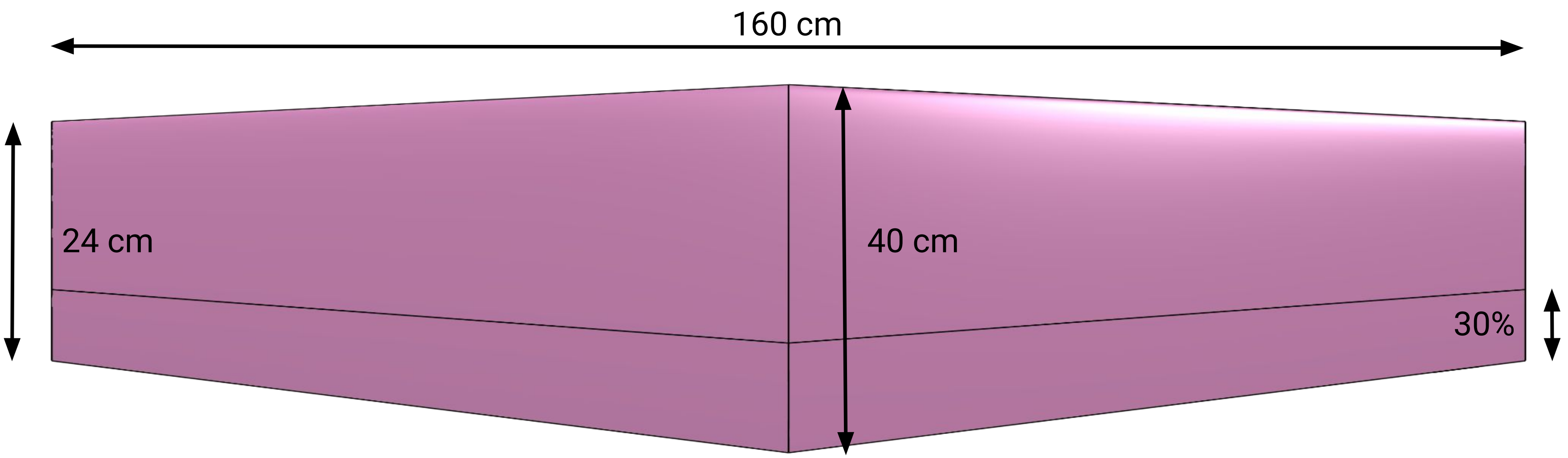
Split Mold Layup Diagram



Boom Removable Assembly Joint Design

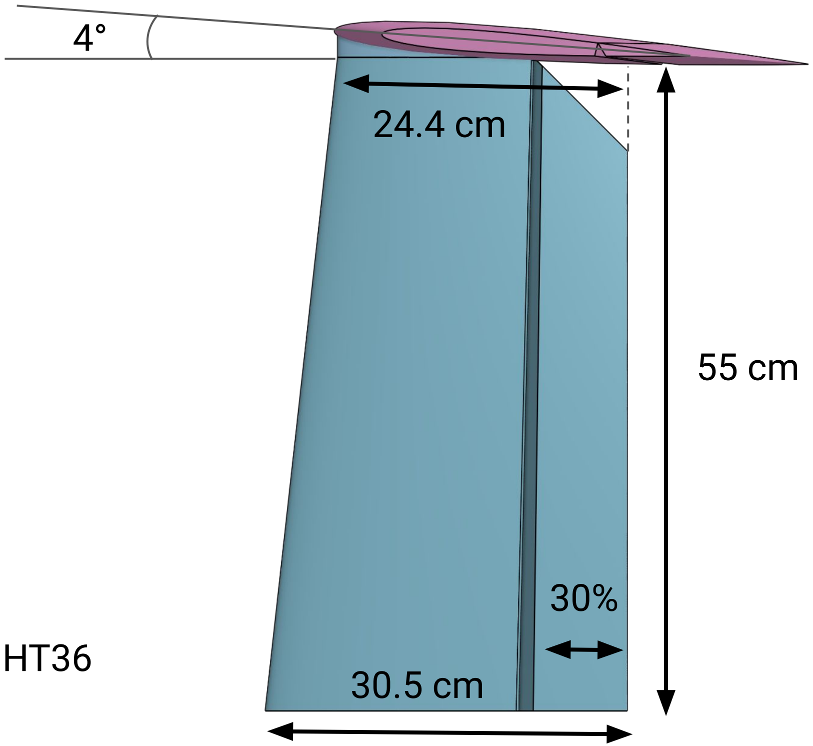
Presenter:

Horizontal Tail Detailed Design [BACKUP]

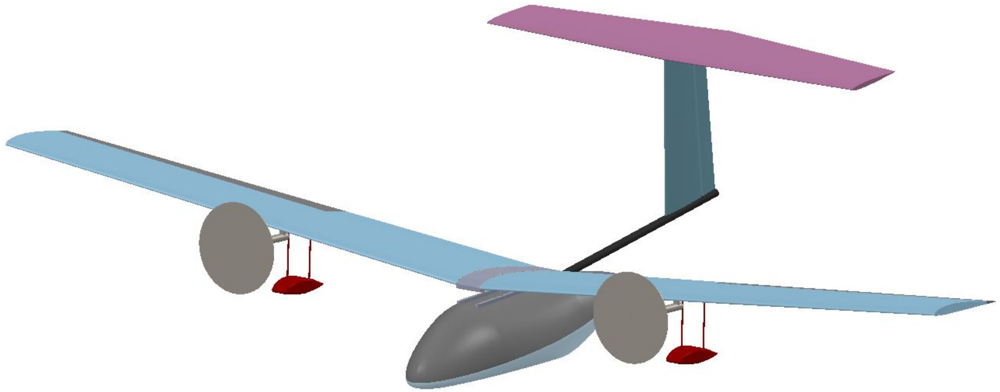


Airfoil: HT36

Vertical Tail Detailed Design [BACKUP]



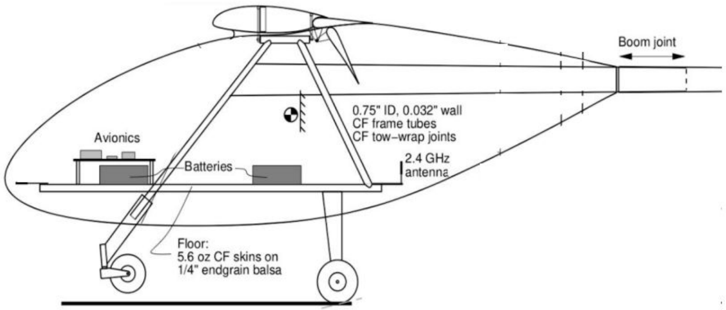
Airfoil: HT36



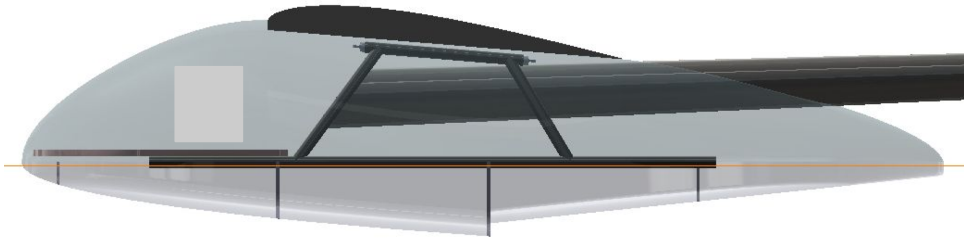
Wet Appendix

Internal Structure (IS) Inspiration: Kestrel eSTOL

Kestrel eSTOL (2019)



Solar Surfer (2023)



Inspired our:

- Boom-Truss Attachment
- Wing Center Section-Truss Attachment
- Floor and Ceiling Rails