EML4551-2

DR 5
Team 518:
Light-Weight UAV

February 18, 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

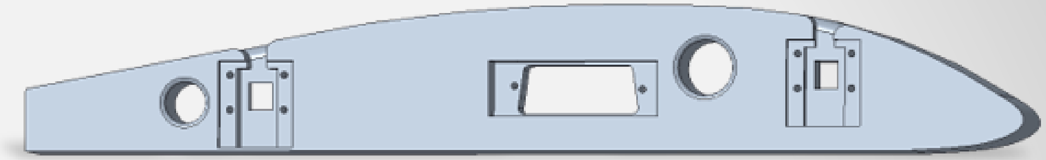
Jackson Dixon

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.

Jackson Dixon

Previously



- Took inventory of UAV parts purchased by previous team
- Got the electrical system working → Motors now controlled by remote
- Weight comparison between the 2 batteries
  - New battery saves 27g and provides an additional 2000mAh

- Parts were remodeled in CREO to be printed with LW-PLA

Jackson Dixon

Motor Selection

- Recommended motor is the *SunnySky X2814 900KV* motor
  - 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 $\frac{rev}{min}$ (intended for bigger propellers, up to 13 inches long)

John Storms

Previously | Motor & Propeller Selection | Thrust Testing | Modification of Auxiliary Parts | Redesign of Auxiliary Parts | 3-D Printing Process | Estimated Weight Savings | Future Work

Motor Selection

iFlight XING X2814 880KV

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

John Storms

Previously | Motor & Propeller Selection | Thrust Testing | Modification of Auxiliary Parts | Redesign of Auxiliary Parts | 3-D Printing Process | Estimated Weight Savings | Future Work

Propeller Selection

- Recommend propellers for *SunnySky X2814 900KV* motor:
  - APC* 11x5.5, 11x7, 11x8 inch propellers
  - Thrust output, current draw and power consumption varies for each
  - Weight varies per propeller

	APC 11x5.5	APC 11x7	APC 11x8
Weight (g)	22.96	39.97	41.11

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

John Storms

Propeller Selection

- 11x5.5-inch propellers selected:
  - Lightest of the three choices
  - Consume less current and power compared to 11x7 and 11x8 inch props
  - More efficient than other propeller sizes (gf/W)
  - Remains 12°C cooler at full throttle
  - Produce just 3% less thrust (1950)

John Storms

Propeller Selection

Quanum Carbon Fiber Propeller

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

John Storms

Propeller Selection

Quanum Carbon Fiber Propeller

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

John Storms

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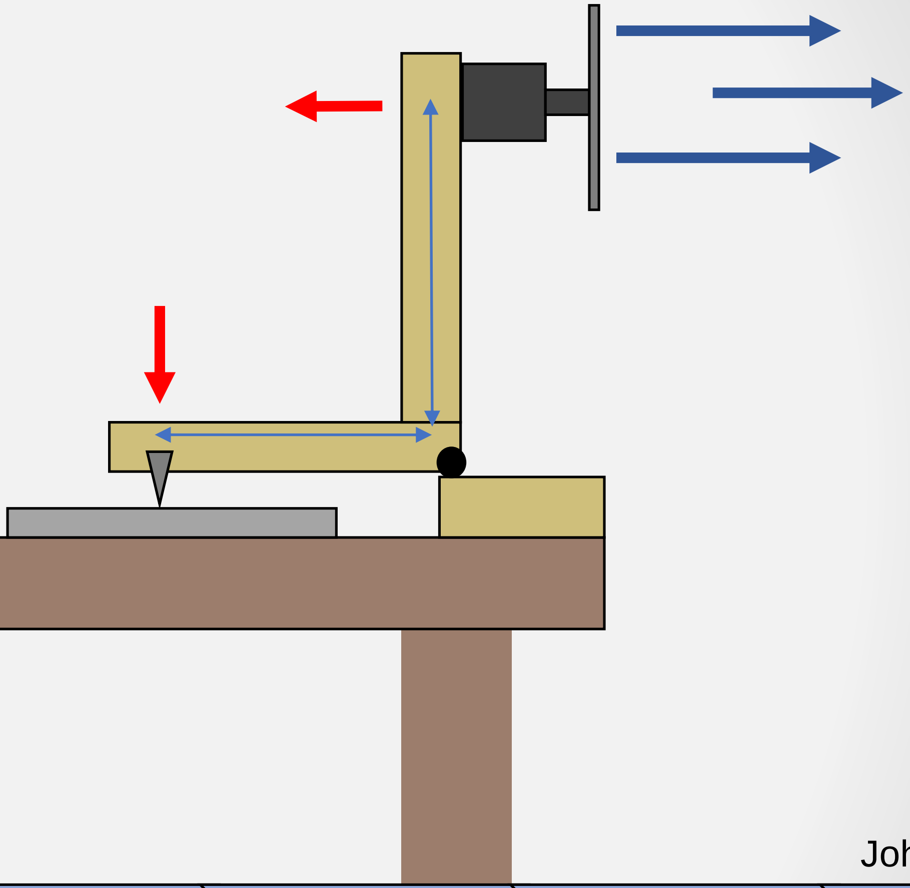
Thrust Testing

Static thrust stand 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

- Preliminary thrust tests were done to analyze the *iFlight XING 2184 880KV*
- APC 11x4.5-inch propellers were used for these tests as well

Thrust generated (N)				
	25% throttle	50% throttle	75% throttle	100% throttle
Thrust Test 1	2.136	4.655	10.760	19.865
Thrust Test 2	2.175	4.400	10.849	19.747
Thrust Test 3	2.136	4.371	10.349	19.607
Thrust Test 4	2.146	4.400	10.506	19.718
Avg. Thrust	**2.148**	**4.457**	**10.616**	**19.735**

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.

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

VS.

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

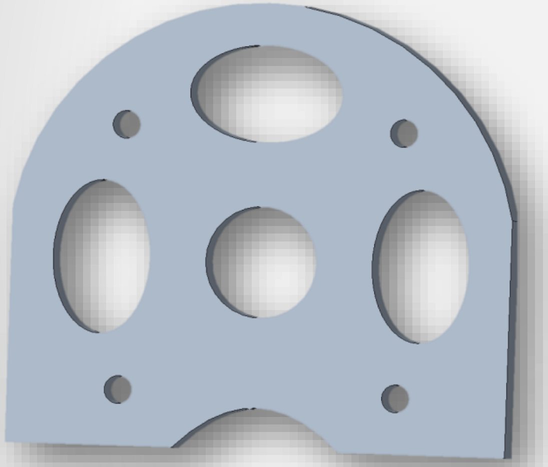
*Data taken from Motor Manufacturer

John Storms

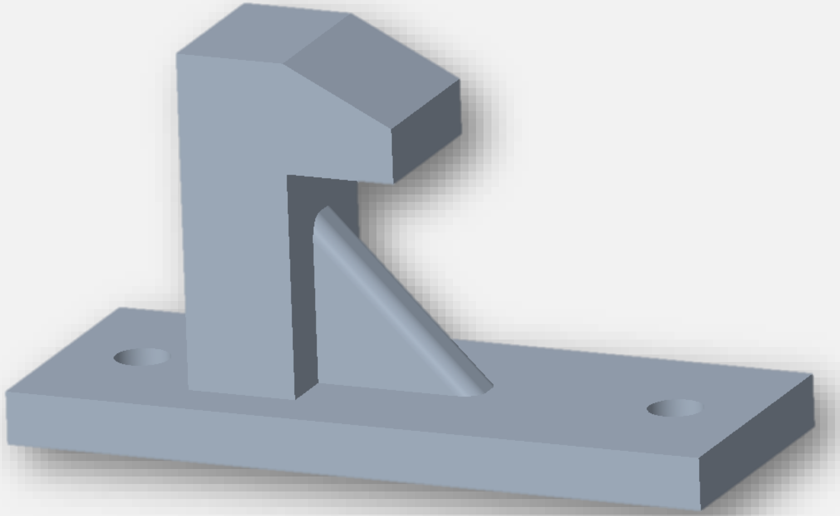
Previously | Motor & Propeller Selection | Thrust Testing | Modification of Auxiliary Parts | Redesign of Auxiliary Parts | 3-D Printing Process | Estimated Weight Savings | Future Work

Modification of Auxiliary Parts

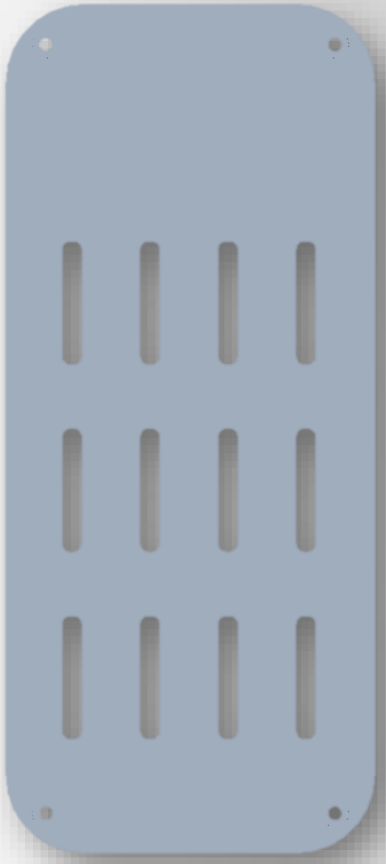
- Made drawings for all the parts that can be reprinted at a lower weight.



Motor Installing Base



Latching Hook



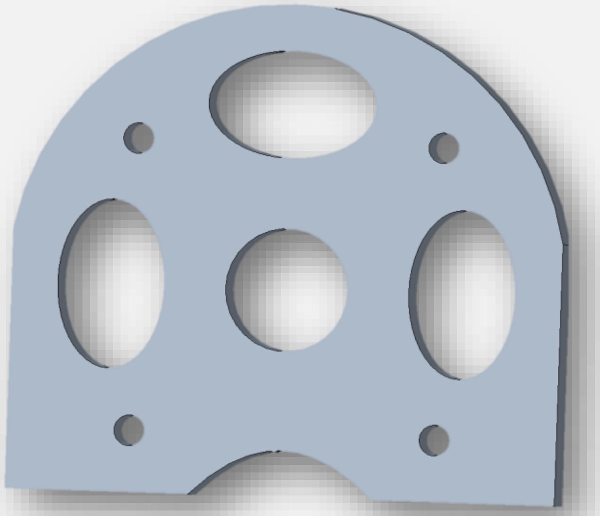
Regulating Cover

Jackson Dixon

Changing Material of Auxiliary Parts

- Preparing drawings of existing parts that can be reprinted at a lighter weight

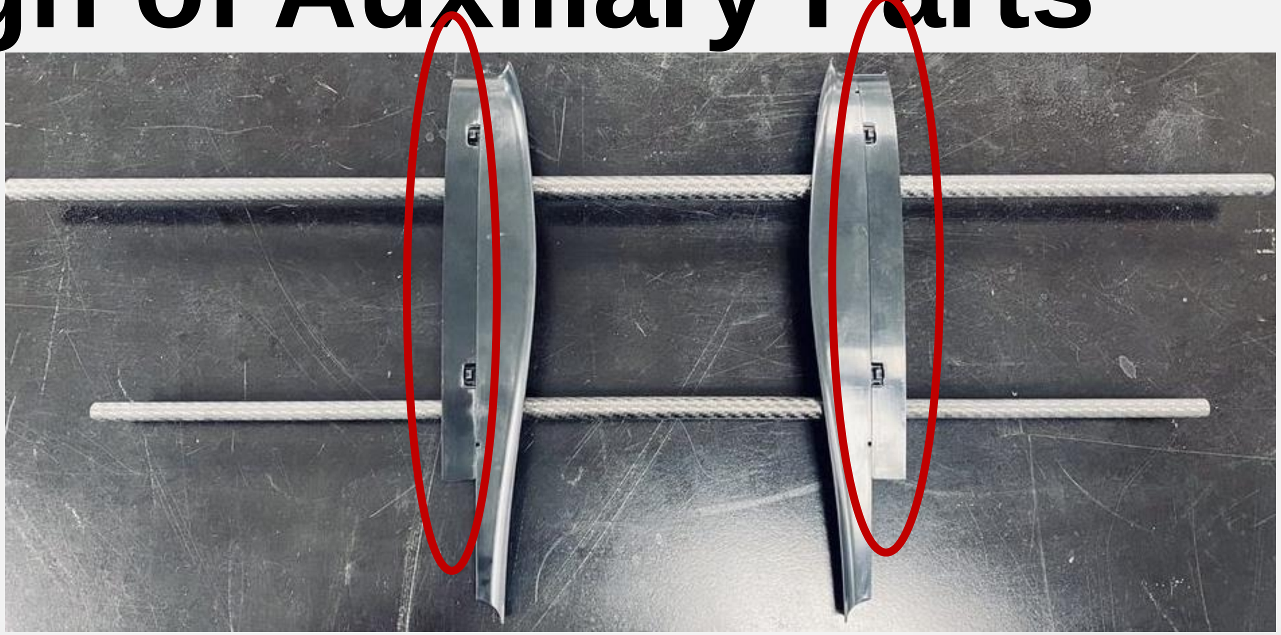
Wooden: 9g

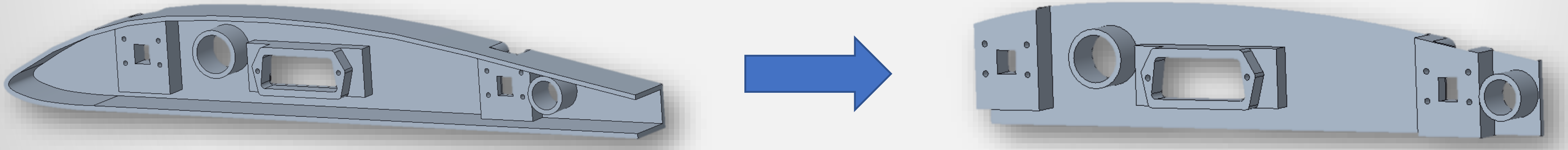


LW-PLA: 3g

Jackson Dixon

Redesign of Auxiliary Parts



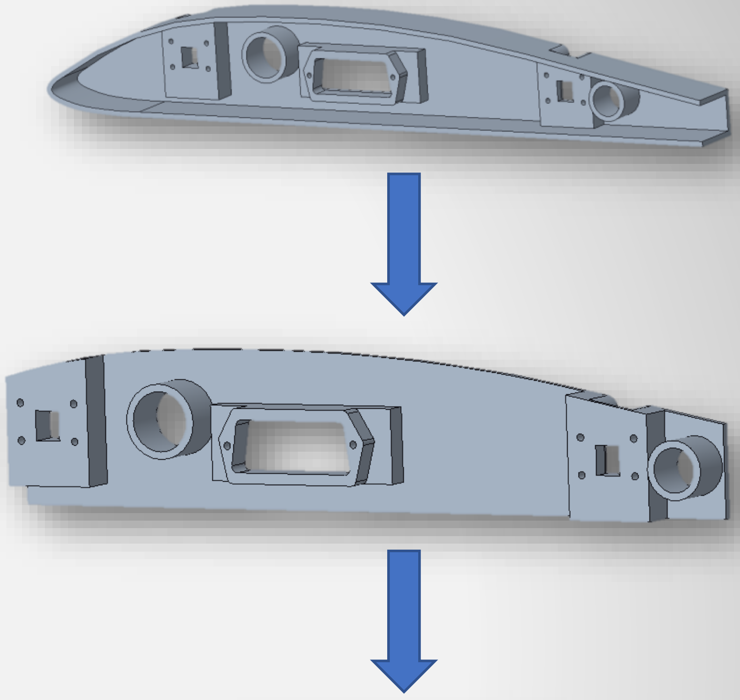


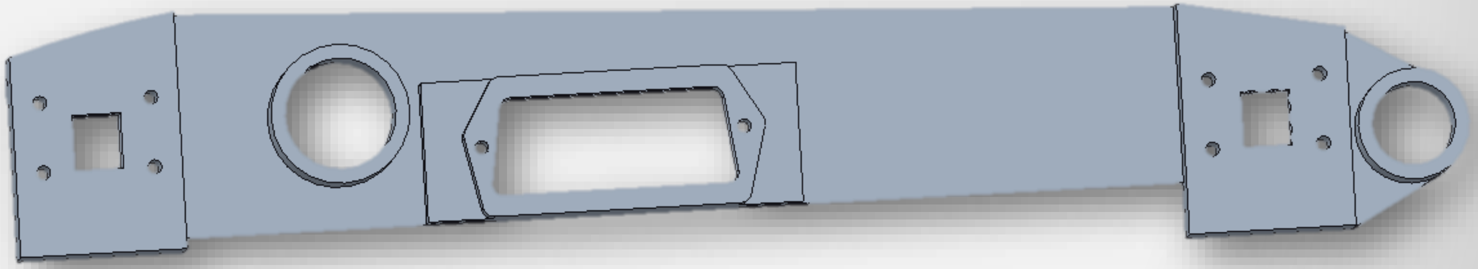
Jackson Dixon

Previously | Motor & Propeller Selection | Thrust Testing | Modification of Auxiliary Parts | Redesign of Auxiliary Parts | 3-D Printing Process | Estimated Weight Savings | Future Work

Redesign of Auxiliary Parts

- Utilizing stress concentration tables in Appendix E of the *Design of Machinery* textbook.
- Research adhesives for part assembly.





Jackson Dixon

PLA vs. LW-PLA

PLA (Polylactic Acid)

Most common 3-D printing filament

Density: 1.210-1.430 $\frac{g}{cm^3}$

LW-PLA (Light-Weight Polylactic Acid)

New filament made by ColorFabb

Densities: Non-Activated-> 1.210-1.430 $\frac{g}{cm^3}$

Maximum Activated-> 0.403-0.476 $\frac{g}{cm^3}$

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

Existing Print Settings for LW-PLA

Team 513: SAE Aero Design (2020)

Print Settings

- Printer: Lulzbot Taz 6
- Nozzle Temperature: 230 C
- Flow Rate: 50%

Electric Regulating Cover

Joseph Ledo-Massey

Previously | Motor & Propeller Selection | Thrust Testing | Modification of Auxiliary Parts | Redesign of Auxiliary Parts | 3-D Printing Process | Estimated Weight Savings | Future Work

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

- Existing print settings did not translate to the Dremel printer being used for this project

Joseph Ledo-Massey

Printer Calibration for LW-PLA

Print Settings	
Layer thickness	0.2 mm
Shell thickness	0.4 mm
Infill %	10%
Print speed	$25 \frac{\text{mm}}{\text{s}}$
Part cooling	0%
Nozzle Temperature	230 – 270 C
Flow Rate	100 – 30 %

Joseph Ledo-Massey

Printer Calibration for LW-PLA

Print Settings	
Layer thickness	0.2 mm
Shell thickness	0.4 mm
Infill %	10%
Print speed	$25\ \frac{\text{mm}}{\text{s}}$
Part cooling	0%
Nozzle Temperature	230 – 270 C
Flow Rate	100 – 30 %

Varied Nozzle Temperature (Prints 1–5)

Varied Flow Rate (Prints 6–12)

Print	Temp (C)	Flow Rate	Thickness (mm)
1	230	100%	0.73
2	240	100%	0.78
3	250	100%	1.3
4	260	100%	1.27
5	270	100%	1.18
6	250	90%	1.04
7	250	80%	0.96
8	250	70%	0.88
9	250	60%	0.78
10	250	50%	0.67
11	250	40%	0.61
12	250	30%	0.46

Joseph Ledo-Massey

Printer Calibration for LW-PLA

Print Settings	
Layer thickness	0.2 mm
Shell thickness	0.4 mm
Infill %	10%
Print speed	$25\ \frac{mm}{s}$
Part cooling	0%
Nozzle Temperature	230 – 270 C
Flow Rate	100 – 30 %

Varied Nozzle Temperature (Prints 1–5)

Varied Flow Rate (Prints 6–12)

Print	Temp (C)	Flow Rate	Thickness (mm)
1	230	100%	0.73
2	240	100%	0.78
3	250	100%	1.3
4	260	100%	1.27
5	270	100%	1.18
6	250	90%	1.04
7	250	80%	0.96
8	250	70%	0.88
9	250	60%	0.78
10	250	50%	0.67
11	250	40%	0.61
12	250	30%	0.46

Joseph Ledo-Massey

Calibrated Print Settings for LW-PLA

Nozzle Temperature: 250 C

Flow Rate: 30%

Layer Thickness: 0.2 mm

Shell Thickness: 0.4 mm

Infill: 10%

Print Speed: 25 $\frac{\text{mm}}{\text{s}}$

Part Cooling: 0%

Electric Regulating Cover

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

- Calibrated print settings resulted in failed prints when used for full scale parts

Joseph Ledo-Massey

Final Print Settings

Nozzle Temperature: 240 C

Flow Rate: 50%

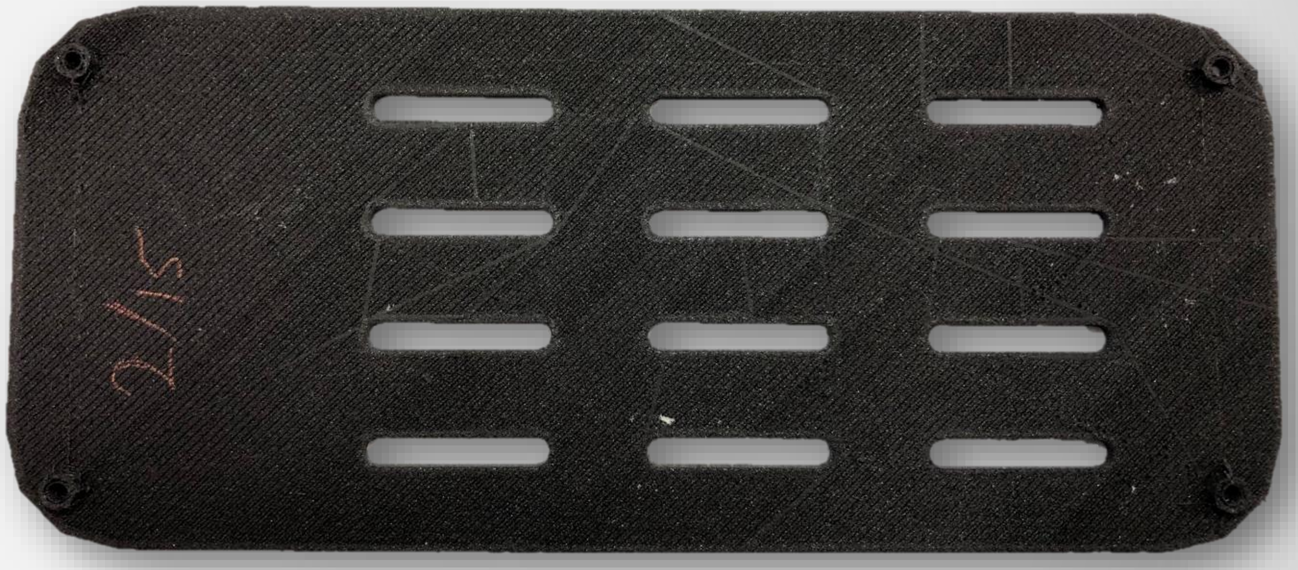
Layer Thickness: 0.2 mm

Shell Thickness: 0.8 mm

Infill: 0%

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

Part Cooling: 0%



Electric Regulating Cover

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

- Reduction in Nozzle temperature and an increase in flow rate yielded in successful prints with noticeable weight reduction compared to standard PLA filament

Joseph Ledo-Massey

Estimated Weight Savings

Method	Savings	Total
Electrical Components	Battery -> 27g Motors -> 38g	65g
3-D Printing	Wood -> 62% -> 32.24g Metal -> 97% -> 23.28g Plastic -> 41% -> 77.47g	133g
Propellers	Carbon Fiber -> 13g APC 11x4.5 -> 5g	13g

Overall Weight Savings: 211g

Joseph Ledo-Massey

Future Work

Complete Redesign of Auxiliary Parts

Finish 3-D Printing

Develop Light-Weight Validation Tool

Assembly & Testing UAV

Jackson Dixon

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 Design

LW-PLA Constructed Parts

John Storms