EML4551-2

DR 6
Team 518: Light-Weight UAV

April 1, 2021

Department of Mechanical Engineering

FAMU-FSU Engineering

Team Introductions

Ethan Hale
Manufacturing and Systems Engineer

Jackson Dixon
Supply Chain Engineer

Maxwell Sirianni
Flight Dynamics Engineer

John Storms
Test Engineer

Joseph Ledo-Massey
Design Engineer and Project Manager

Sponsor and Advisor

NORTHROP GRUMMAN

Jennifer Tecson

Manager of Engineering

FSU Electrical Engineering Graduate

Lance Cooley, Ph.D.

Professor of Mechanical Engineering

Research interests in superconducting materials

Joseph Ledo-Massey

Objective

The objective of this project is to use multiple light-weighting techniques to reduce the overall weight of a UAV and increase the flight time.

Joseph Ledo-Massey

Background

Adaptation of the project Team 518 performed during 2019-2020 school year

Primary focus was on light-weighting the battery, the tail, and wing components with lighter materials

Based design on Believer 1960mm

Senior Design Team 2020-2021

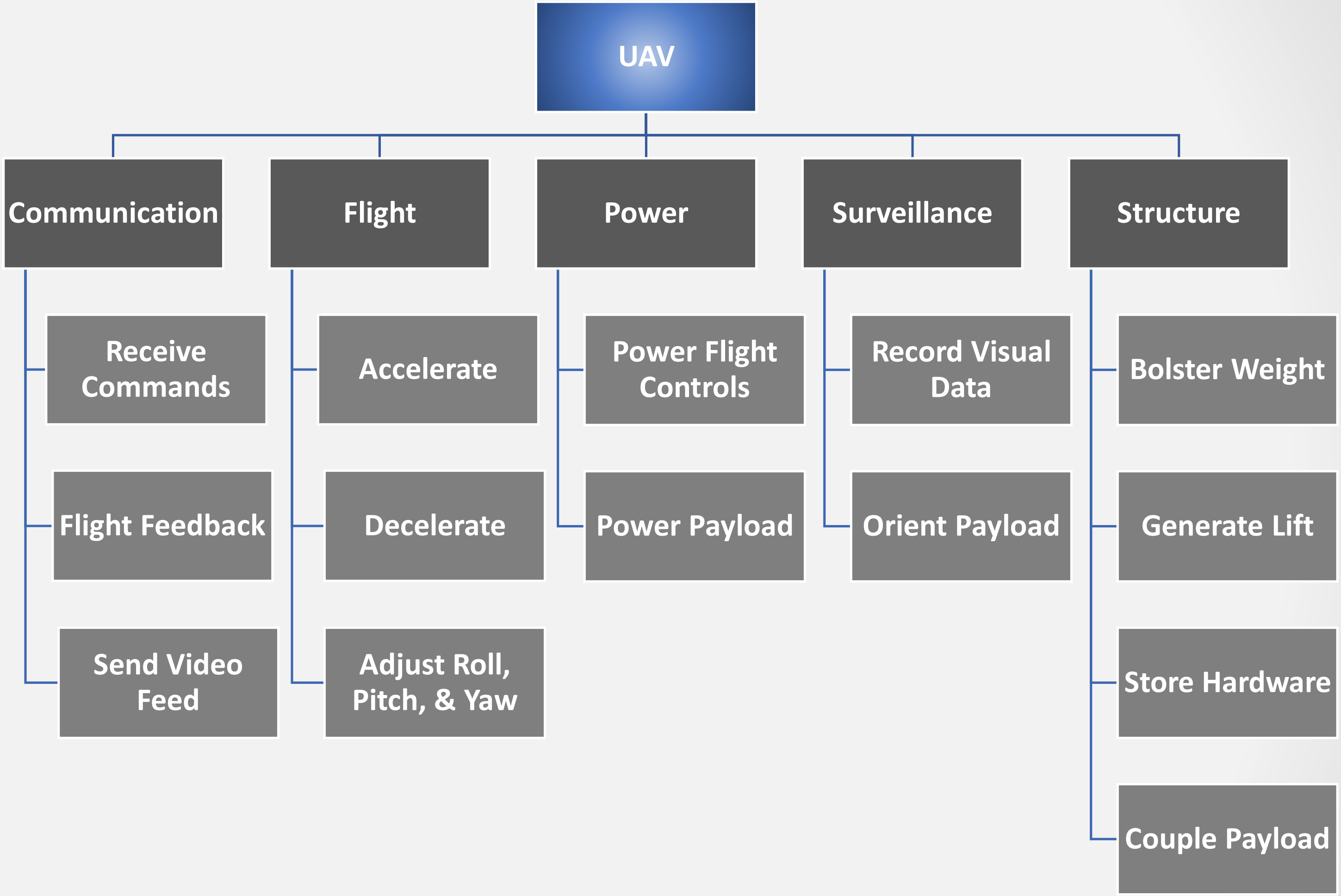
Max Sirianni

Markets

Max Sirianni

Functional Decomposition

- Primary Functions
  - Communication
  - Flight
  - Power
  - Surveillance
  - Structure



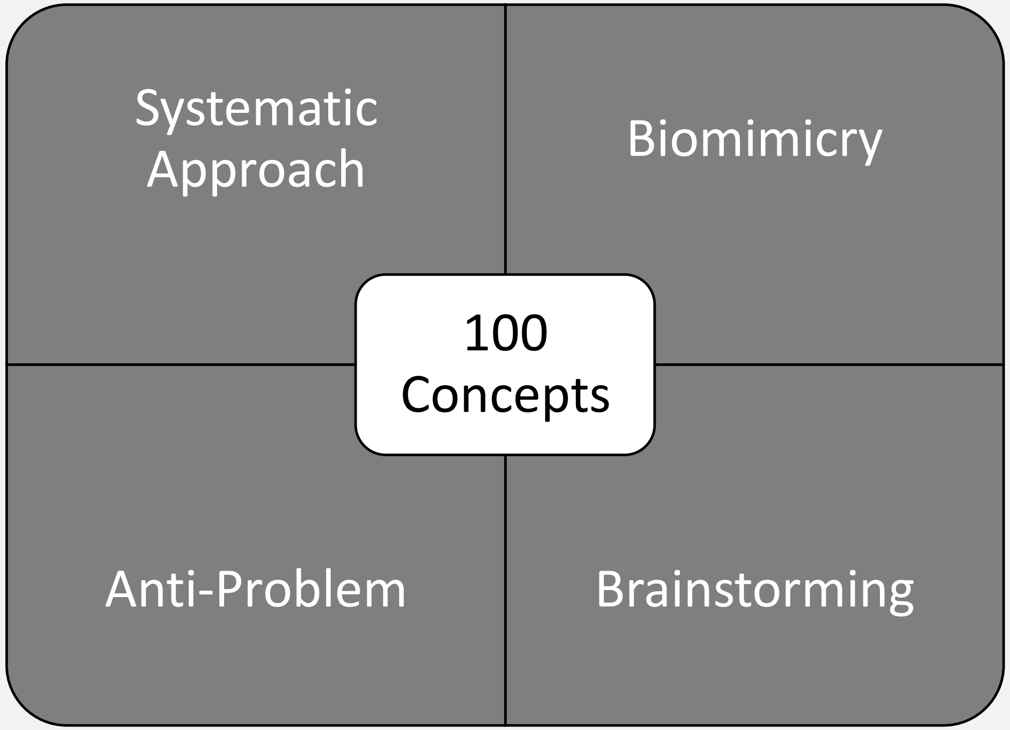
Max Sirianni

Critical Targets and Metrics

Functions	*Metrics*	*Targets*
1) Bolster weight	1) Support moment due to wing	1) 1.128 Nm
2) Generate Lift	2) Airfoil produces greater lift force than gross weight	2) 54 N
3) Couple Payload	3) Mass of payload supported	3) 600 g
4) Endurance	4) Overall flight time	4) 60 mins

Max Sirianni

Concept Generation



Max Sirianni

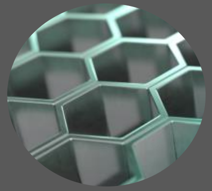
Concept Generation

Medium Fidelity

Regenerative Power Source

Generative Design

Honeycomb Structures



Electric Components used as Support

Complete Wing Design

High Fidelity

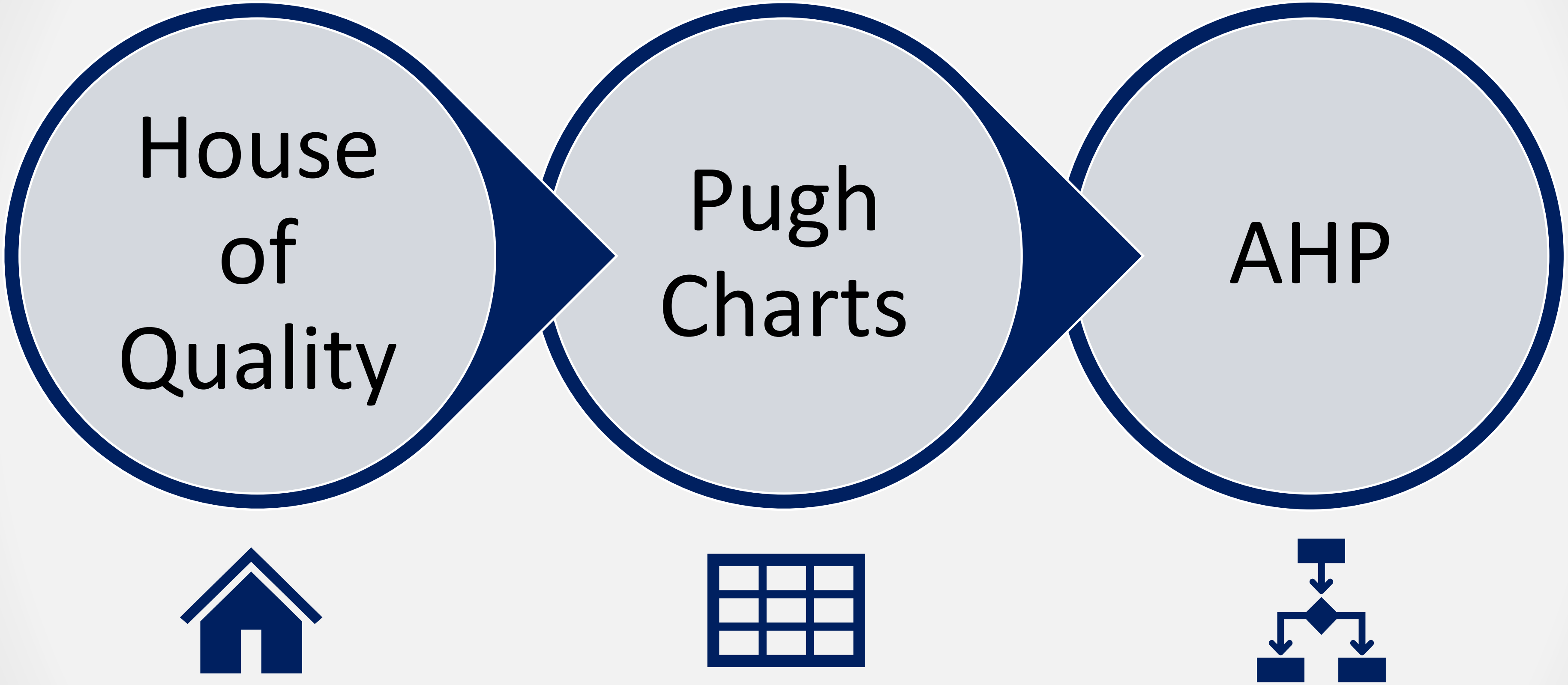
LW-PLA Constructed Parts

Lighter Electrical Components

Improve Propeller Construction

Max Sirianni

Concept Selection



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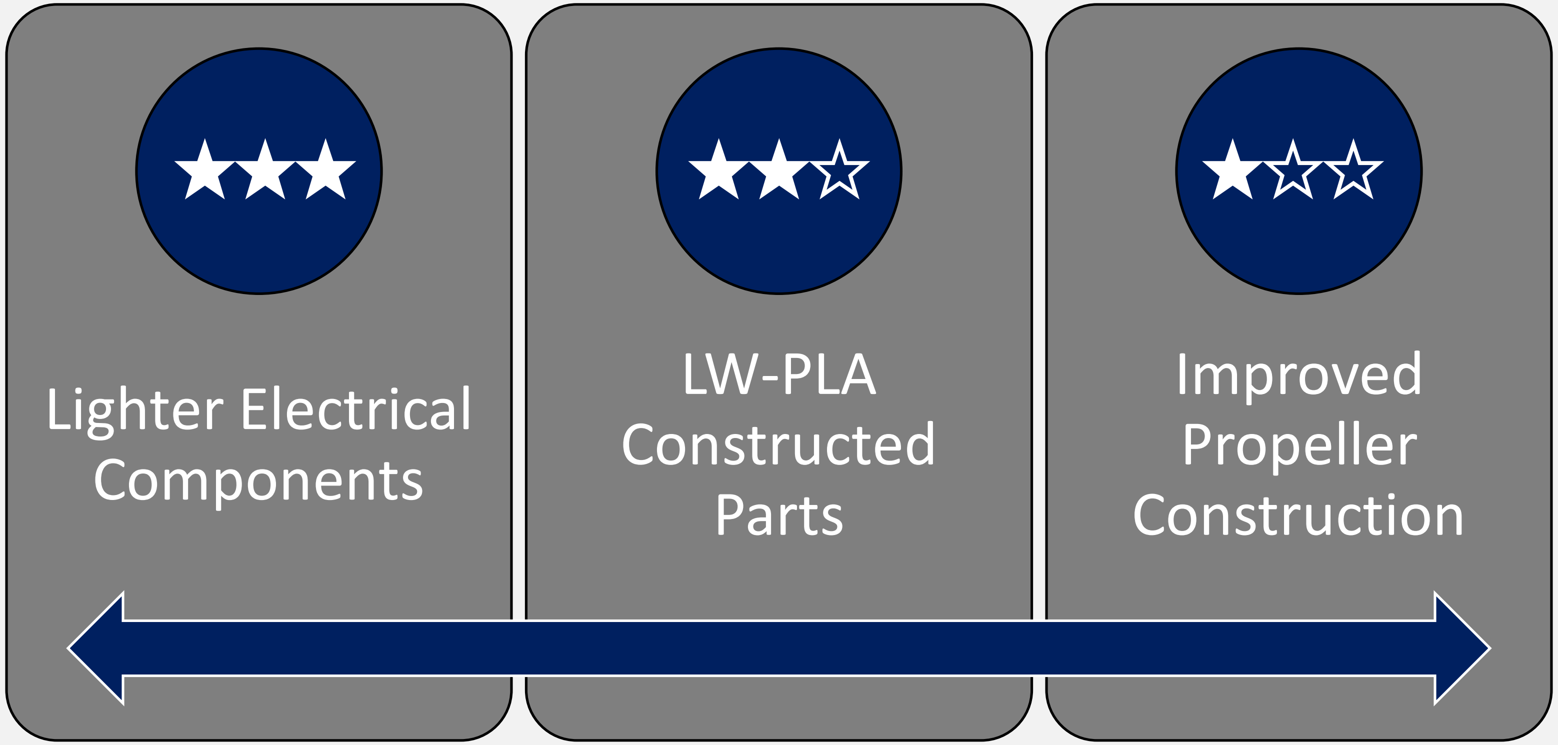
Concept Selection



Max Sirianni

Materials Assessment

What do we have to work with?

Ethan Hale

Materials Assessment

Believer 1960mm

- Aerial Mapping UAV
- Light Weight Construction
- Optimal Payload Space

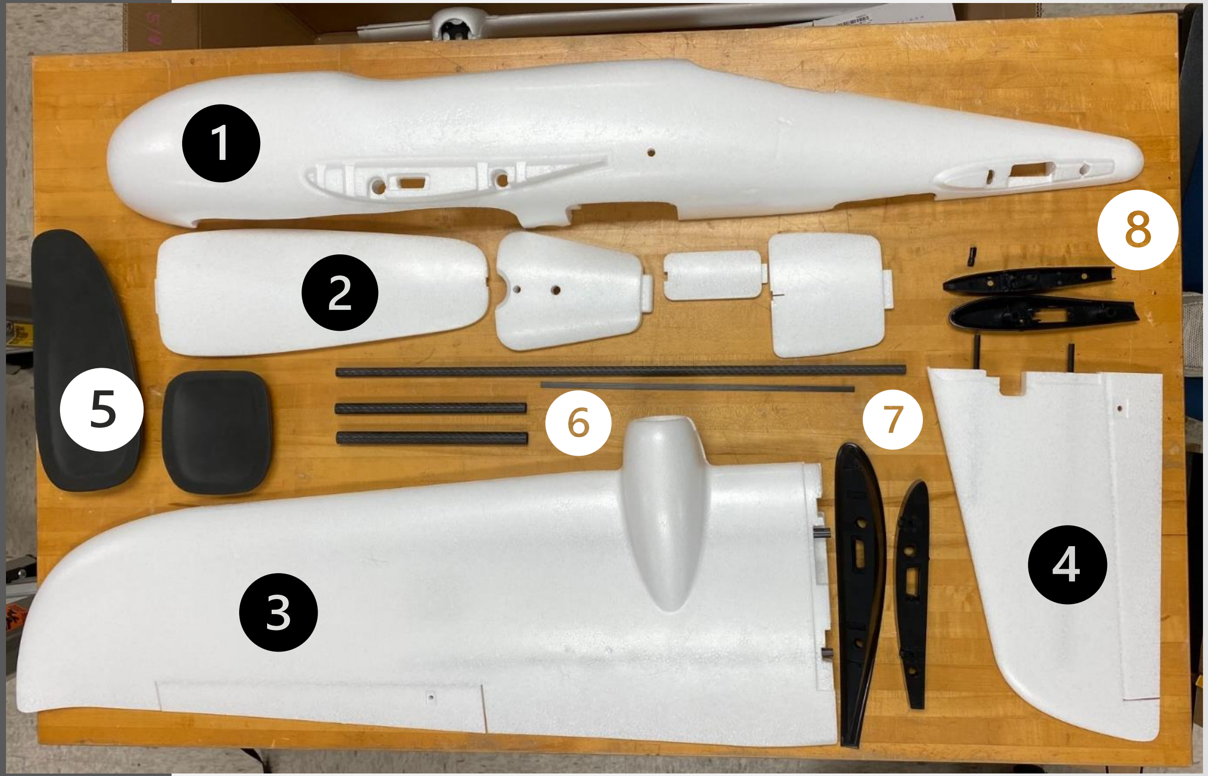




Ethan Hale

Materials Assessment: Airframe

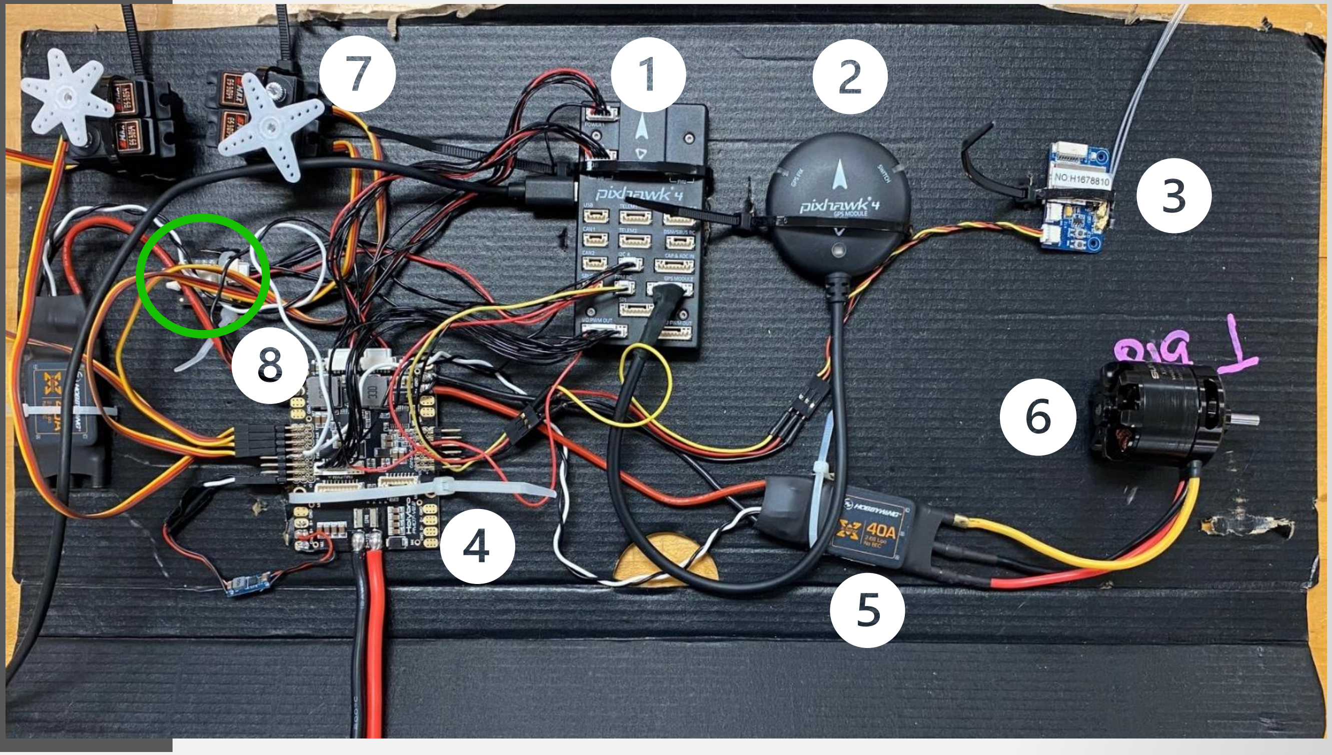
1. Fuselage
2. Fuselage Covers
3. Wing
4. Empennage
5. Bottom Covers
6. Carbon Fiber Rods
7. Wing Mounting Brackets
8. Empennage Mounting Brackets



Ethan Hale

Materials Assessment: Electrical System

1. Flight Controller
2. GPS Module
3. Radio Receiver
4. Power Control Board
5. Electronic Speed Controller
6. Motor
7. Servo Motor
8. Air Speed Sensor



Ethan Hale

Materials assessment: Electrical System

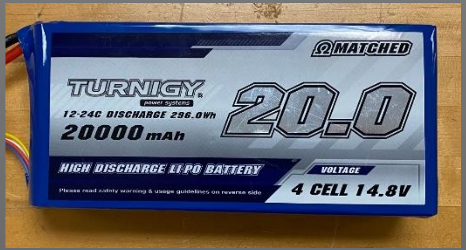
1. Flight Controller
2. GPS Module
3. Radio Receiver
4. Power Control Board
5. Electronic Speed Controller
6. Motor
7. Servo Motor
8. Air Speed Sensor
9. Controller

9

Ethan Hale

Materials Assessment: Batteries

Turnigy battery:



- Recommended battery via Believer 1960 handbook
- 20000mAh
- 4 cell 14.8v
- 12-24C discharge

Lumenier battery:

- Battery ordered during 2019-2020 school year
- 22000mAH
- 4 cell 14.8v
- 20-40C discharge

Ethan Hale

Lighter Electrical System

Batteries and Motors

John Storms

Batteries

Turnigy
14.8V

- Volume per data sheet: **883cm³**
- Recorded volume: **805cm³**
- Weight per data sheet: **1775g**
- Recorded weight : **1729g**

Lumenier
14.8V

- Volume per data sheet: **766cm³**
- Recorded volume: **831cm³**
- Weight per data sheet: **1600g**
- Recorded weight: **1702g**

John Storms

Batteries

Lumenier 14.8v battery

- Greater battery capacity, 2000mAh greater
- 27g of weight savings
    - Advertised as 175g of weight savings
- Comparable in size to the Turnigy battery

John Storms

Motors

SunnySky X2814 900KV Motors

- Recommended motor for the Believer 1960
- Can produce over 2000 gram-force of thrust depending on propeller applied
- Light-weight aluminum construction
  - Weight: 110g
- Large drone applications
  - Max of 13,320 rev/min (intended for bigger propellers, up to 13 inches long)

John Storms

Motors

iFlight XING X2814 880KV

- Designed for large drone applications
- Suited for 2-6s battery configurations
- Comparable thrust compared to old motors
    - 1924gf (12x5) vs. 1950gf (11x5.5)
- Weight: 91g per motor
    - **Total savings of 38g**

John Storms

LW-PLA Constructed Parts

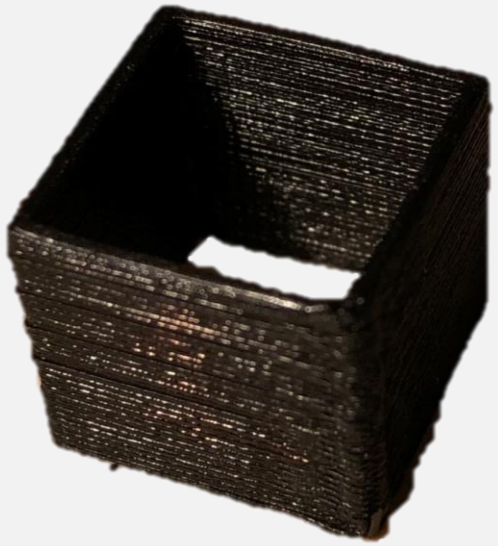
Lightweight filament

Joseph Ledo-Massey

PLA vs. LW-PLA

PLA (Polylactic Acid)

*Test Prints



Most common 3-D printing filament
Density: 1.210-1.430 $\frac{\mathrm{g}}{\mathrm{cm}^3}$

LW-PLA (Light-Weight Polylactic Acid)

New filament made by ColorFabb
Densities: Non-Activated-> 1.210-1.430 $\frac{\mathrm{g}}{\mathrm{cm}^3}$
Maximum Activated-> 0.403-0.476 $\frac{\mathrm{g}}{\mathrm{cm}^3}$

Joseph Ledo-Massey

3-D Printing Process

Utilized existing print settings from 2020 SAE Aero Team → Calibrated Printer for LW-PLA Material → Adjusted Calibrated Print Settings for Scaled Prints

Joseph Ledo-Massey

3-D Printing Process: Final Settings

Nozzle Temperature: 240 C

Flow Rate: 50%

Layer Thickness: 0.2 mm

Shell Thickness: 0.8 mm

Infill: 0%

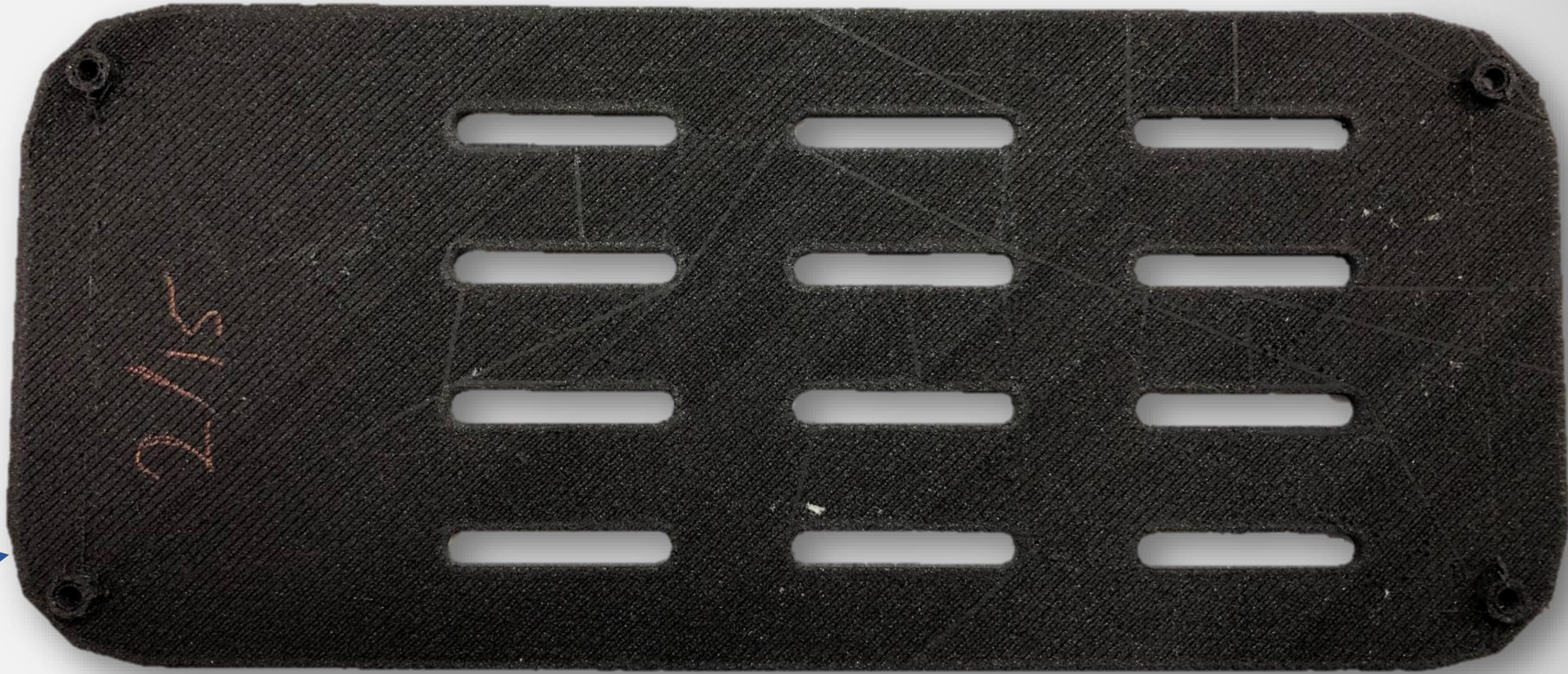
Print Speed: 40 $\frac{\text{mm}}{\text{s}}$

Part Cooling: 0%

Dremel 3D45

Joseph Ledo-Massey

Print with Final Settings

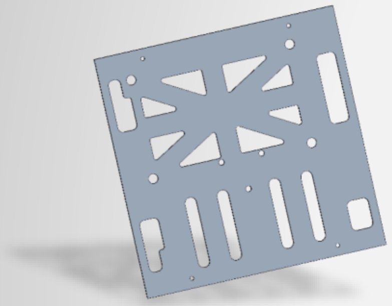


Electrical Regulating Cover

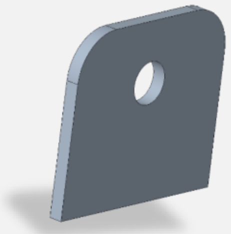
Joseph Ledo-Massey

LW-PLA Parts

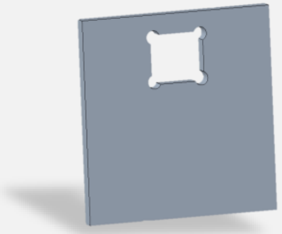
- Many of the small parts on the UAV were recreated in CREO so they could be reprinted out of LW-PLA



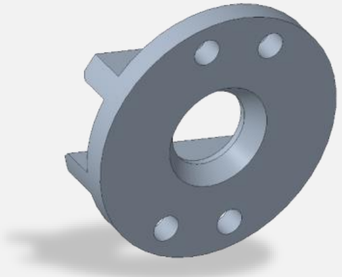
Autopilot Locating Board



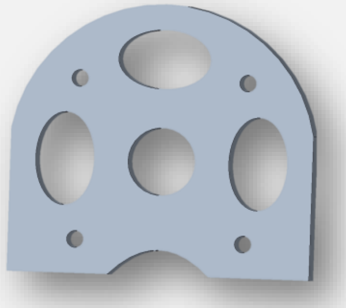
Parachute Hatch Cover



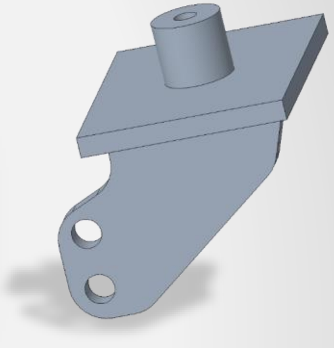
Cabin Cover



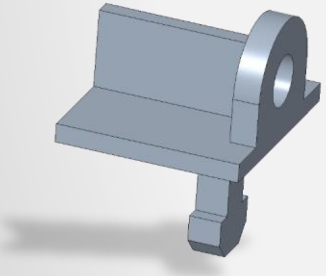
Chuck



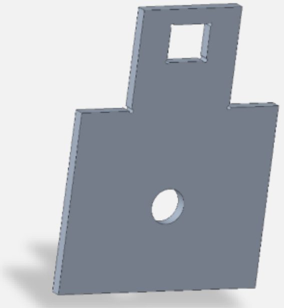
Motor Mount



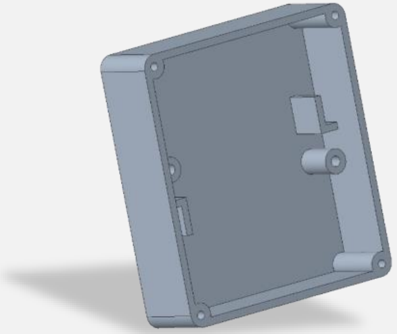
Helm angle



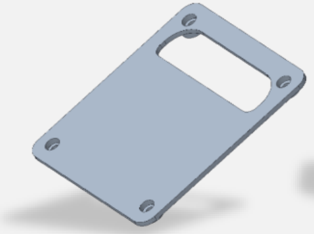
Cabin Cover Locking Nail



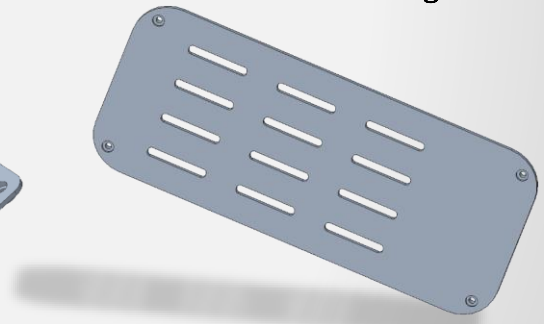
Antenna Fixing Board



Servo Installing Base



Servo Covering Plate

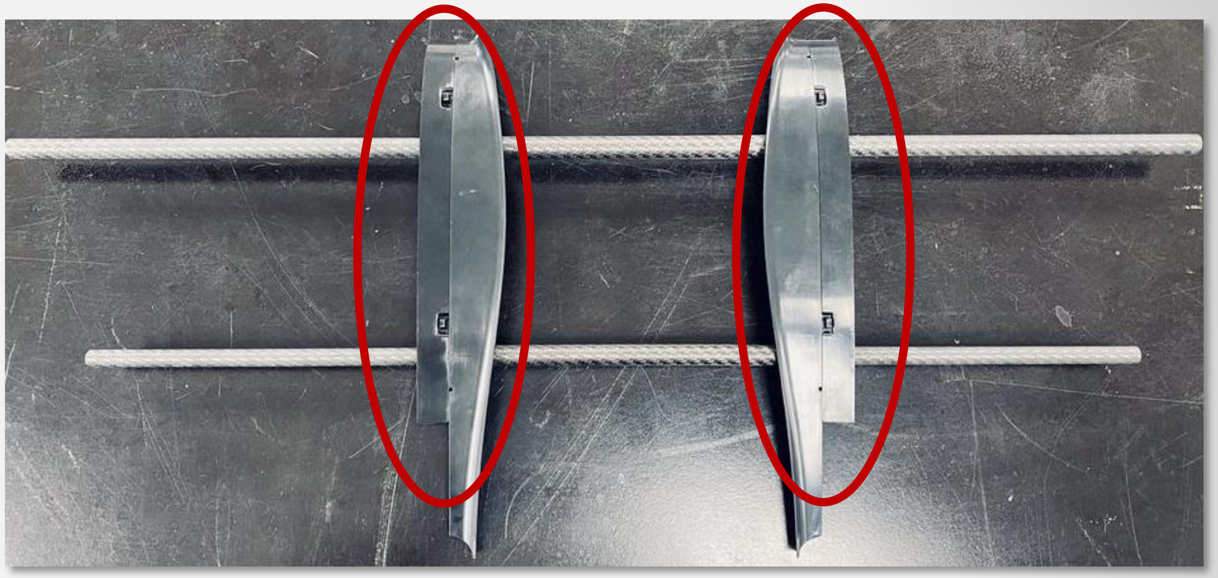


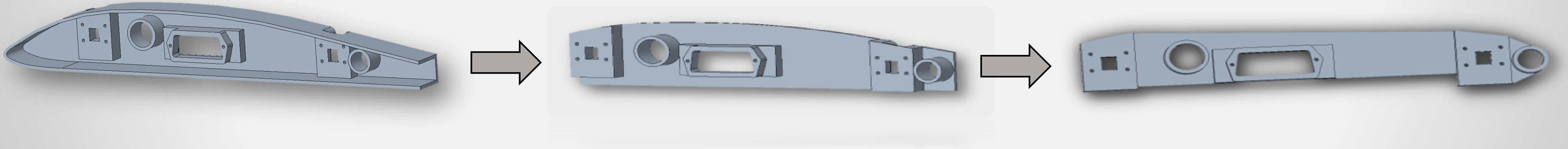
Electric Regulating Cover

Jackson Dixon

LW-PLA Parts

- For the larger parts, we were able to look at the geometry.
- We changed the shape and material of the wing and empennage mounting brackets





Jackson Dixon

Improved Propeller Construction

Carbon Fiber

Jackson Dixon

Propellers

- The manual for the Believer 1960 suggests 3 different propeller sizes for the original *SunnySky* motors.
- Each propeller has difference performance qualities

	APC 11x8	APC 11x7	APC 11x5.5
Mass(g)	41.10	39.97	22.96
Thrust(gf)	2020	2020	1950
Current Draw(A)	37.5	34.4	29.3
Power Consumption(W)	555	509.12	433.64
Efficiency(gf/W)	3.64	3.97	4.50

*APC Propellers are an industry leading brand of injection molded propellers

Jackson Dixon

Propellers

- APC 11x5.5-inch propellers were deemed to be the best suited base line propellers for extending the flight time of the UAV
  - Best efficiency, lightest weight, comparable thrust produced.

Jackson Dixon

Propellers

Quanum Carbon Fiber Propeller

- Extremely light and strong construction
- Size: 11x5.5 inch
- Weight: 9g each
  - Total savings of 18g (50% weight reduction)

Jackson Dixon

Propellers

Quanum Carbon Fiber Propeller

- Consumes **61% less energy** from the motor than APC 11x5.5 inch propellers

Jackson Dixon

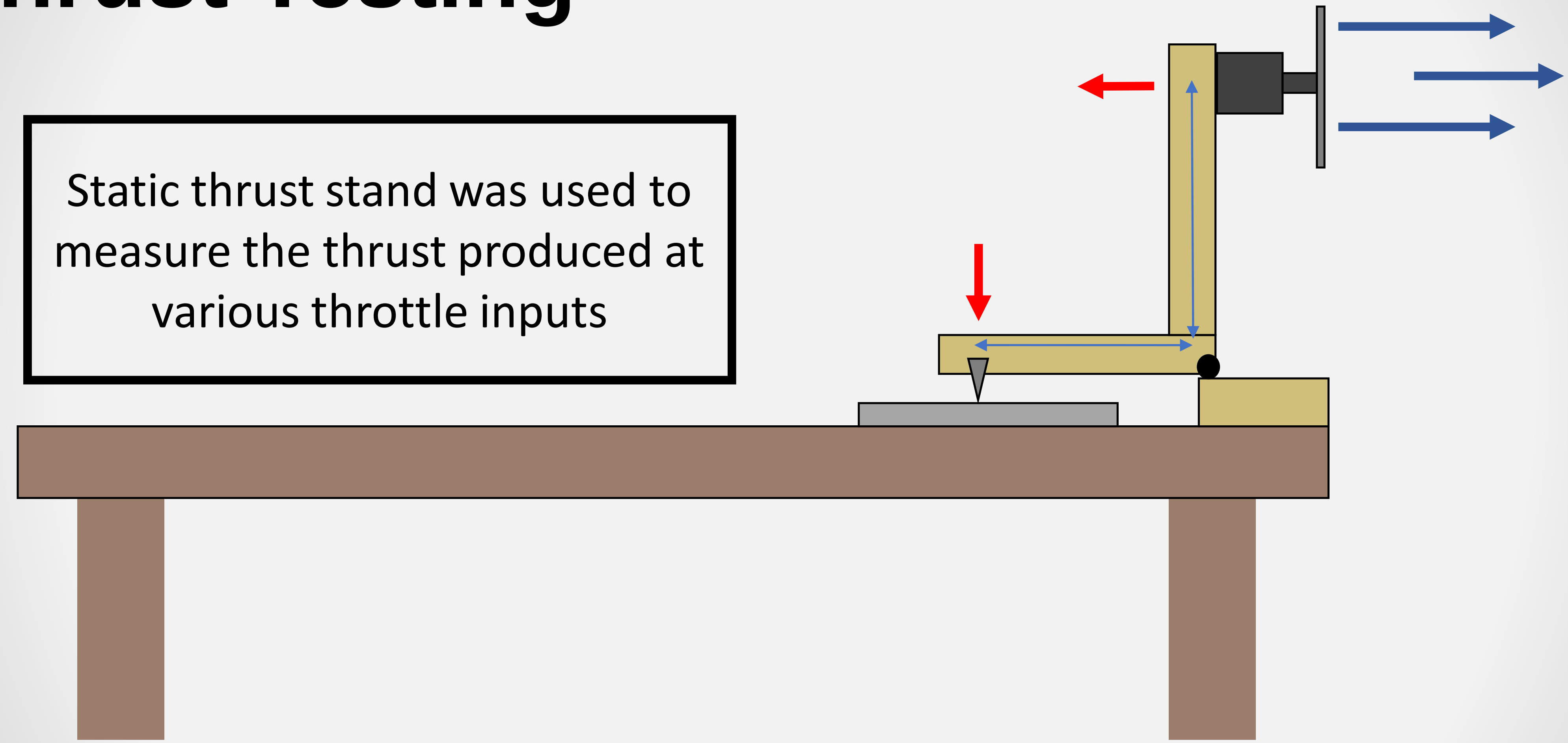
Thrust Testing

Motor & Propeller Validation

John Storms

Thrust Testing

Static thrust stand was used to measure the thrust produced at various throttle inputs



John Storms

Thrust Testing

- Preliminary thrust tests were done to analyze the *SunnySky X2814 900KV* motor
- APC 11x4.5-inch propellers were used for these tests as they were available in the Senior Design Lab (weight: 17.01g)

Thrust generated (N)				
	25% throttle	50% throttle	75% throttle	100% throttle
Thrust Test 1	1.756	4.199	11.654	23.230
Thrust Test 2	1.854	4.307	12.164	23.328
Thrust Test 3	1.815	4.375	12.243	23.240
Thrust Test 4	1.776	4.081	12.056	23.230
Avg. Thrust	**1.800**	**4.241**	**12.028**	**23.257**

John Storms

Thrust Testing

- The thrust testing using the 11x4.5-inch propeller provided more force than expected
  - With a less aggressive pitch, less thrust should be generated than the APC 11x5.5 propeller

SunnySky X2814 900KV	
APC 11x4.5	Thrust (N)
100% Throttle	23.257

vs.

SunnySky X2814 900KV	
APC 11x5.5*	Thrust (N)
100% Throttle	19.123

*Data taken from Motor Manufacturer

John Storms

Thrust Testing

- The new motors can now be compared to the original motors.
  - The new motors supply less thrust, but it is still greater than the thrust specifications from the motor manufacturer

SunnySky X2814 900KV	
APC 11x4.5	Thrust (N)
100% Throttle	23.257

VS.

iFlight XING 2814 880KV	
APC 11x4.5	Thrust (N)
100% Throttle	19.735

John Storms

Thrust Testing

- The iFlight X2814 880KV motors are well suited for this application.

- Still waiting on the carbon fiber propellers to arrive
- They are expected to produce more thrust than the propellers used during testing.

John Storms

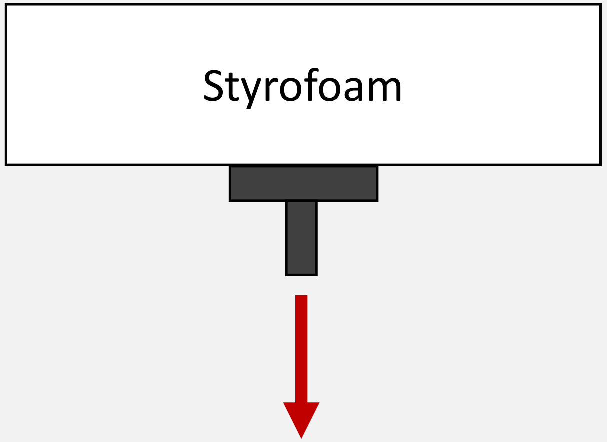
LW-PLA Parts

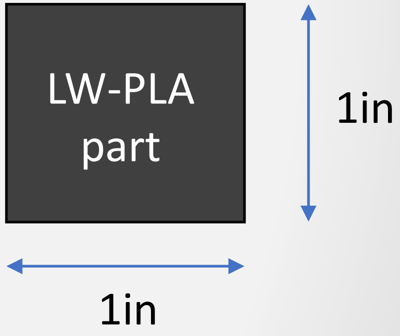
Component Redesign Validation

Jackson Dixon

Validation of Part Redesign

- 1in x 1in test part was glued to a piece of Styrofoam
- Failed with an applied weight of 1700g



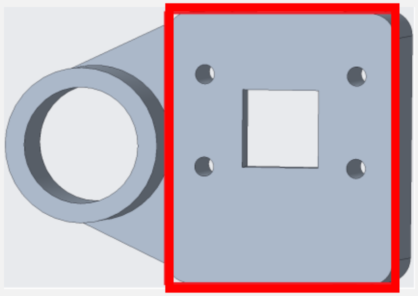


Jackson Dixon

Validation of Part Redesign

- Using this test piece's surface area and corresponding fracture weight, we can use them to make a ratio with the weight of a wing
- X = 0.172in^2 + 50% = 0.258in^2

$$\frac{1\ in^2}{X} = \frac{1700\ g}{292\ g}$$



7/8"

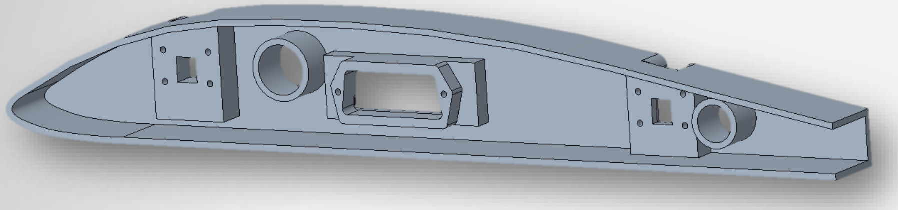
1/2"

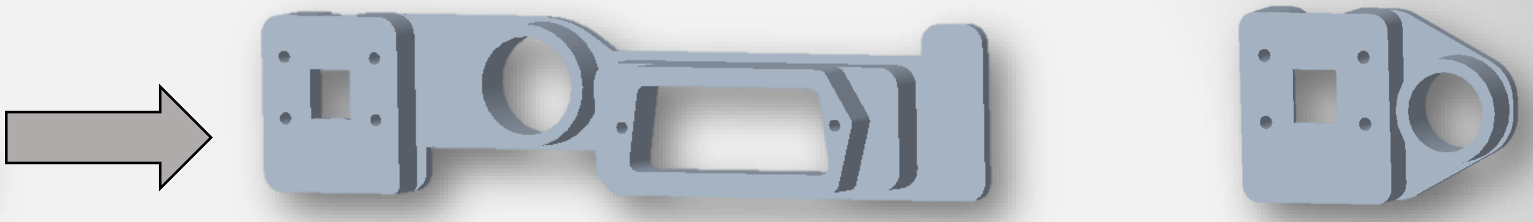
Surface Area = Total Area – Area of Rectangle – Area of Circles
(Red Square)

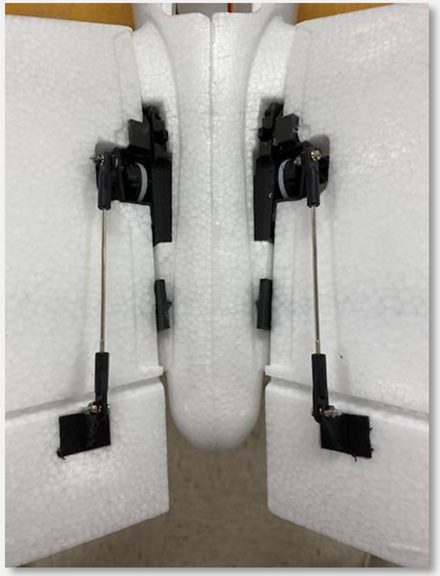
Total Surface Area = 0.370 in^2

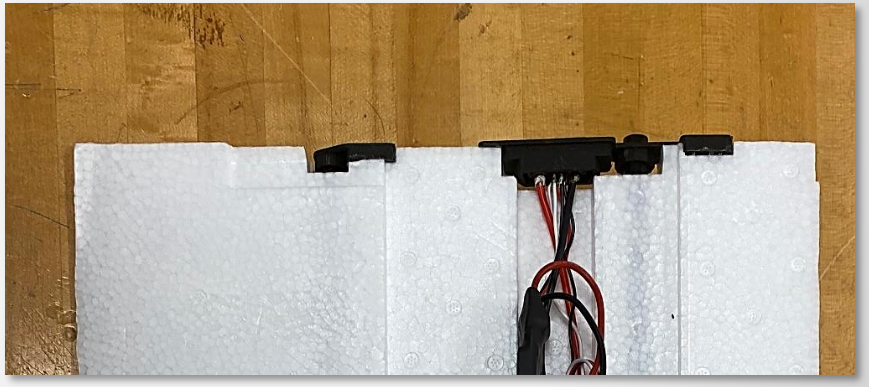
Jackson Dixon

Validation of Part Redesign









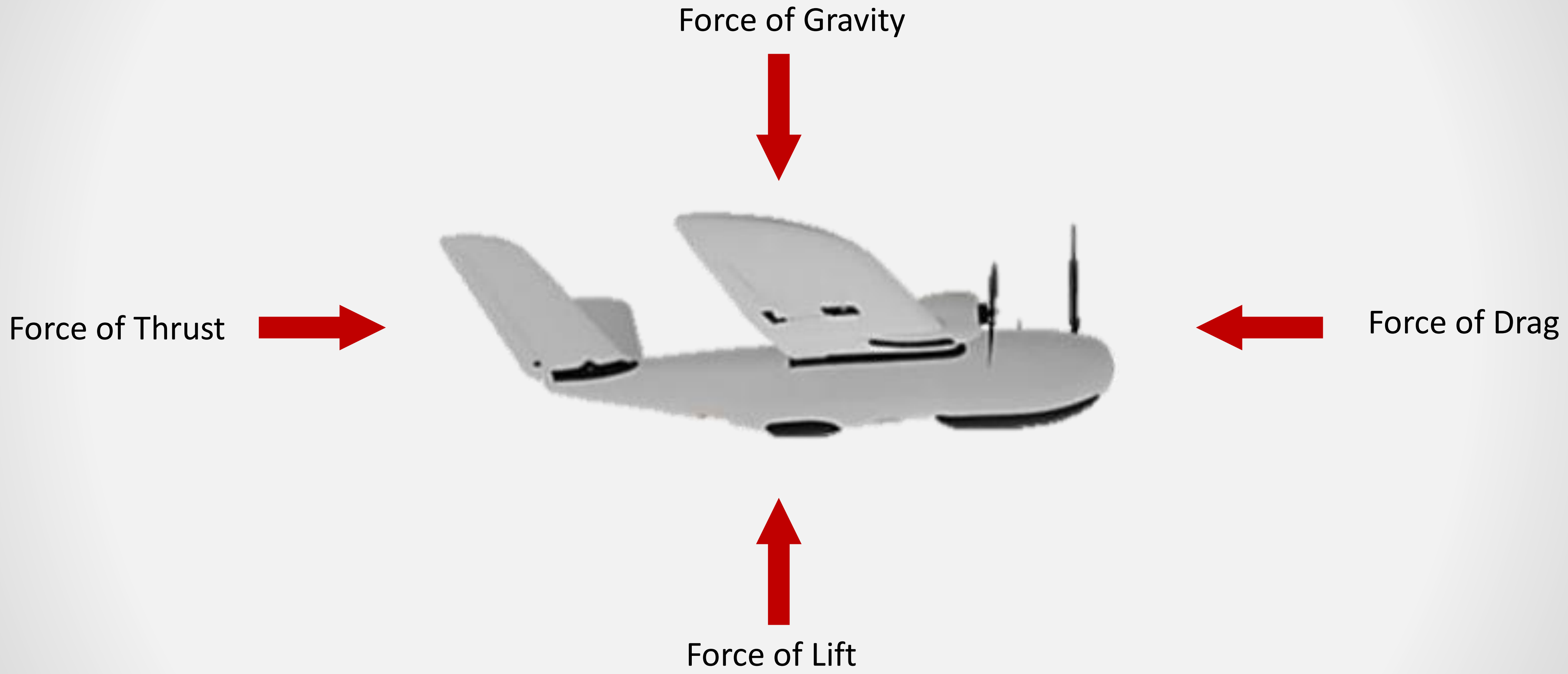
Jackson Dixon

UAV Analysis

Objective Validation

Ethan Hale

UAV Analysis



Ethan Hale

UAV Analysis

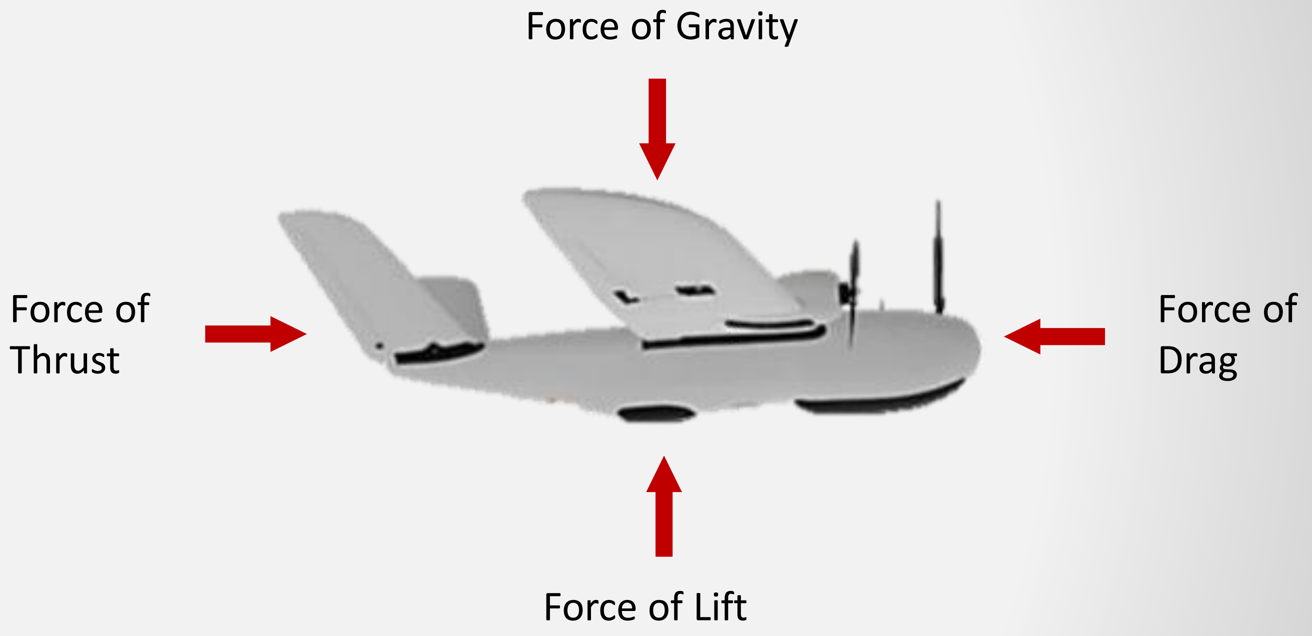
$$\sum \boldsymbol{F} = \boldsymbol{ma}$$

$$F_D = \frac{1}{2}\rho v^2 C_D A$$

$$F_L = \frac{1}{2}\rho v^2 C_L A$$

$$T = \dot{m}(v_e - v_i)$$

$$F = mg$$



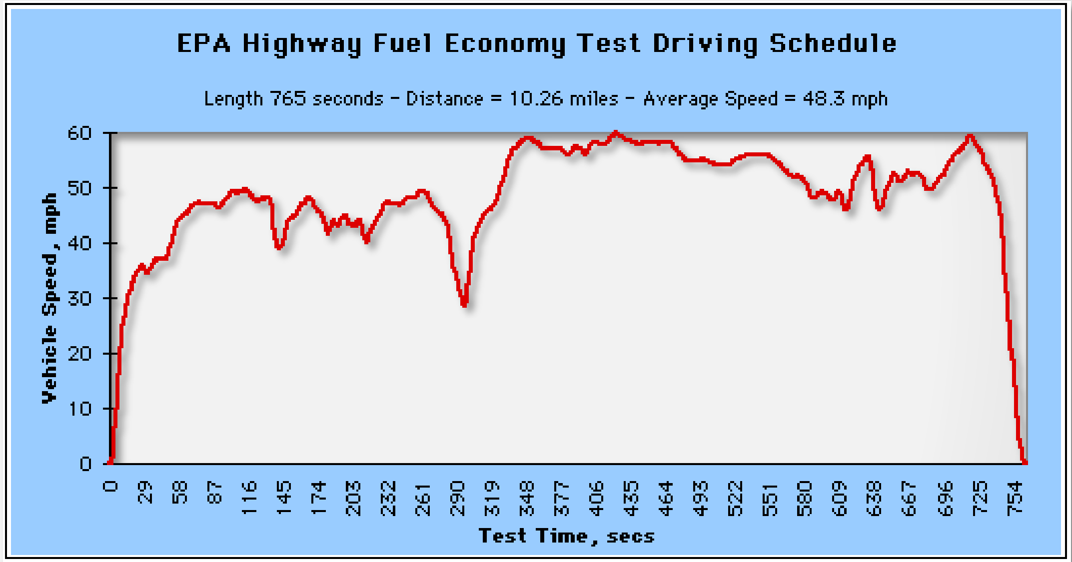
Ethan Hale

UAV Analysis

Using the forces acting on the UAV, the energy consumed can be analyzed:

$$E = \int Fv\,dt$$

We need a velocity profile of the UAV:



Highway Fuel Economy Driving Schedule (HWFET)

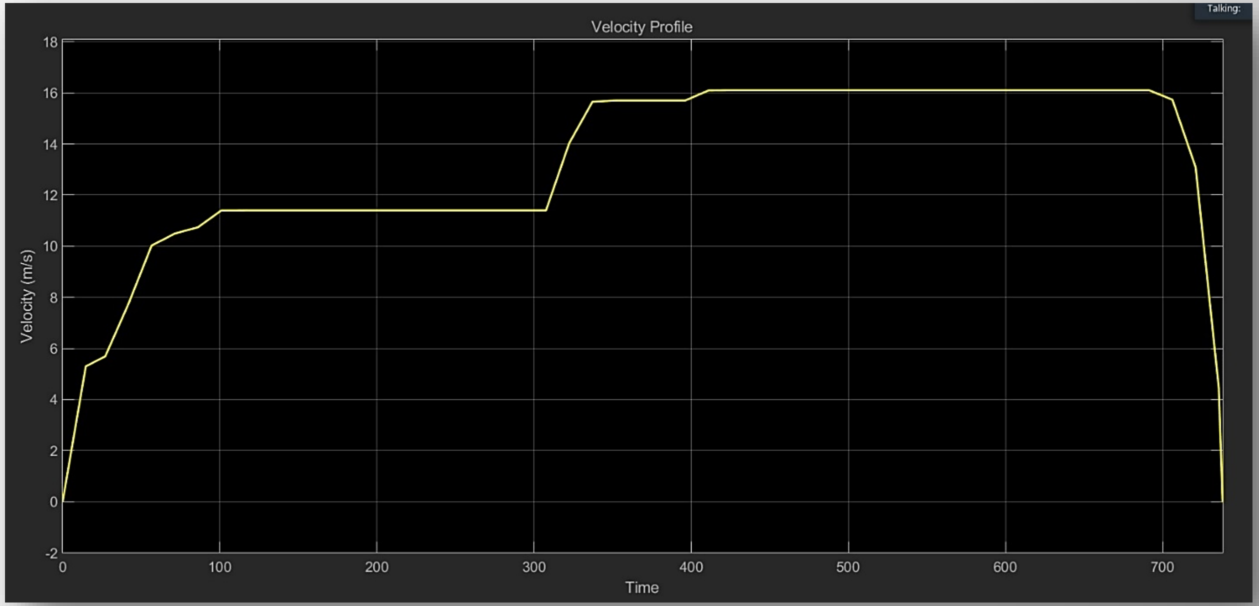
Ethan Hale

UAV Analysis

Using the forces acting on the UAV, the energy consumed can be analyzed:

$$E = \int Fv\,dt$$

We need a velocity profile of the UAV:



Modified Highway Fuel Economy Driving Schedule (HWFET)

Ethan Hale

UAV Analysis

Original Weight: 3812.6g

New Weight: 3436g

Weight Savings: 376.6g (~10%)

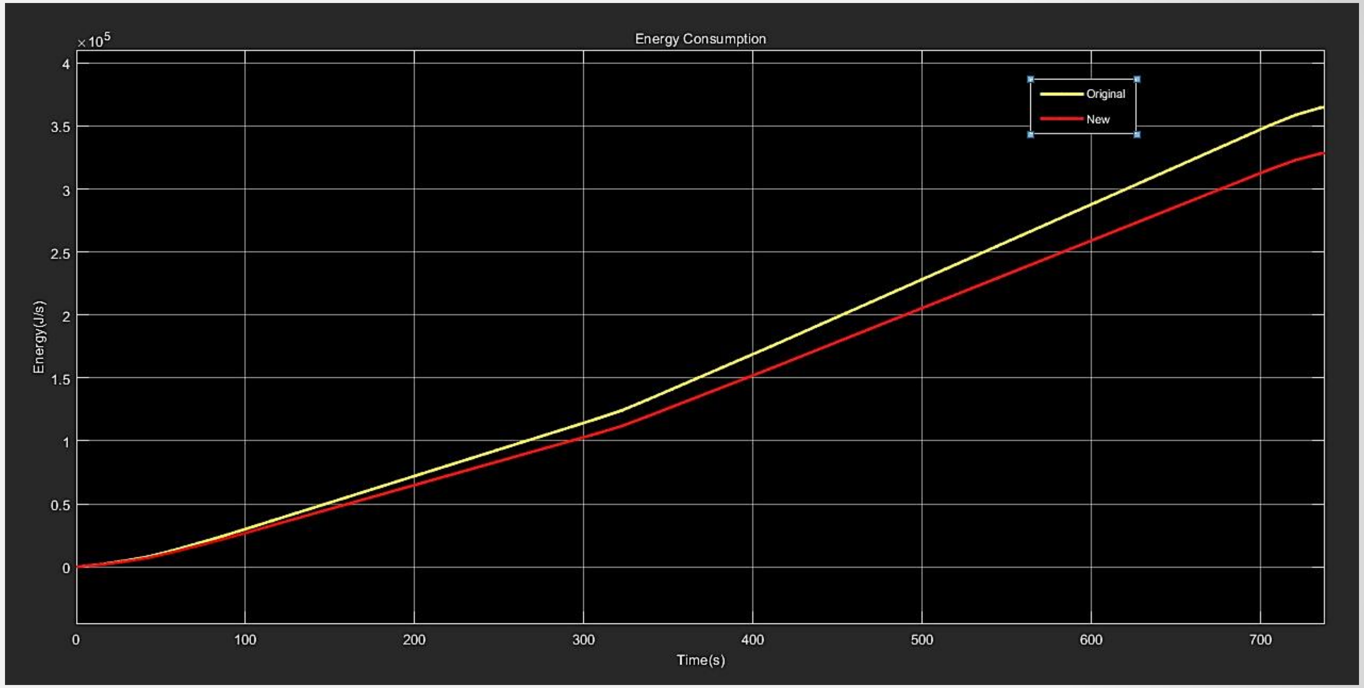
Ethan Hale

UAV Analysis

Using SimuLink, the energy consumption for the given velocity profile was analyzed.

Implementing the final weight savings of 376.6g, the difference in the energy profiles can be seen.

Energy savings due to weight reduction: **10%**



Ethan Hale

UAV Analysis

Where can future energy savings come from? → Perform a sensitivity analysis

Design Changes	Energy savings
800g weight savings	20%
1900g weight savings	49%
Improve CL/CD ratio to 14	0.3%
Increase CL to 1.5	0.49%
Increase CL to 2(double)	1.85%
Decrease CD to .06	0.03%
Decrease CD to 0.04(half)	0.03%

Ethan Hale

Critical Targets and Metrics

Functions

1) Bolster weight
2) Generate Lift
3) Couple Payload
4) Endurance

Metrics

1) Support moment due to wing
2) Airfoil produces greater lift force than gross weight
3) Mass of payload supported
4) Overall flight time

Targets

1) 1.128 Nm
2) 54 N
3) 600 g
4) 60 mins

Validation

1) Max moment of wing is 0.75Nm
2) 104.53N of lift produced
3) Fuselage supports over 600g
4) Flight time increased by at least 6 minutes

Ethan Hale

Concept Takeaways

- The LW-PLA is very tricky to work with.
  - The variability in the material density and size of the parts caused tolerancing errors.
- Not all parts are as advertised online
  - Lumenier battery should've had a much greater weight savings impact (27g vs. 175g)
  - Quanum Propellers showed in stock but reported as on backorder when placed in the cart (Feb. 5 order date)

Joseph Ledo-Massey

Assembled Believer 1960

Joseph Ledo-Massey

Future Work

Looking Ahead

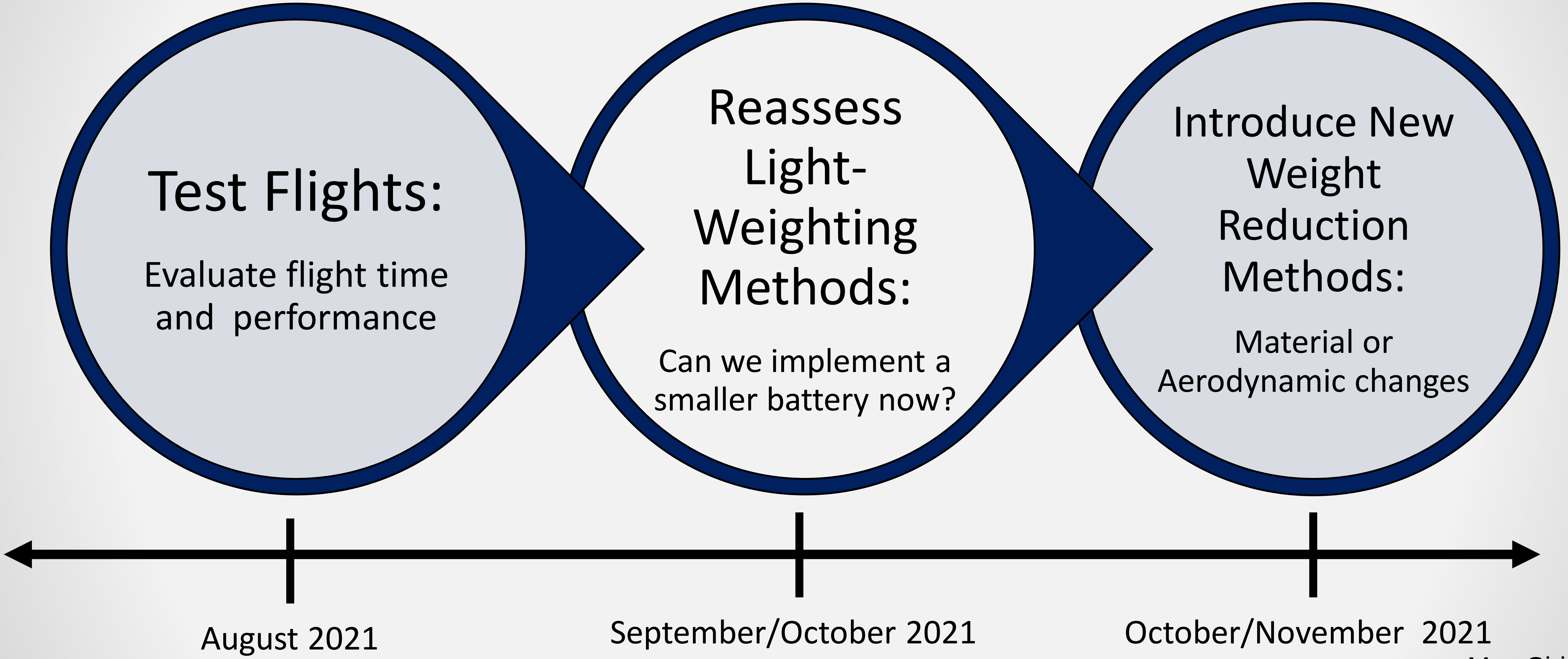
Max Sirianni

What We Learned

- The pre-design items are critical
  - Customer Needs, Targets and Metrics, Concept Generation
- Background Research is essential
  - You never know too much about your project and what you're working on
- Nothing is ever as easy or quick as you think it is.

Max Sirianni

Future Work



Max Sirianni

Recap

Lighter Electrical Components

The objective of this project is to use multiple light-weighting techniques to reduce the overall weight of the Believer 1960 and increase the flight time.

Improve Propeller Construction

LW-PLA Constructed Parts

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