FSGC-SAE Aero Design Team 507 - Fuselage

Team 507 Introductions

Bridget Andrews
Aerodynamics Engineer

John Healy
Systems Engineer

Alejandro Toro
Mechanical Engineer

Alejandro Toro

Sponsors and Advisor

Florida Space
Grant Consortium

Project Sponsor

Seminole RC Club

Project Sponsor

Dr. Simone Hruda

Project Advisor

Alejandro Toro

Project Brief

Design a 3D-printed, remote-controlled (RC) plane for the 2022 Society of Automotive Engineers (SAE) Aero Design Competition abiding by regular class restrictions.

We are not attending the competition

Alejandro Toro

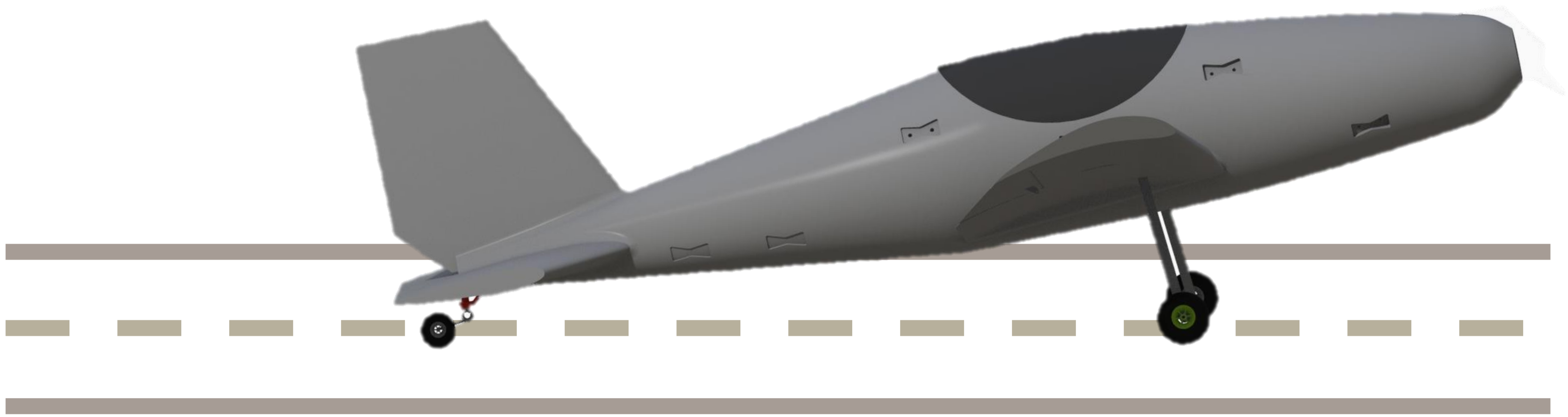
Project Brief

The aircraft will operate from short runways and complete the necessary flight path…

Alejandro Toro

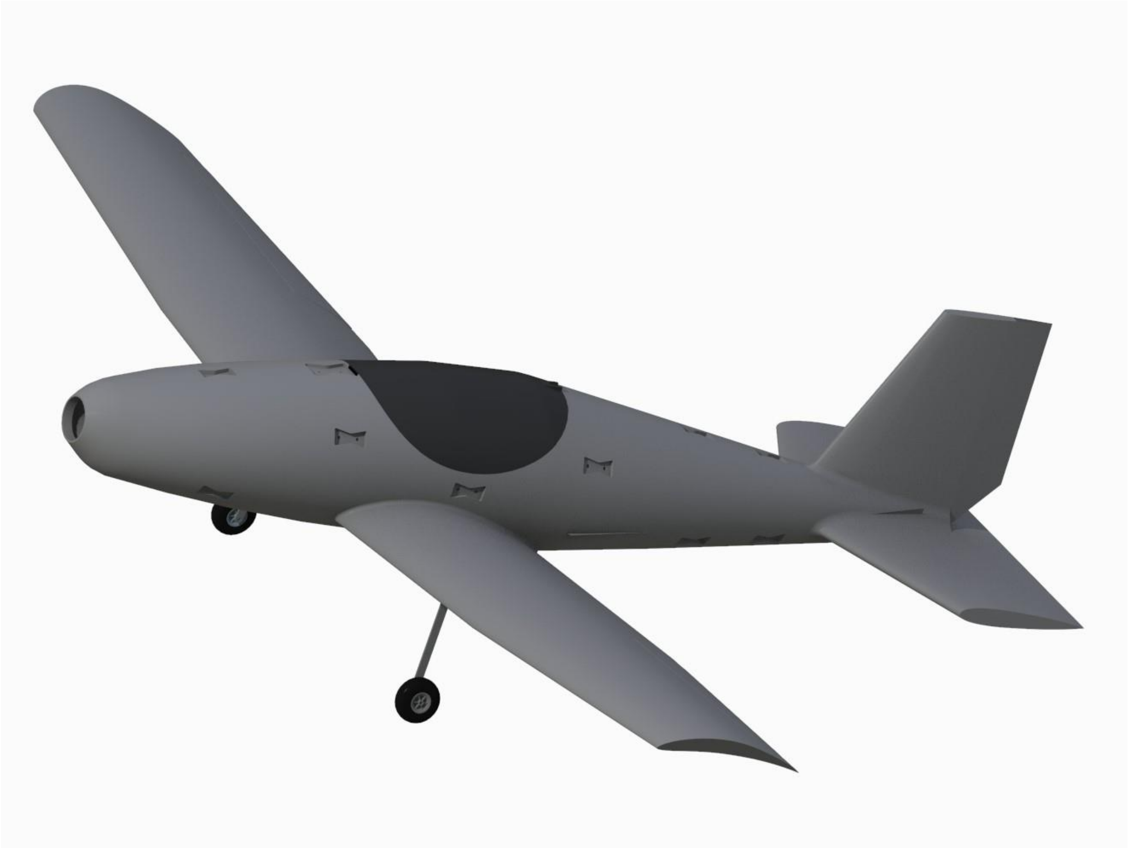
Project Brief

...While carrying outsized spherical cargo as well as regular boxed cargo.



Alejandro Toro

Project Brief



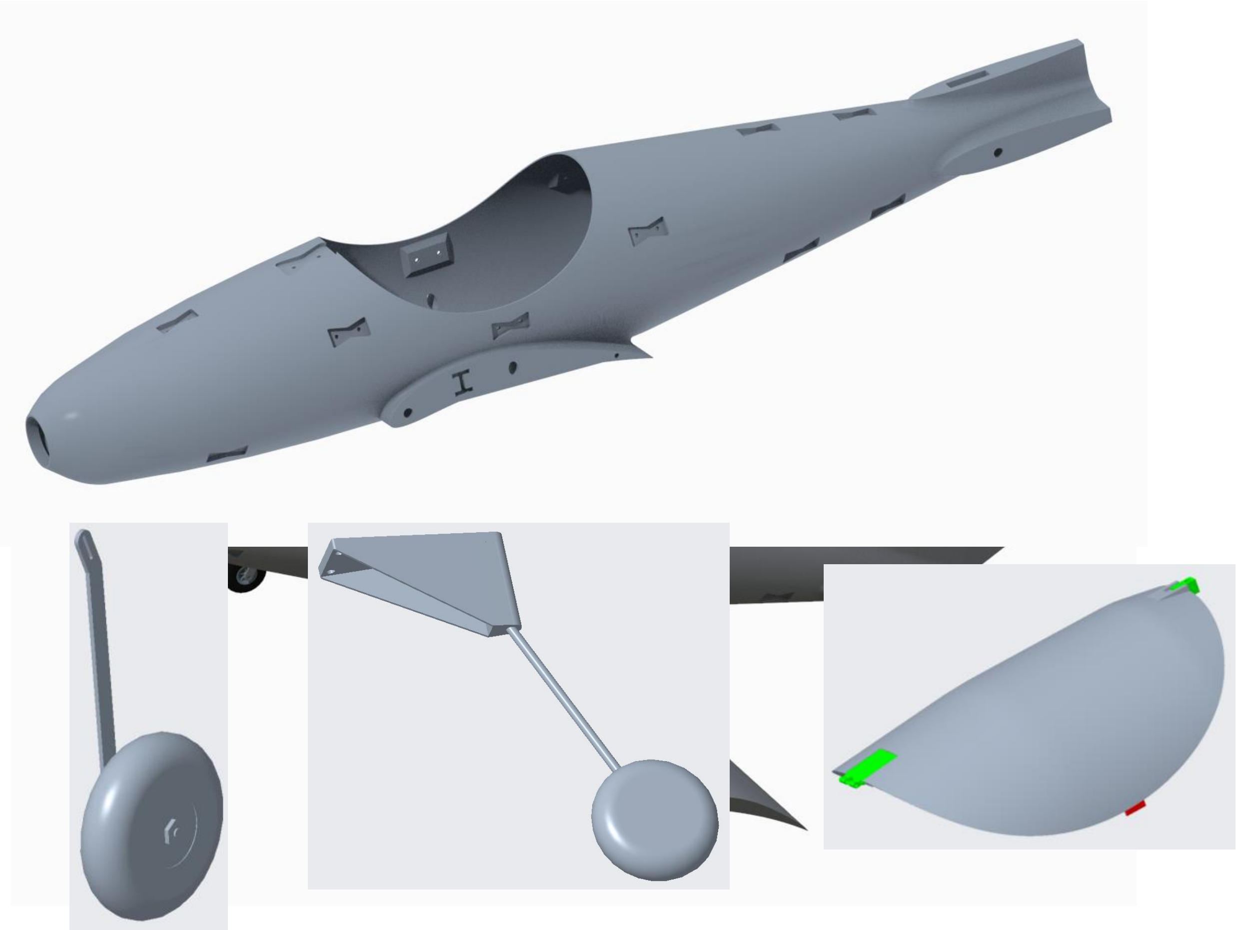
Team 507 & 508

Alejandro Toro

Project Brief

Scope of Team 507:

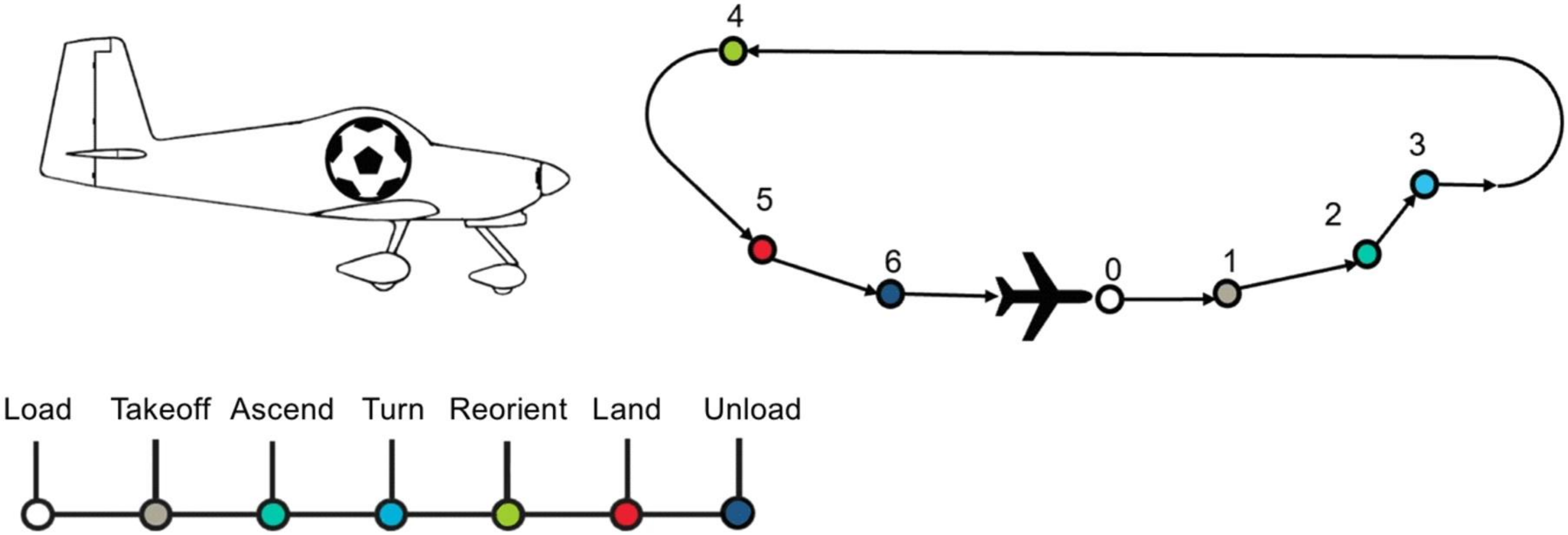
- Fuselage
- Landing Gear
- Payload
- Wiring
- Electronics placement
    - Electronics (508)



Team 507 & 508

Alejandro Toro

Objective(Mission Flight)



Alejandro Toro

Key Goals

1. Primarily construct of 3D-printed parts
2. Plane can operate with and without payloads
3. Landing gear can withstand impact.
4. Landing gear can steer the airplane.

LW-PLA

Alejandro Toro

Targets / Metrics

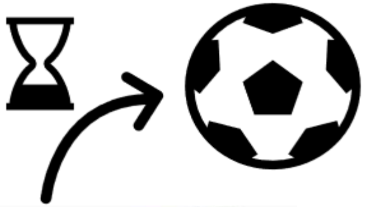
1. Secure Payload: Cannot move inside fuselage

2. Unload Payload in under one minute

3. Ensure Stability: Static Margin of 12%

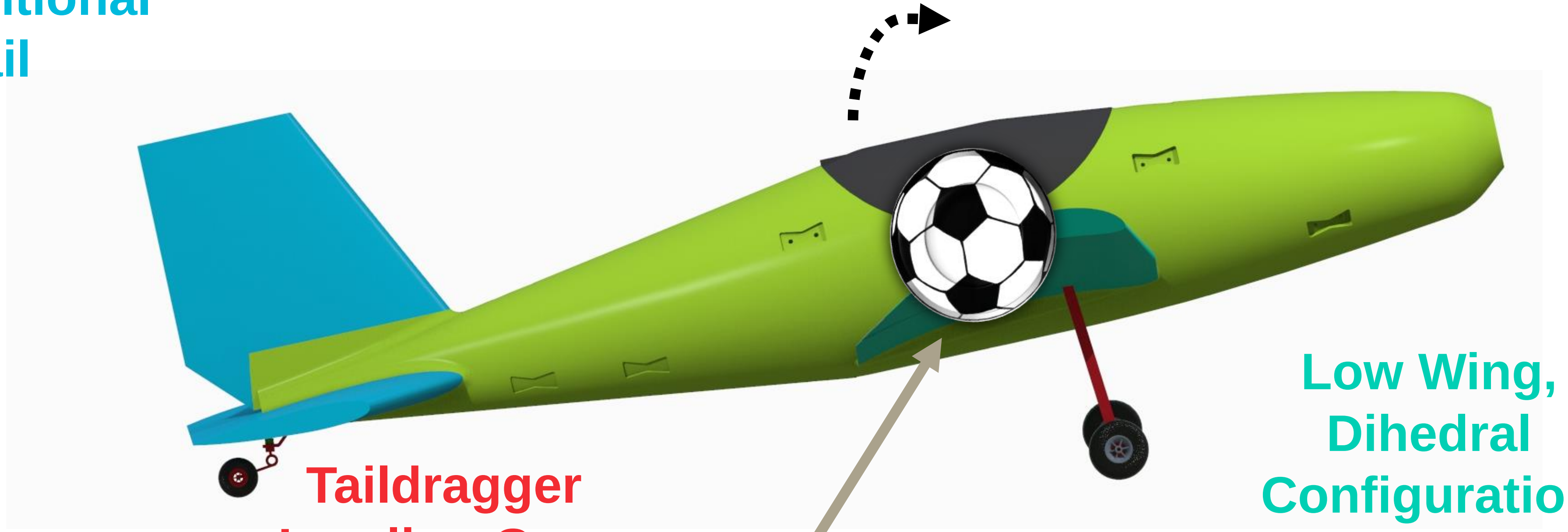
4. Plane weighs 15lbs or less

    Fuselage weighs 5lbs or less



Alejandro Toro

Final Concept



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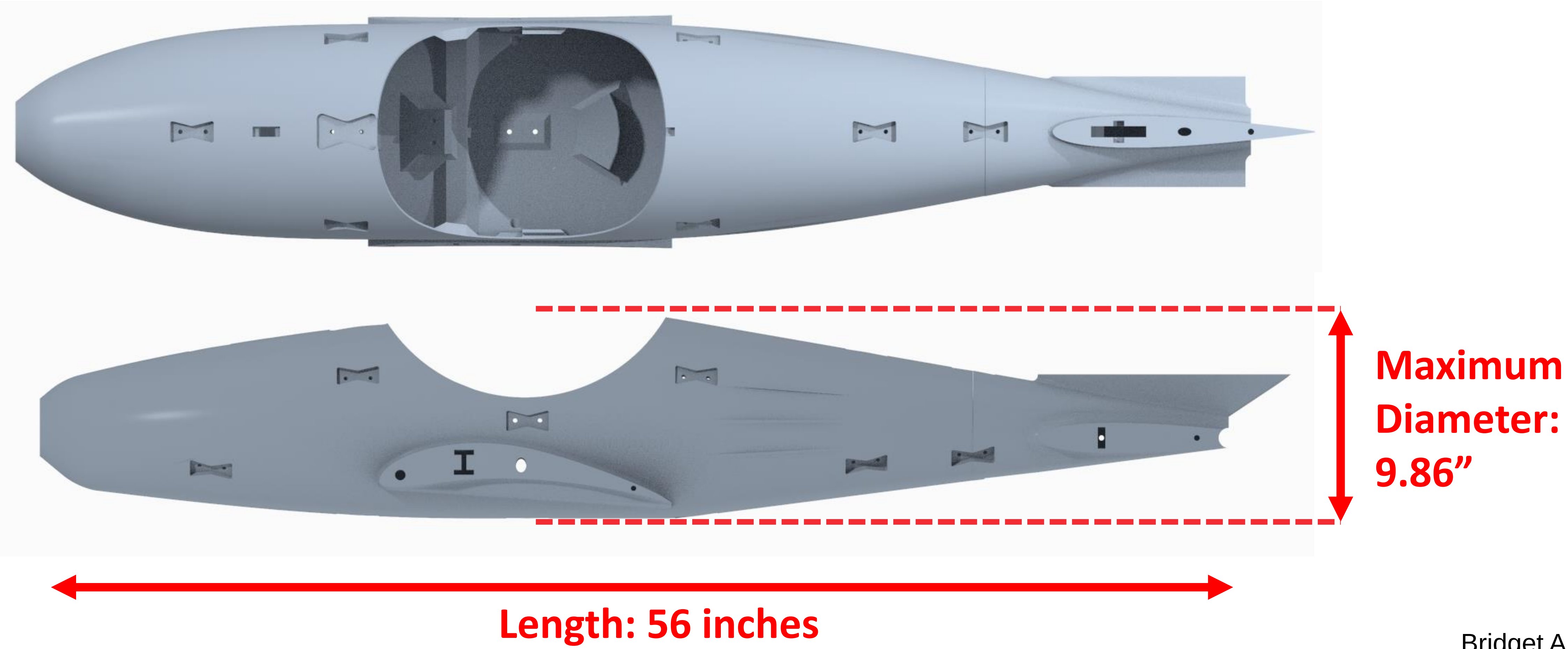
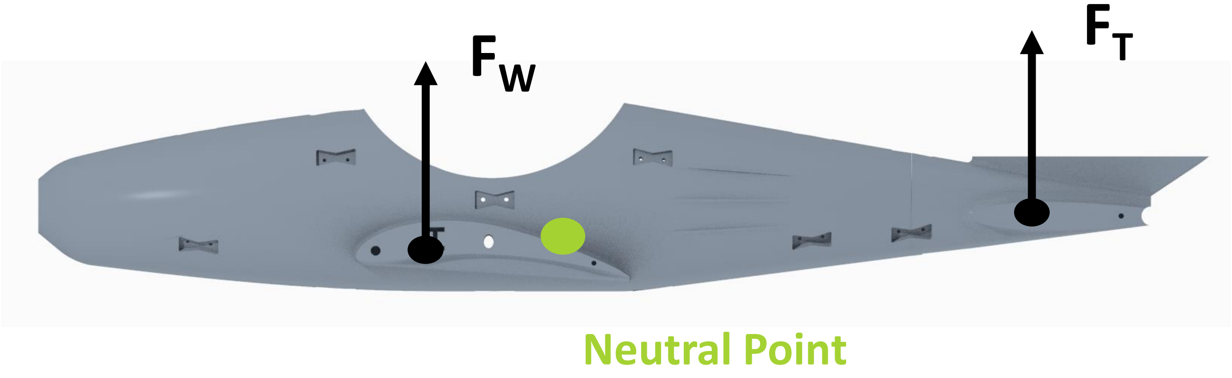
Fuselage Design



Bridget Andrews

Fuselage Design: Static Margin

Determined
- Wing Placement
- Tail Placement
- Center of Gravity



What is Static Margin?
- The percent difference between the center of gravity and the neutral point

What is the Neutral Point?
- Moment of Wing = Moment of Tail

Need:
- Static Margin to be between 10% and 15%. *12% is ideal*
- The Center of Gravity to be between 25% and 33% of the wing chord length

Bridget Andrews

Fuselage Design: Printability

Tight fit on the printer bed

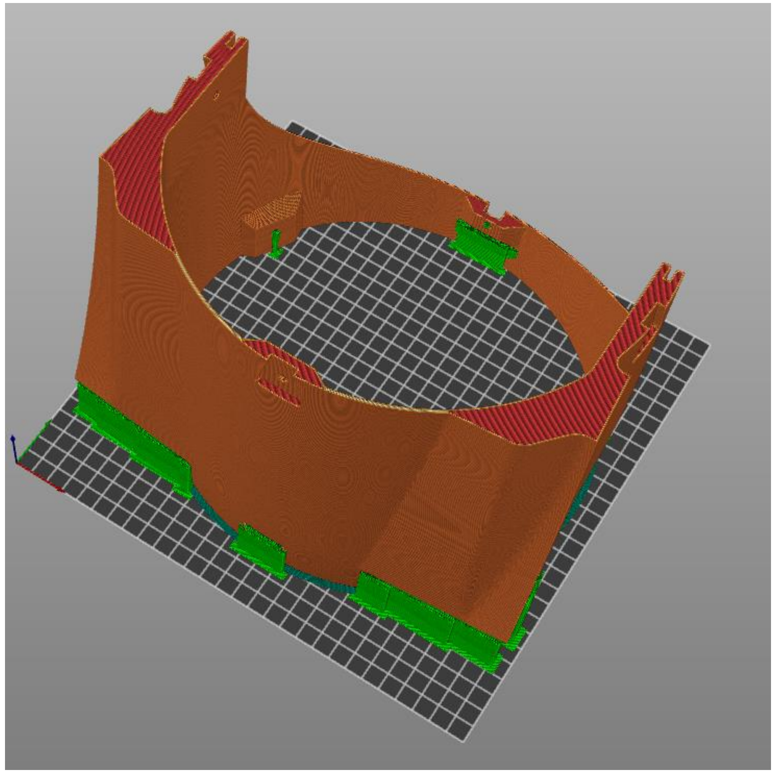
- 11” x 11” printer bed
- Expected contributor: Ball and Wing Placement
- Unexpected contributor: Dihedral Wings

Solution:

- Decreased the maximum diameter by ½”

Result:

- Maximum Diameter of 9.86”
- Sections to wing interface did not need additional sectioning



Section 4 on Prusa Slicer

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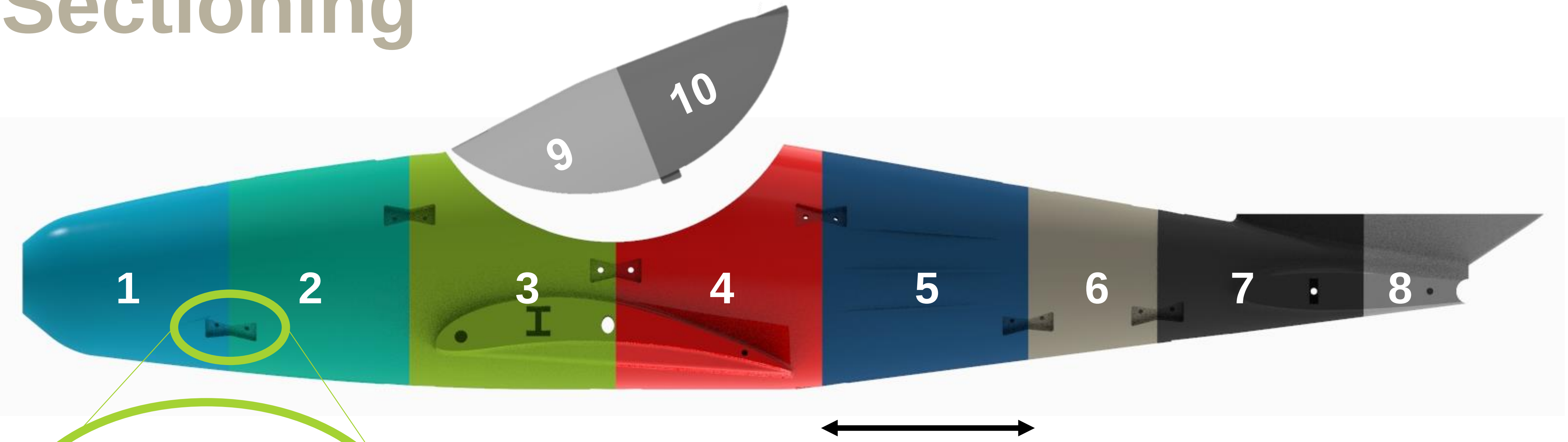
Sectioning



Bow Tie

Maximum of 8 inches

Total print time: 07d 6h 38m

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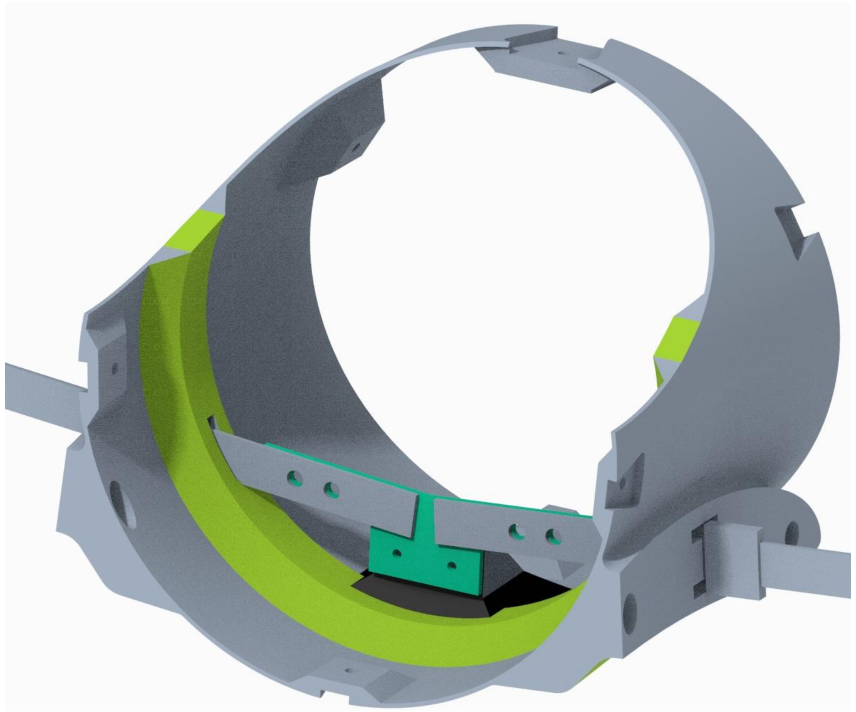
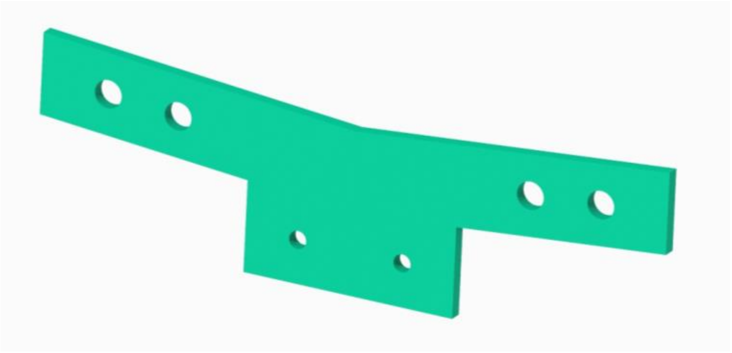
Wing Interface

Wing Spars are connected to the bracket by Cotter-Pin Lockable Screws and Bracket





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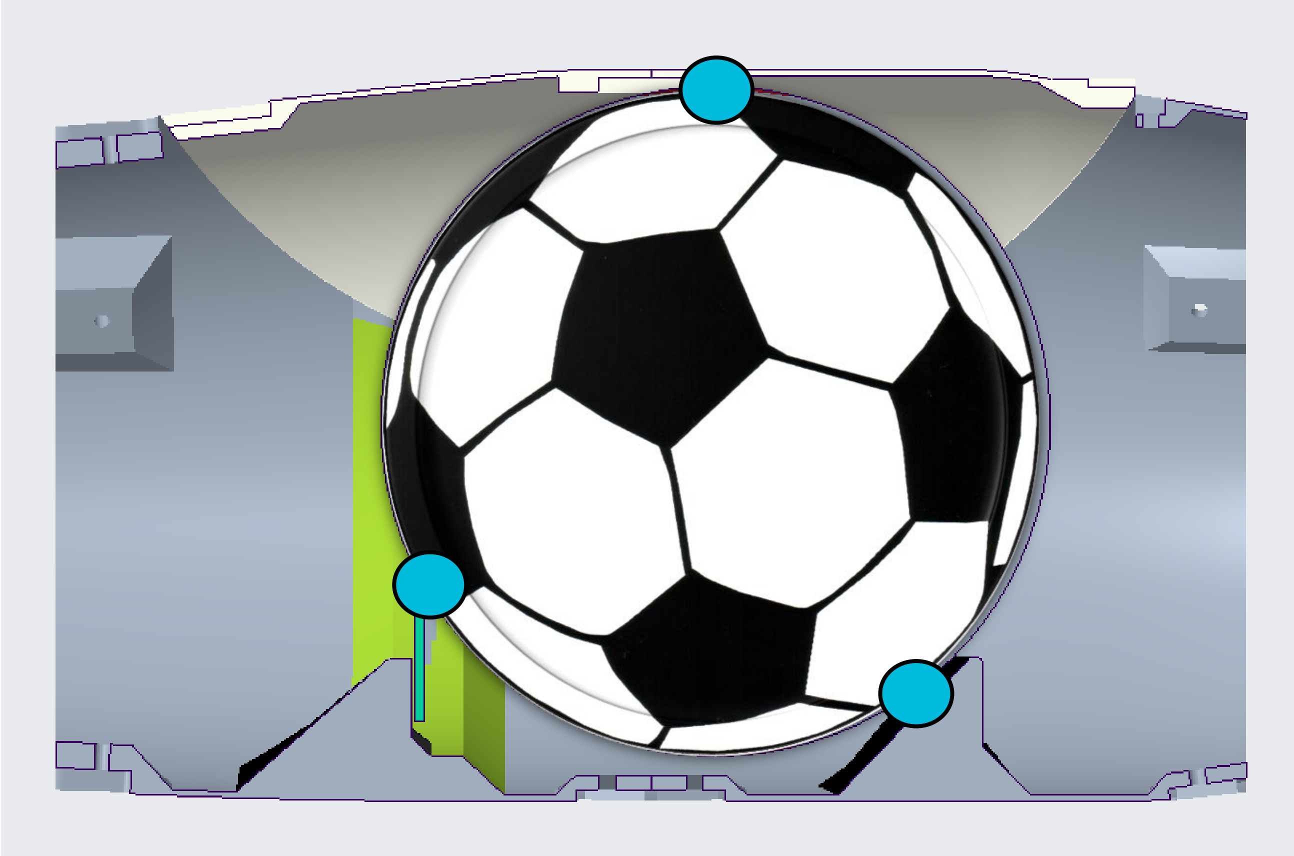
Payload Securement



Points of Contact

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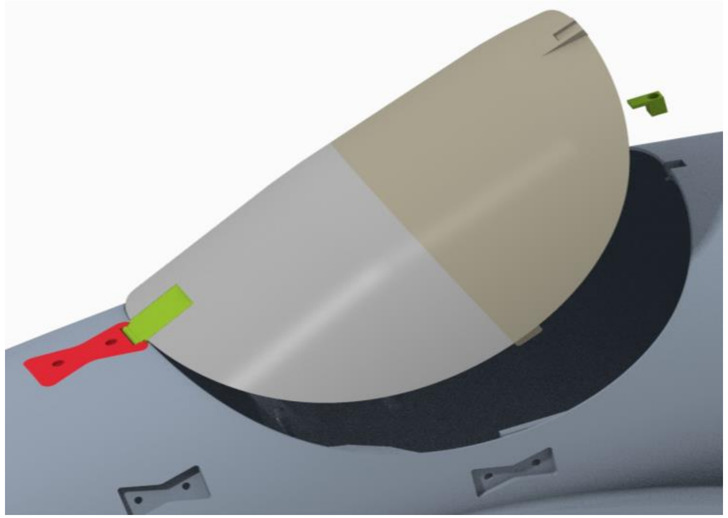
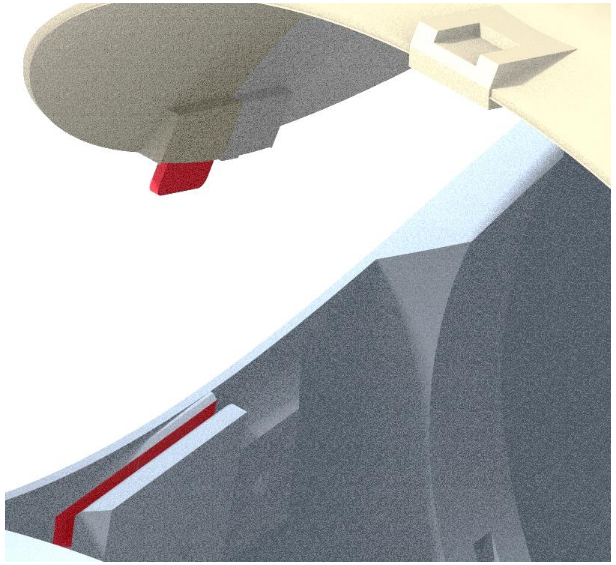
Hatch

- Top loading mechanism
- Hinge + Bow tie
- Ball placed behind the wing spar
- Single latch to hold hatch down



Hinge

Latch



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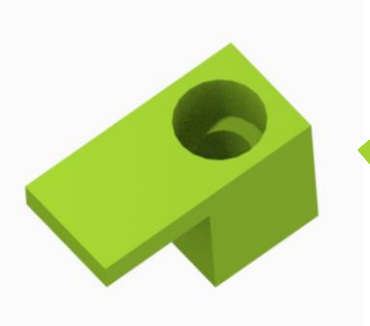
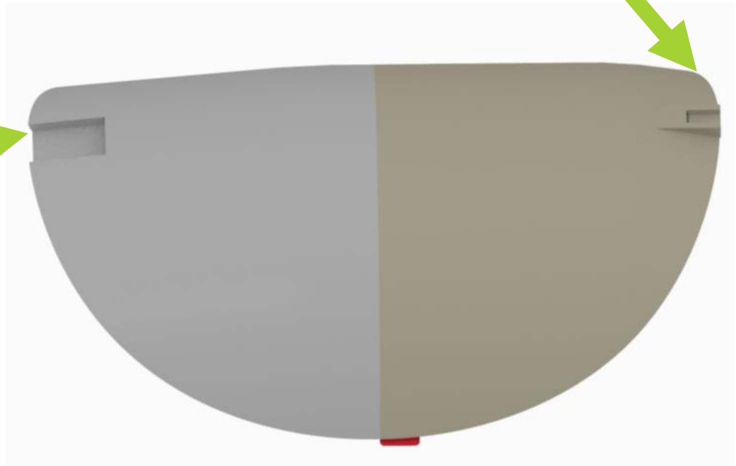
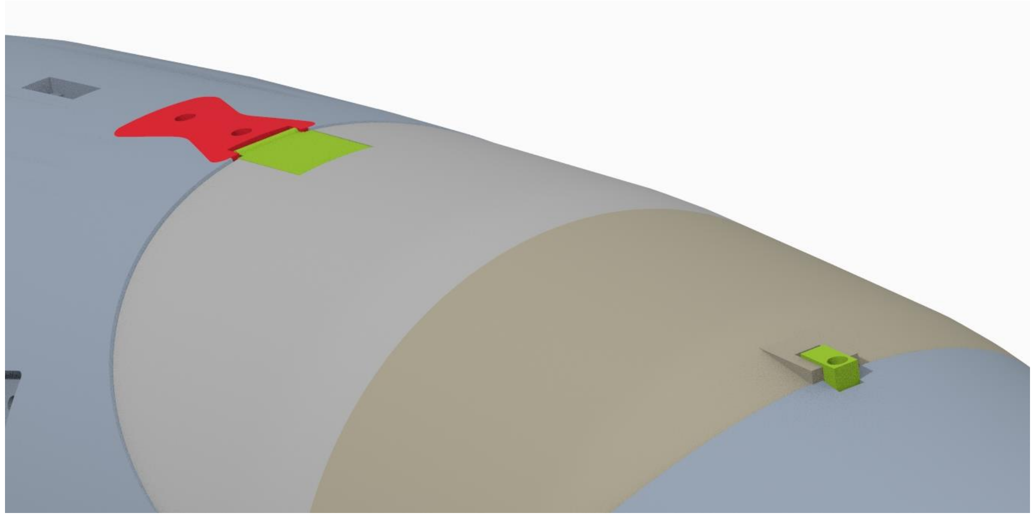
Hatch







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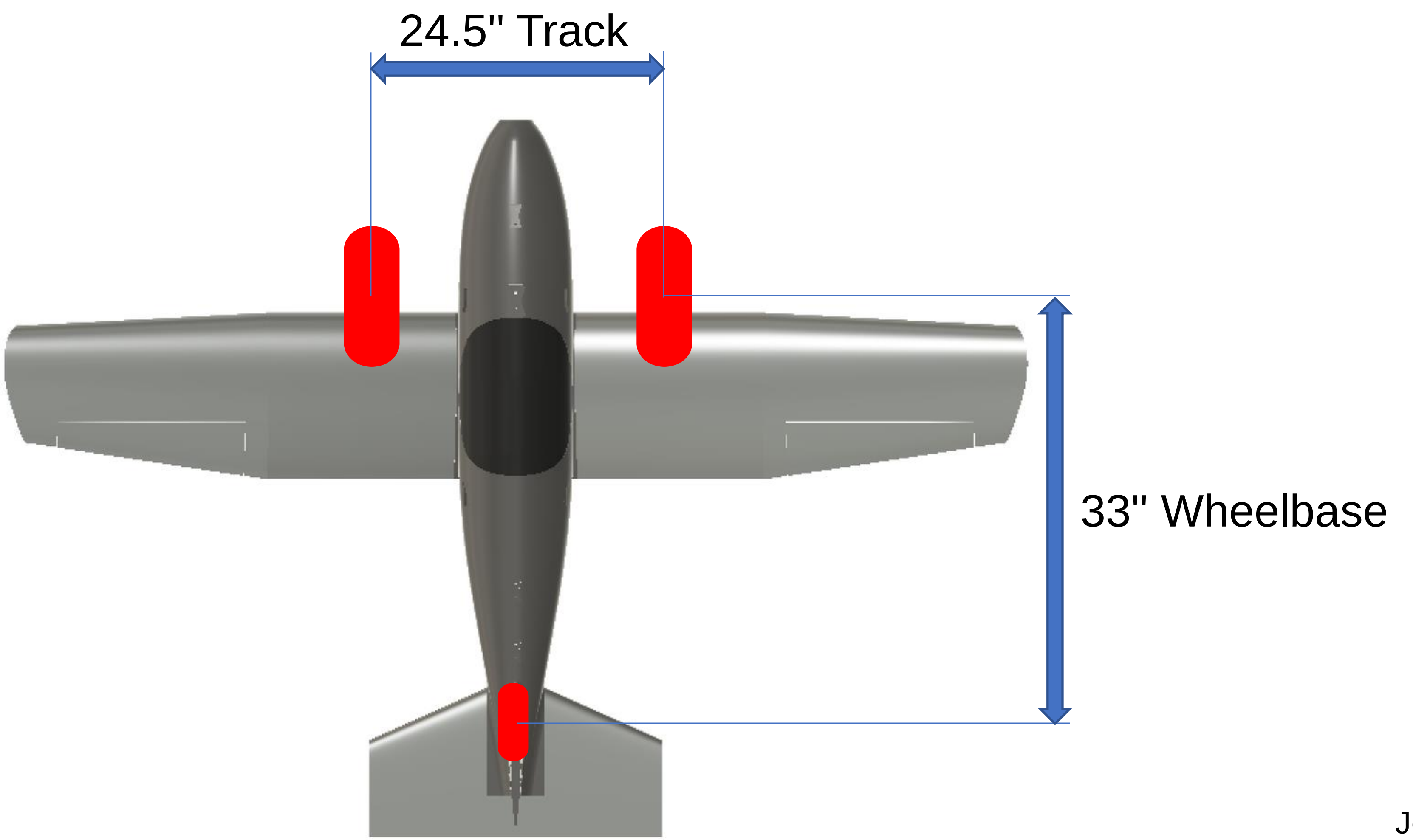
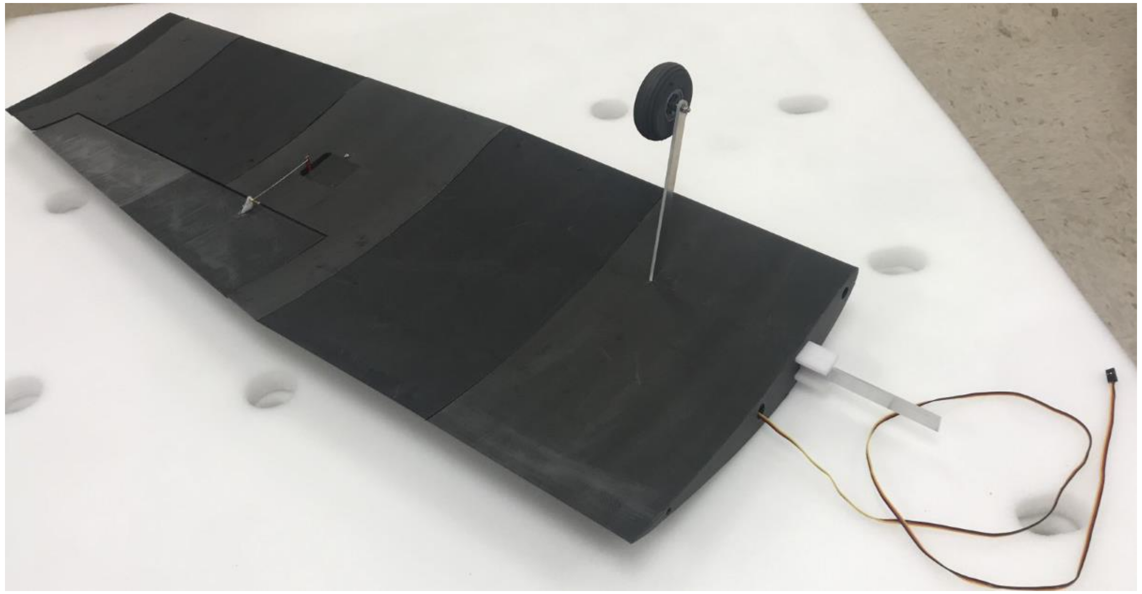
Landing Gear Layout



John Healy

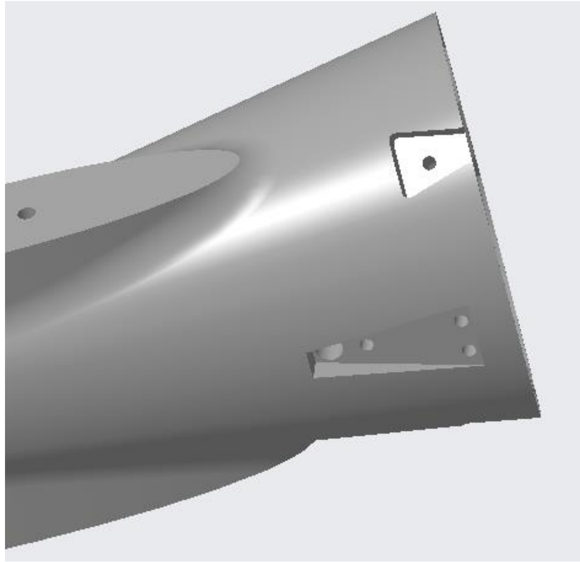
Main Landing Gear Design

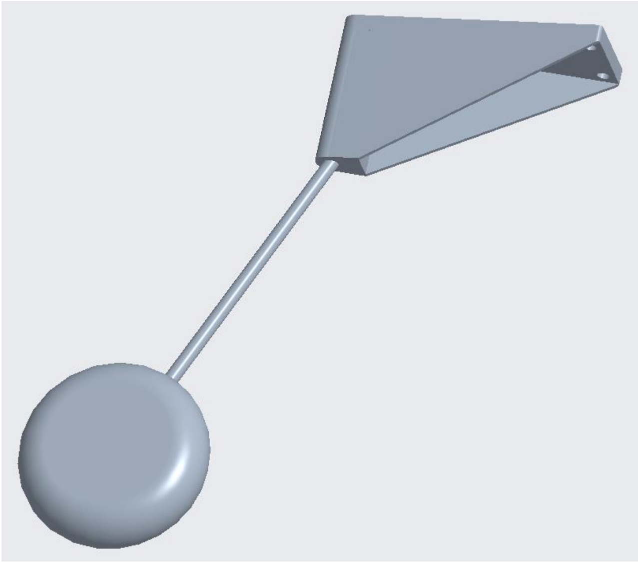
- Added spar through wheels
- Added epoxy putty to wing connection



John Healy

Tailwheel Design





John Healy

Validation:

- ☑ Primarily construct of 3D-printed parts

John Healy

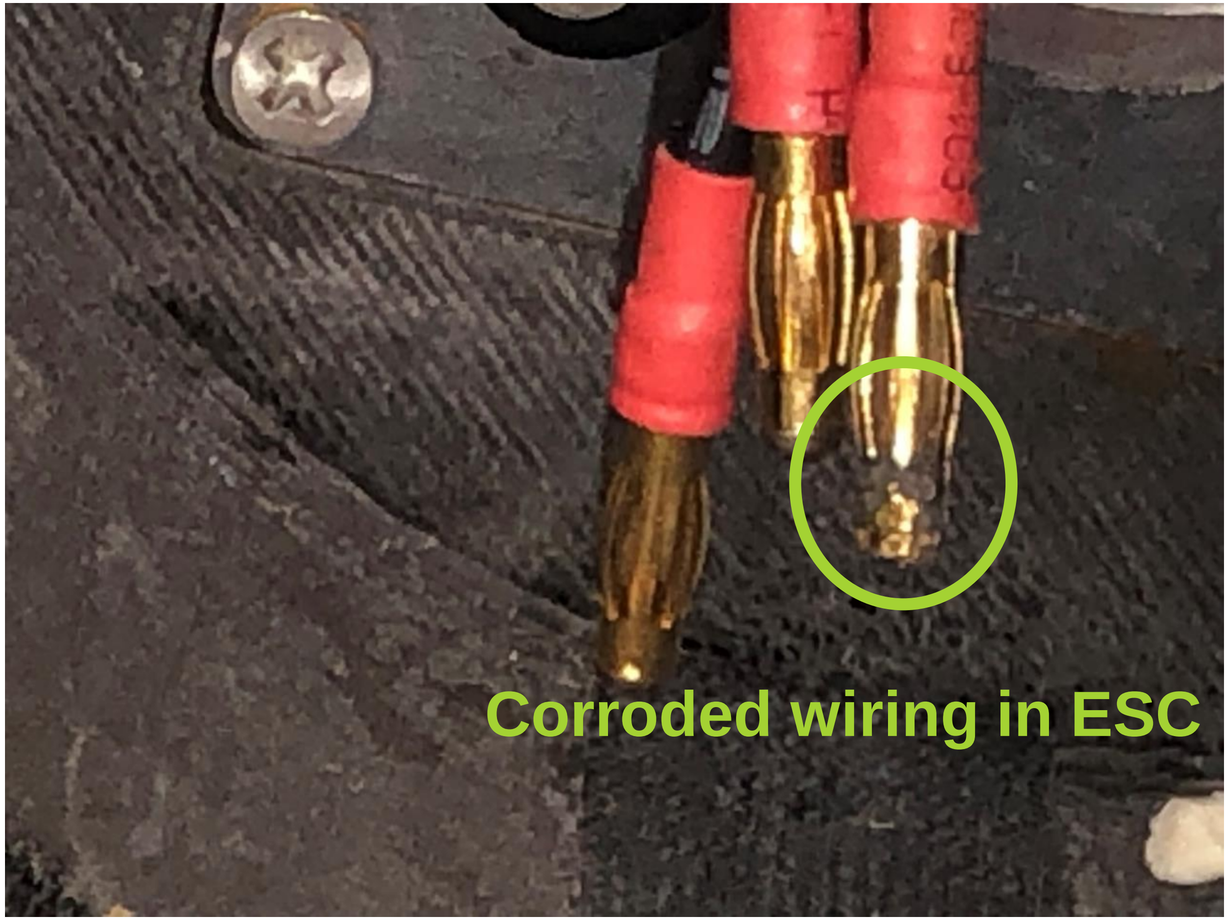
Validation: Takeoff

- [x] Plane can operate with and without payloads
- [ ] Takeoff in less than 100 ft

John Healy

Validation: Takeoff

- [x] Plane can operate with and without payloads
- [ ] Takeoff in less than 100 ft



John Healy

Validation: Taxi

- [x] Landing gear can steer the airplane.

John Healy

Validation: Smooth Landing

- ✓ Landing gear can withstand impact.

John Healy

Validation: Hard Landing

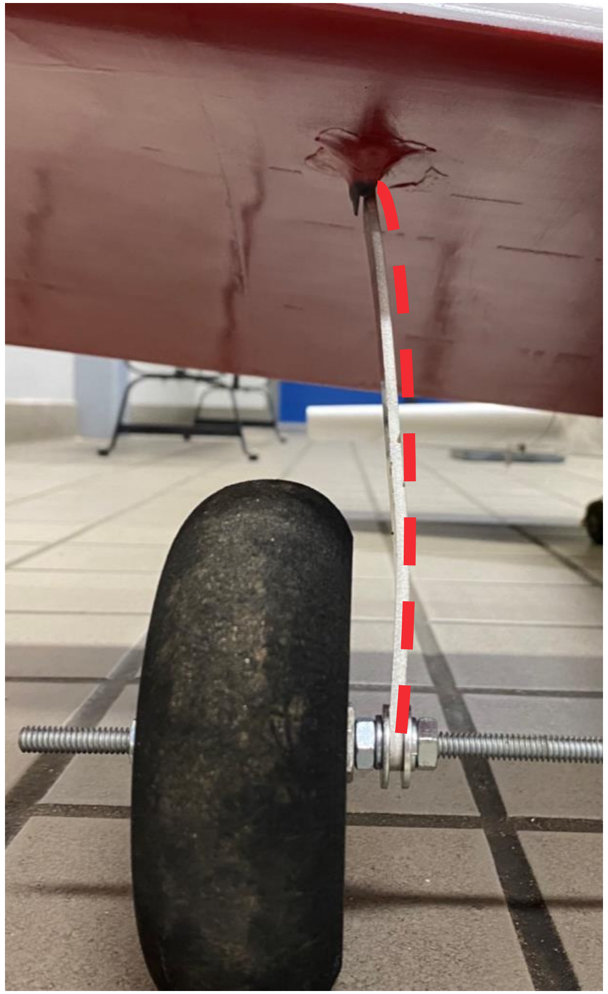
- [x] Landing gear can withstand impact.

John Healy

Validation: Hard Landing

- ☑ Landing gear can withstand impact.

Bent Landing Gear



John Healy

Validation: THE FLIP

John Healy

Validation

- Plane weighs 15lbs or less
  - *Fuselage weighs 5lbs or less*

Actual Weight:

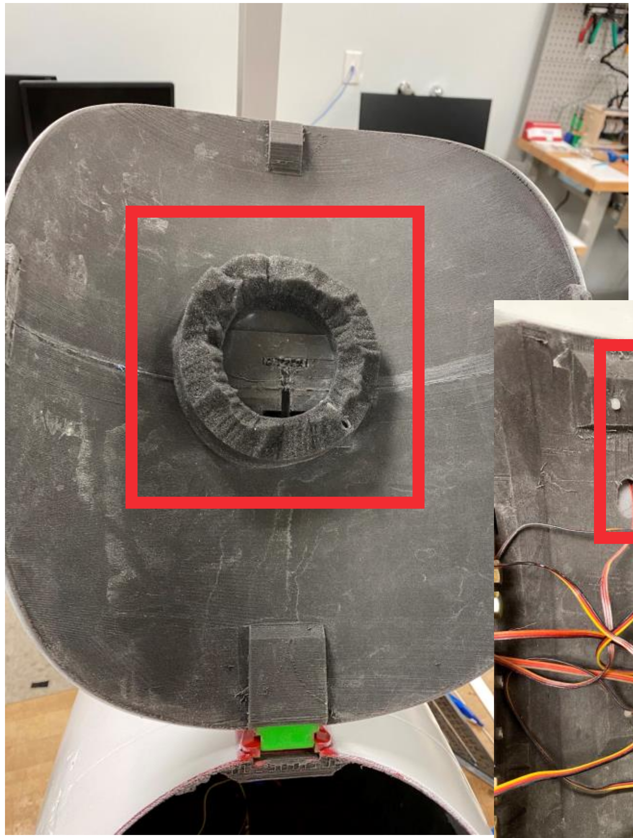
Plane Weight: 15.4lbs

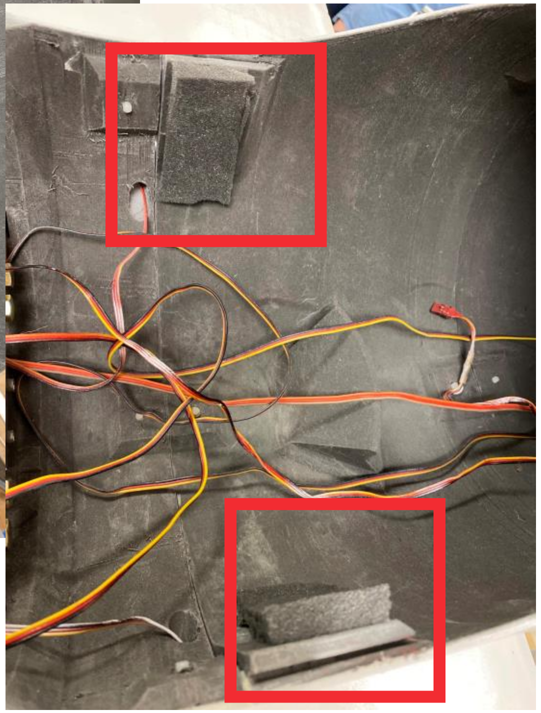
Fuselage Weight: 5.1lbs

John Healy

Validation

- [x] Secure Payload: Cannot move inside fuselage
  - *Payload did not once drop or shift position during flight*
  - *Added foam dampened vibration from the ball*
- [x] Unload soccer ball in under one minute
  - *Roughly 15 seconds*
- [ ] Unload rectangular payload





John Healy

Static Margin Validation

✓ Ensure Stability: Static Margin of 12%

0.3lbs of clay was added to the nose cone of the fuselage

Bridget Andrews

Lessons Learned

- Confirm CAD designs are finalized before printing
- Design for function before innovation
- Establish a task manager system from the beginning
- Plan out tasks with the team at the beginning of every week
- Start designing even when you don't have all the answers
- Have a detailed plan for validation

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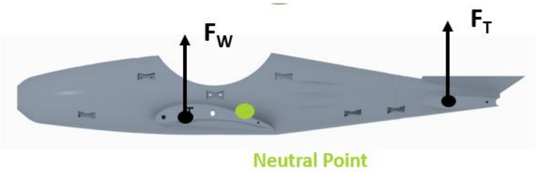
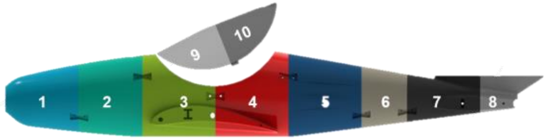
Summary

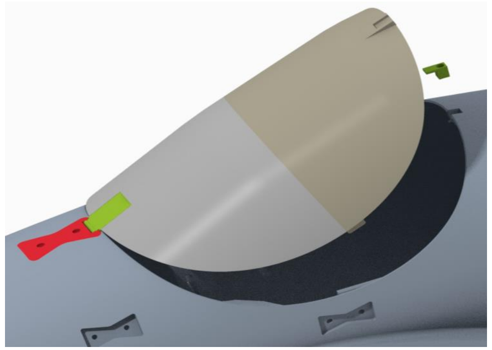
Fuselage Design



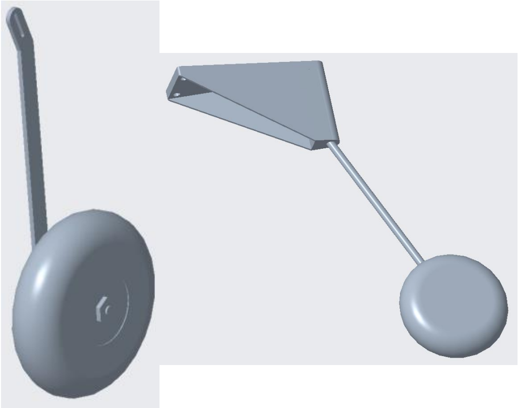
Static Margin



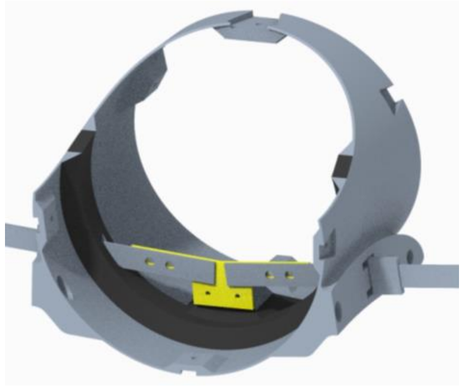
Sectioning



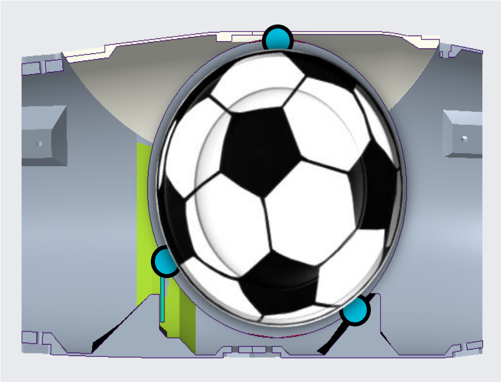
Hatch



Landing Gear



Wing Interface



Payload Securement

Final Design

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References

"Calculating Glider Ratios." *Pitsco Education*, https://asset.pitsco.com/sharedimages/resources/balsa-gliders-activitysample.pdf

"2022 SAE Aero Design Rules." *SAE Aero Design*, www.saeaerodesign.com/cdsweb/gen/DocumentResources.aspx.

Raymer, D. P. (1992). *Aircraft design: A conceptual approach*.

Bridget Andrews

The Team

Bridget Andrews

John Healy

Alejandro Toro

David Jay

Michael Nalovic

Sofia Rodriguez

Tristan Wahl

Bridget Andrews

Backup Slides

Upcoming Presenter’s Name

Static Margin

Upcoming Presenter’s Name

Initial Conditions

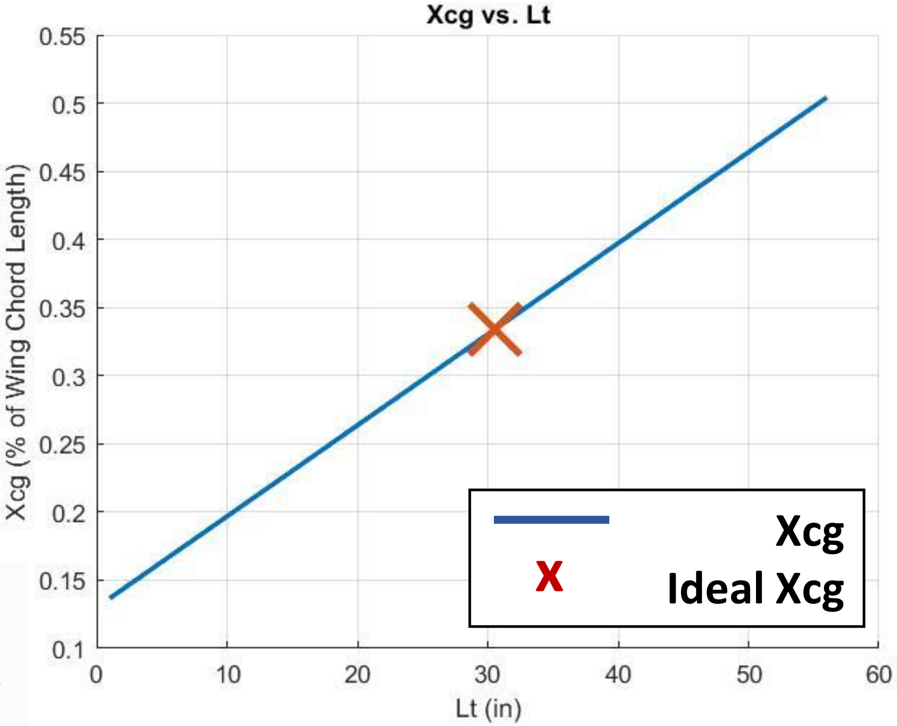
- Base Wing Chord Length: 14in
- Mean Wing Chord Length: 12.1in
- Tail Chord Length: 12in
- Horizontal Tail Area: 200in^2
- Wing Span: 85in
- Tail Span: 20in

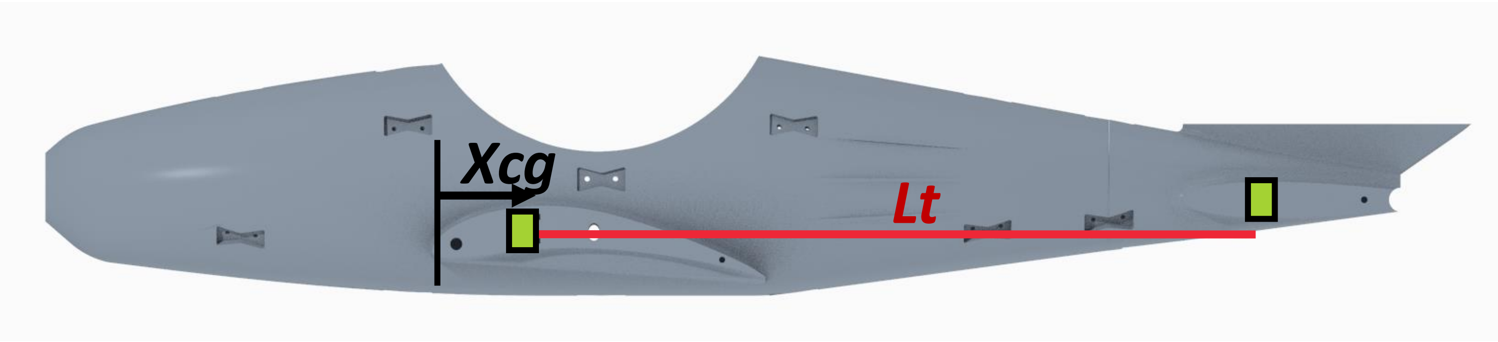
Process

- $V_H = \mathrm{lt} * \frac{\mathrm{St}}{\mathrm{c_{mean}} * \mathrm{Sw}}$
- AR = wing span ^2 / wing area
- ARh = tail span ^2 / tail area
- Xnp = 0.25+ ((1+2/AR)/(1+2/ARh)).*(1-(4/(2+AR))).*Vh;
  - Assumption: Center of Lift of Wing and Tail is ¼ of chord length
- Xcg = Xnp – 0.12

Fuselage Design: Static Margin

Ideal CG is 20.6 in or 37% of the fuselage length and 33% of the mean chord length.





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Process

- L_wing = L_tail - lt;
- IDEAL_CG = L_wing - c*0.25 + c*(Xcg)

Validation for Static Margin

- F_m1 = 6.550;
- F_m2 = 6.595;
- F_r = 2.145;
-
- L_m = 16.0144;
- L_r = 49;
-
- F = [F_m1 F_m2 F_r];
- L = [L_m L_m L_r];
- M = F.*L;
- M_sum = sum(M);
- F_sum = sum(F);
- CG = M_sum/F_sum;

Validation for Static Margin

- `Xnp = 0.25+ ((1+2/AR)/(1+2/ARh)).*(1-(4/(2+AR))).*Vh;`
- `Xcg = (CG - L_wing +c*0.25)/c;`
- `SM = Xnp - Xcg;`
- `fprintf('The current static margin of our plane is %.2f \n', SM);`

Validation for Static Margin

```
• L_plus = 2.27;
• IdealCG = 20.6;
• F_plus = (M_sum - IdealCG*F_sum)/(IdealCG - L_plus);
• fprintf('The weight needed to attach to attach to the motor mount is %.2f
  \n', F_plus);

• L_plus = 56;
• IdealCG = 20.6;
• F_plus = (M_sum - IdealCG*F_sum)/(IdealCG - L_plus);
• fprintf('The weight needed to attach to attach to the end of the fuselage
  is is %.2f \n', F_plus);
•
```

History of Competition

Upcoming Presenter's Name

2022 SAE Aero Design Competition

- Annual RC Plane Design Competition
- Location: Fort Worth, Texas
- When: May 20-22, 2022
- Class of Competition: Regular

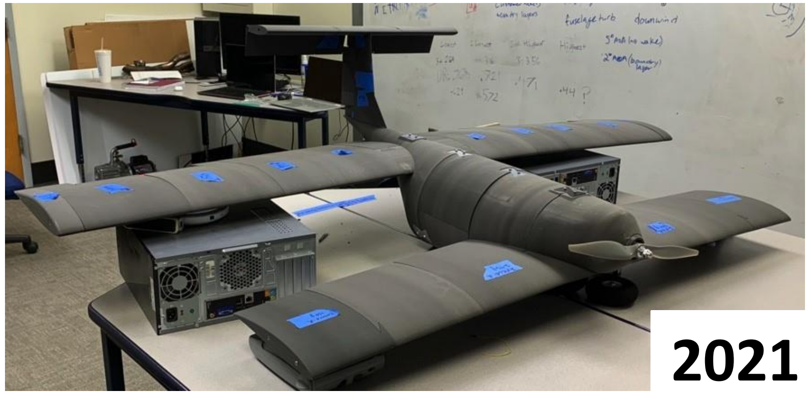
History

2019

Printed with
regular PLA

2020

Mass balance problems
Wing placement difficulty



2021

Stability problems with canards
Heavy landing gear
Wing sagging

Goals and Requirements

Upcoming Presenter’s Name

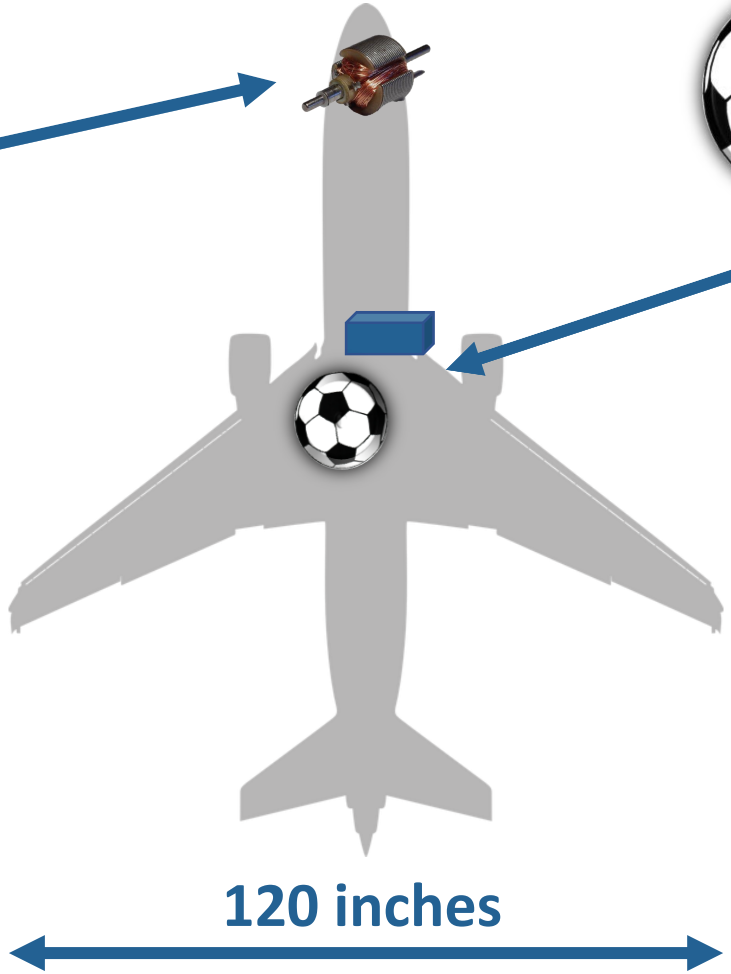
All Goals

- The plane is controllable via remote control operated by a single person
- The airplane's landing gear system is capable of controlling the steering of the airplane while on land the plane's propulsion system will be powered by 1 electric motor
- The cargo bay will secure two payloads that aren't subject to airstream
- The plane is constructed within the SAE competition guidelines
- The plane is primarily constructed of 3D-printed parts
- The plane can operate with and without payloads
- The payloads must load/unload in 1 minute
- The plane can takeoff within 100 feet in 120 seconds
- The plane can securely land within 400 feet

Customer Needs: Design Requirements

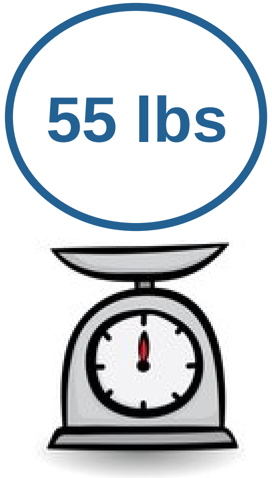
Propulsion System:

- 1 electric motor

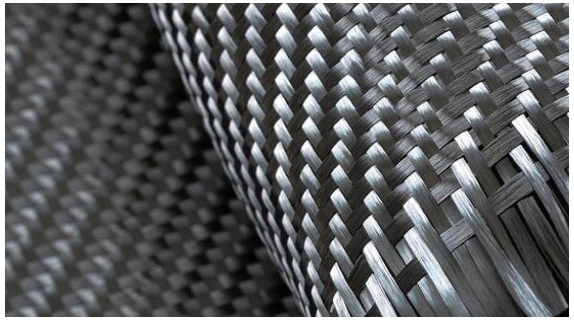


Payloads:

- No integrity contribution
- Size 5 soccer ball
- Boxed cargo

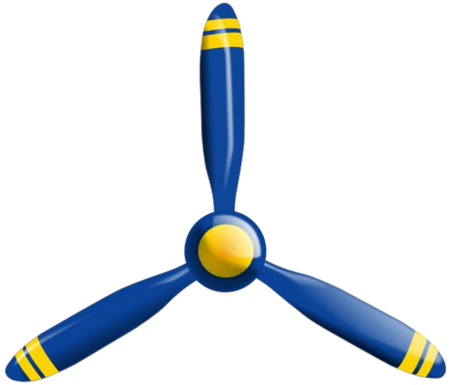


Customer Needs: Materials Requirements



Fiber reinforced plastic is prohibited

Rubber bands cannot secure payload



Metal propellers are prohibited

Lead is prohibited

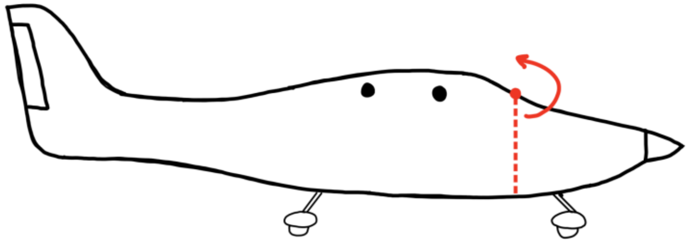
Batteries must be commercially available

A power limiter is required

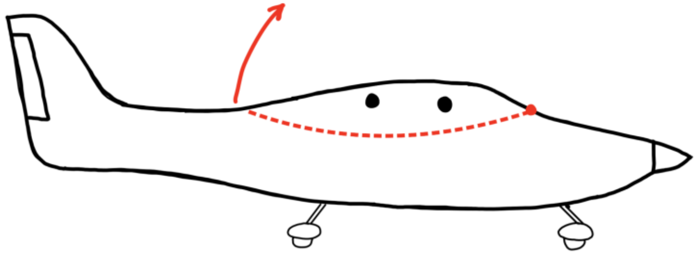
Concept Generation

Upcoming Presenter’s Name

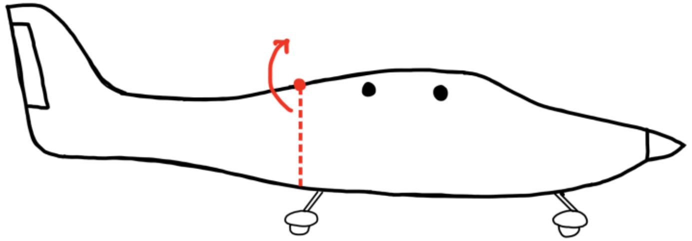
Concept Generation (LOADING MECHANISM)



Front opening



Top opening



Rear opening

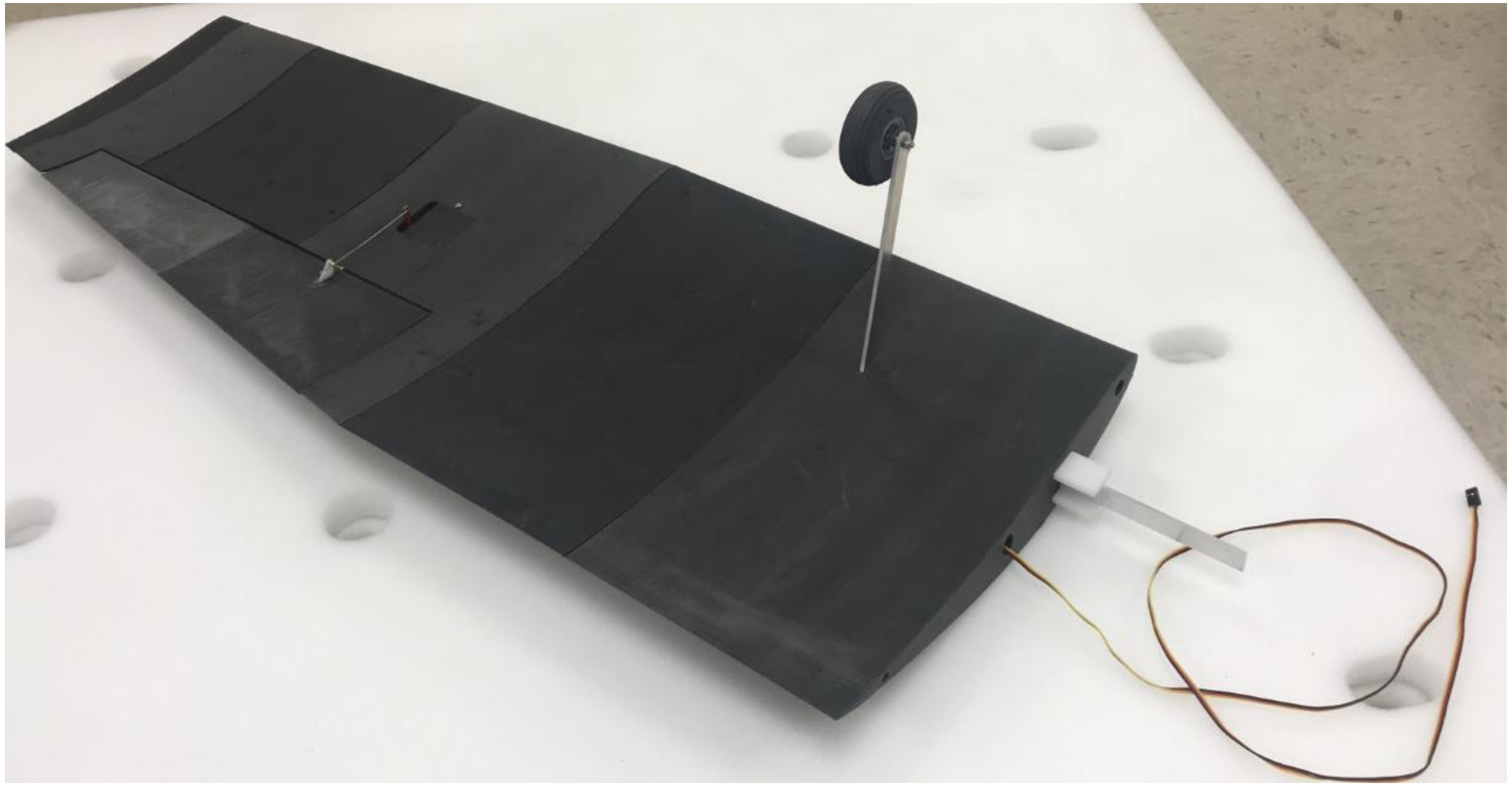
Concept Generation (LANDING GEAR)

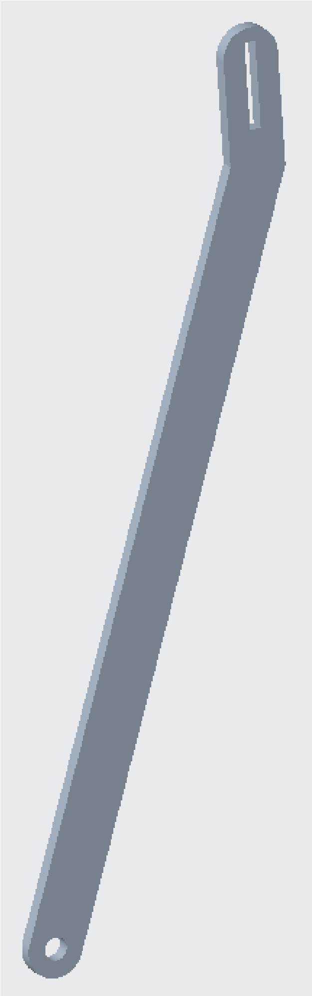
Conventional

Tricycle

Tandem

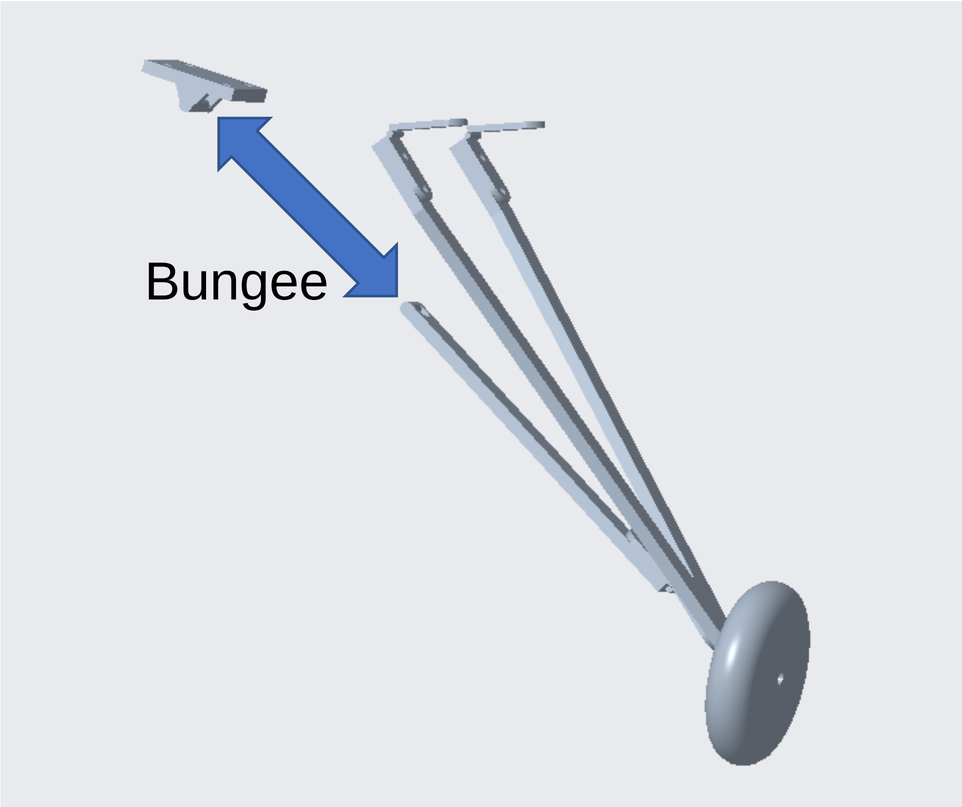
Main Landing Gear Design





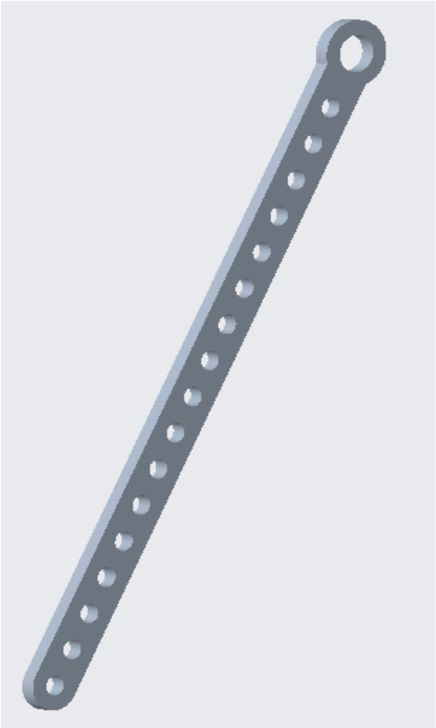
John Healy

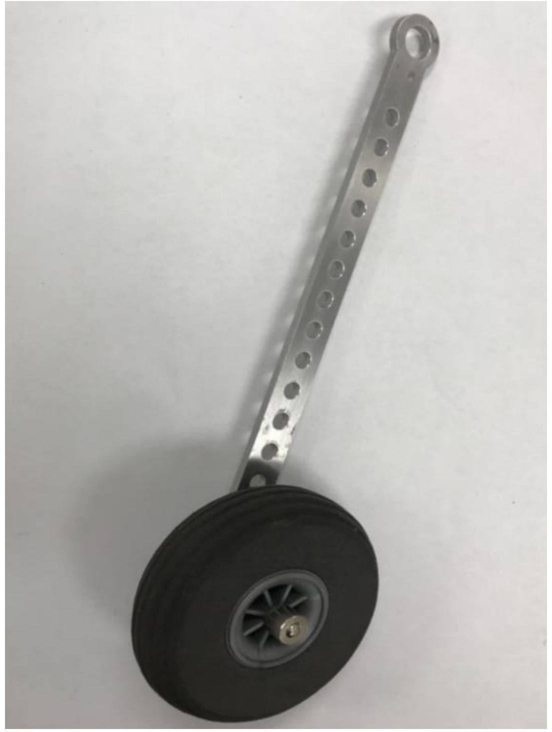
Main Landing Gear Design 1



John Healy

Main Landing Gear Design 2





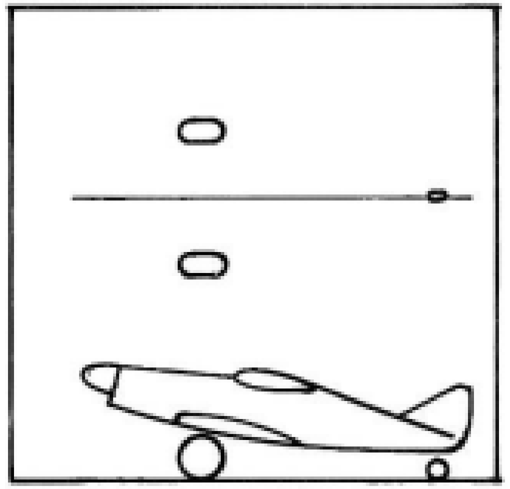
John Healy

Landing Gear Damage

- The main gear had a hard landing on run 2 and suffered a slight bend of the 1/8" Al
- Even with the bent strut, the plane proceeded with a 3rd run, both a smooth takeoff and landing

Concept Selection: Taildragger

- Weight: tailwheel smaller than nose wheel
- Pilot vision not applicable
- The risk of the plane going nose-over from hard breaking not applicable

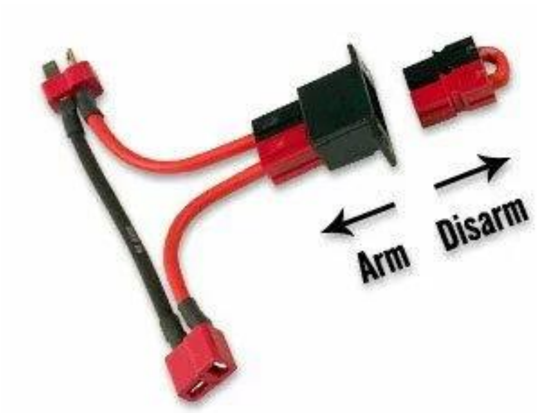

Taildragger

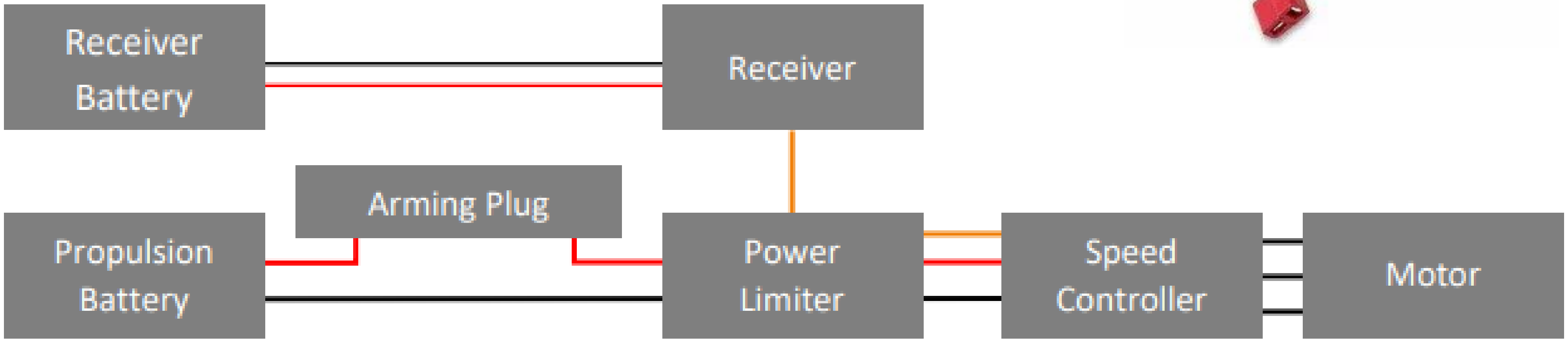
Securement Methods

Upcoming Presenter’s Name

Electronics

- Red Arming Plug secured with glue
- Other components secured inside fuselage with velcro





John Healy

Velcro for Electronics

Verified through testing:

- Proficient adhesion to LW-PLA
- Hook-and-loop fasteners strong enough to hold battery

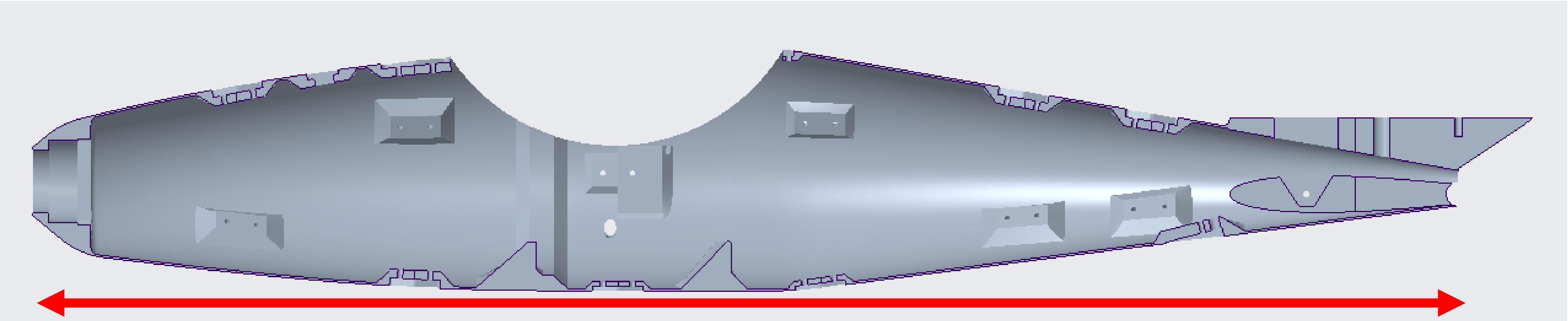
Final Design

Upcoming Presenter's Name

Fuselage Design : Length

- Ratio of Fuselage Length to Wing Chord Length = 4:1
- 14” chord length -> **56” fuselage length**

Wing Chord Length



Length: 56 inches

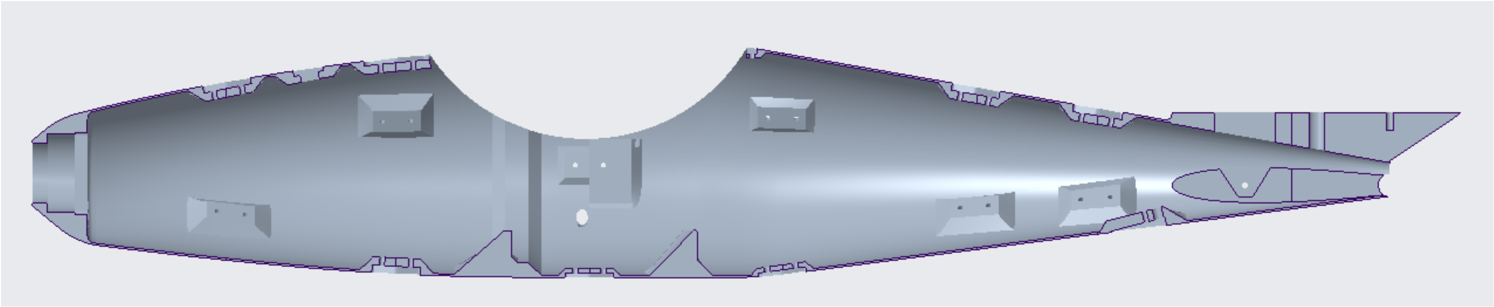
Bridget Andrews

Fuselage Design: General Sketching

- Inspired by Cirrus SR-22
- Parameterized by the side view as shown

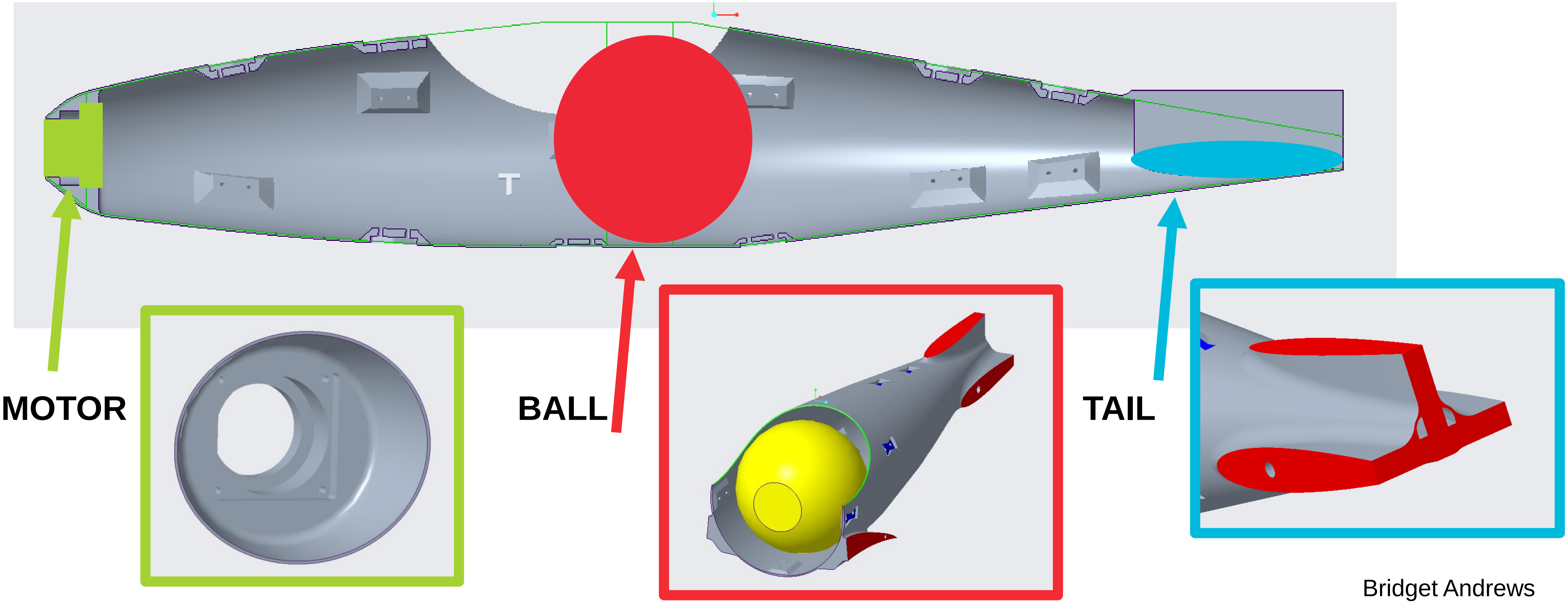
Cirrus SR-22

Taildragger



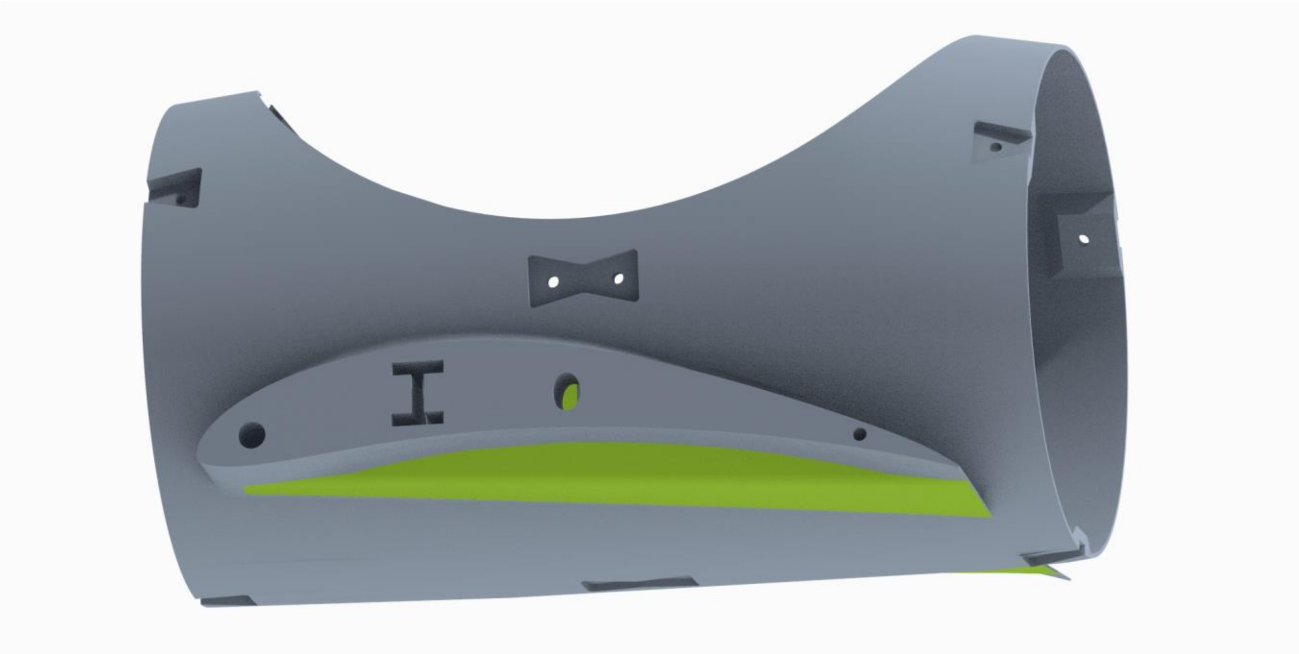
Bridget Andrews

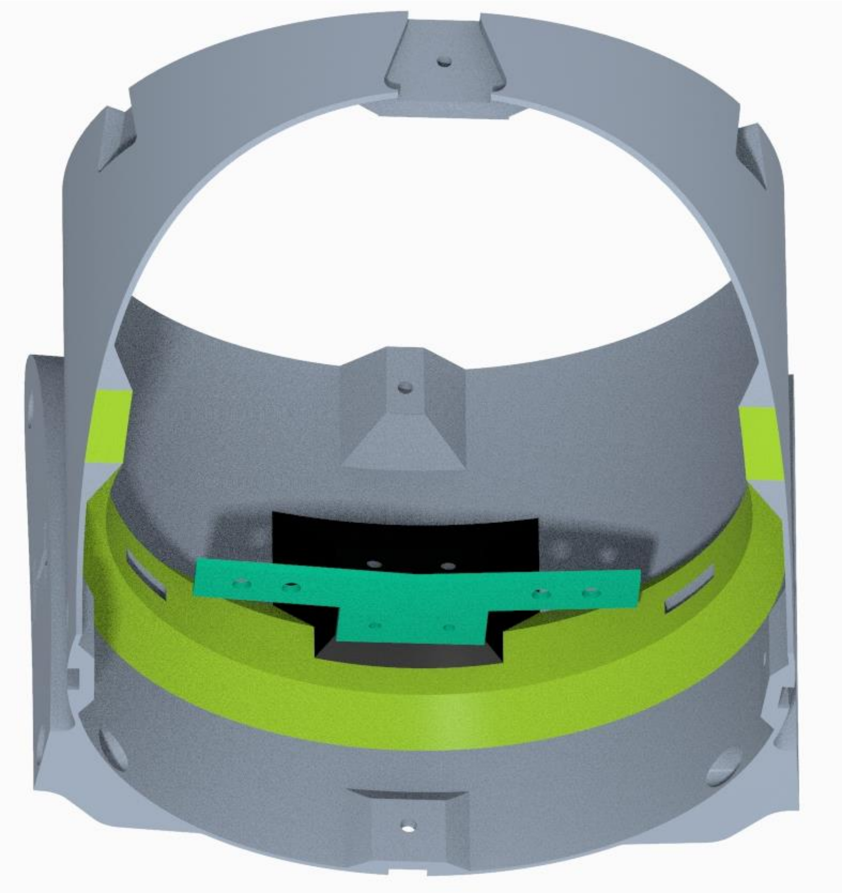
Fuselage Design: Key Aspects



Bridget Andrews

Structural Integrity





Bridget Andrews

Bow Ties

Innovations

- Screws now sit flush
- Tolerancing screw hole sizes
- Nylon Screws
- Labeling

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Tail Interface

Project Selection

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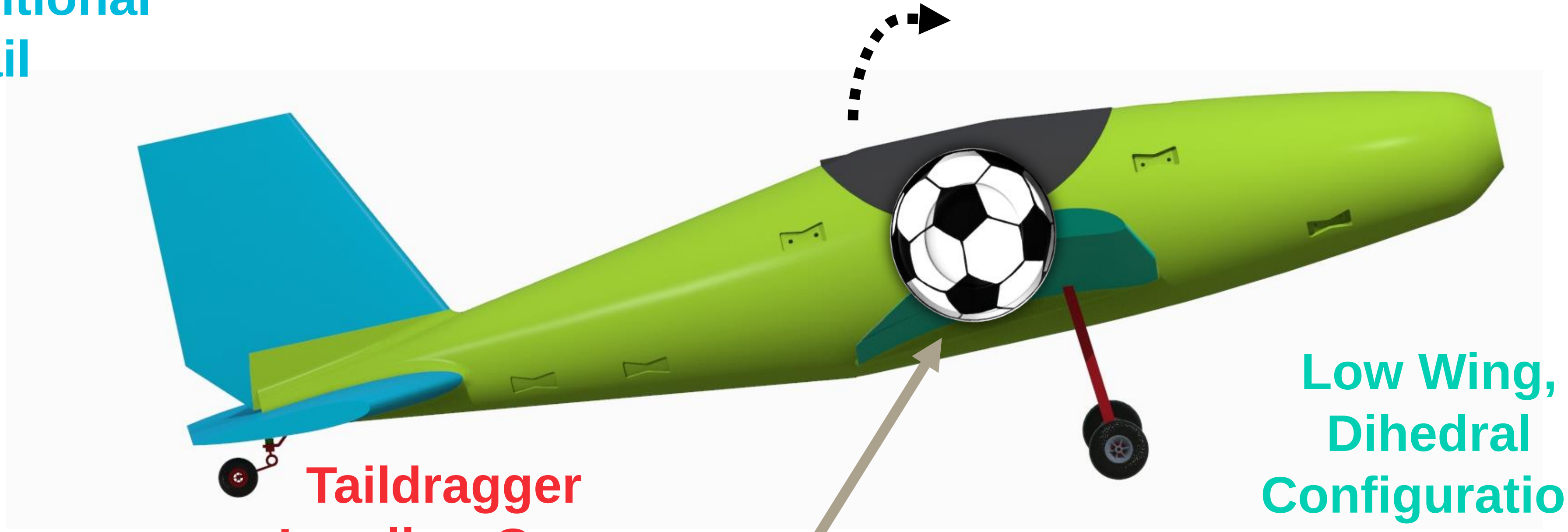
Final Concept



Alejandro Toro

Concept Selection

Center Load Placement

Options:
- Front Load
- Back Load

Reason:
- To minimize payload's effect on CG

Alejandro Toro

Concept Selection

Taildragger Landing Gear

Options:
- Tricycle

Reason:
- Based on team's prediction of CG falling forward
- Low Wing Configuration

Low Wing, Dihedral Configuration

Reason:
- Center Load Placement
- Taildragger Landing Gear

Alejandro Toro

Concept Selection

Hatch-Loading Mechanism

Options:
- Front Open
- Back Open

Reason:
- Center Load Placement
- Low Wing Configuration

Conventional Tail

Reason:
- Team 508 determination

Cirrus SR22 - Inspired Fuselage

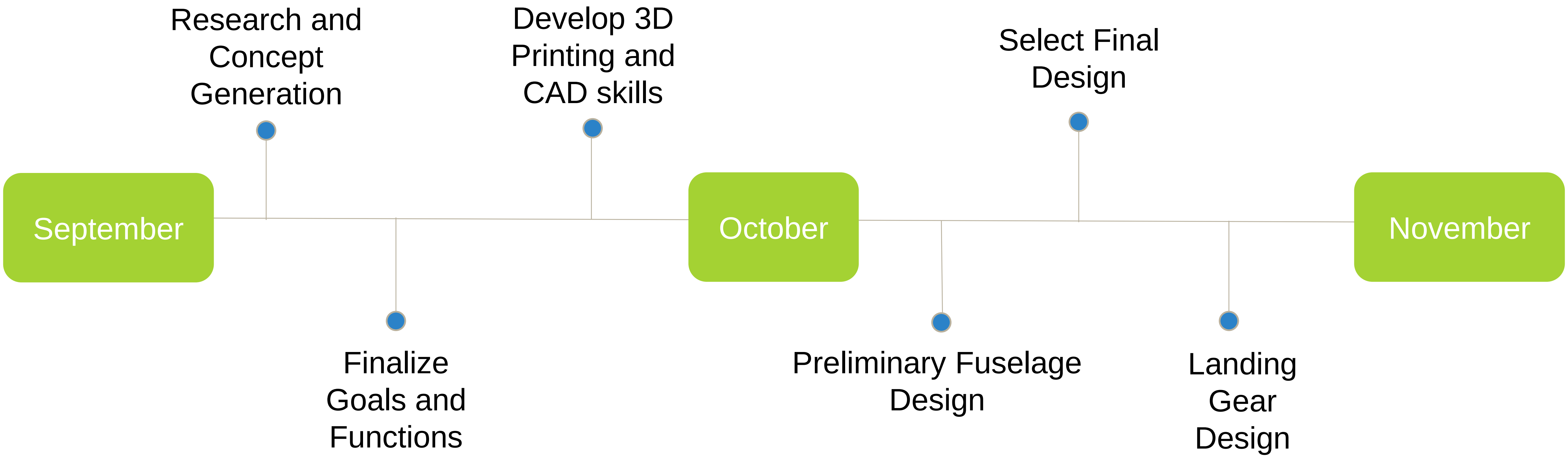
Reason:
- Streamline
- Conventional Tail
- Center Load Placement

Alejandro Toro

Project Timeline

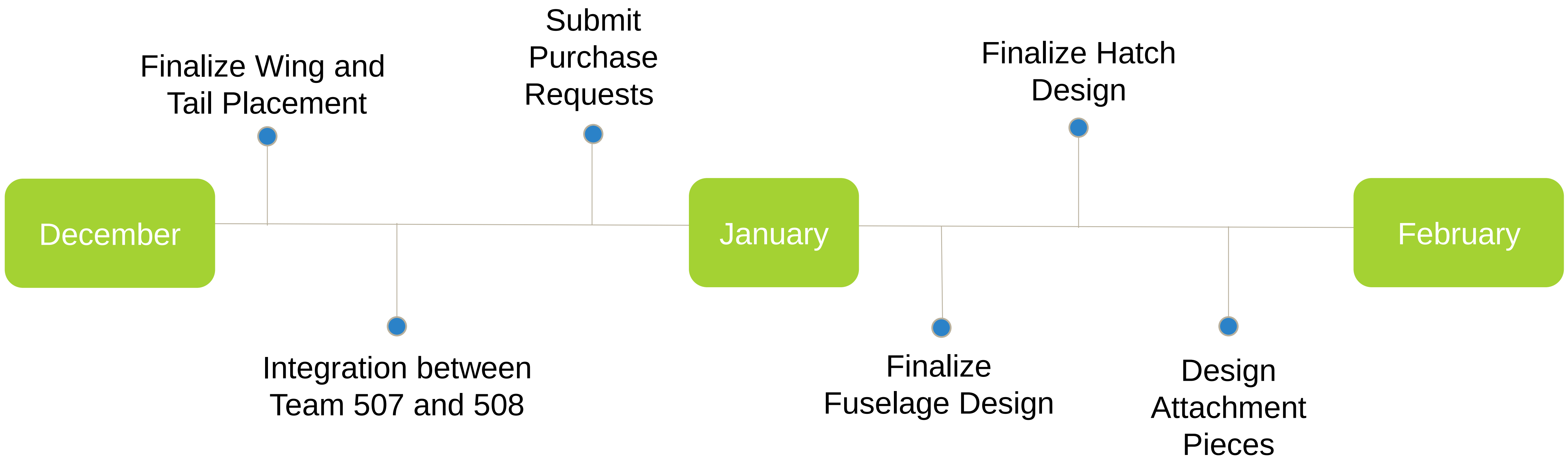
Upcoming Presenter's Name

Timeline



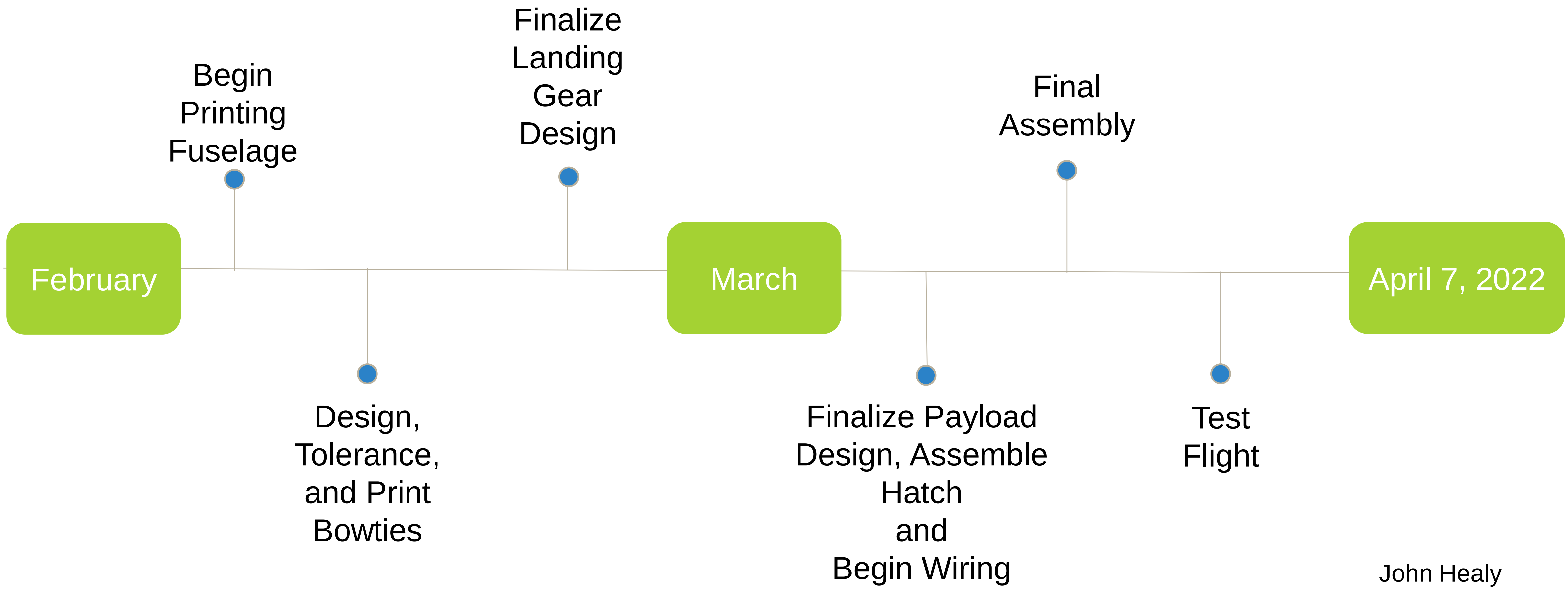
John Healy

Timeline



John Healy

Timeline



John Healy

508 Team Members

Upcoming Presenter’s Name

Team 508 Introductions

David Jay
Manufacturing Engineer

Michael Nalovic
Controls Engineer

Sofia Rodriguez
Aeronautics Engineer

Tristan Wahl
Design Engineer

Alejandro Toro