UCI Rocket Project Fin Design and Integration

Team 11

Project Advisor: Professor Mark Walter

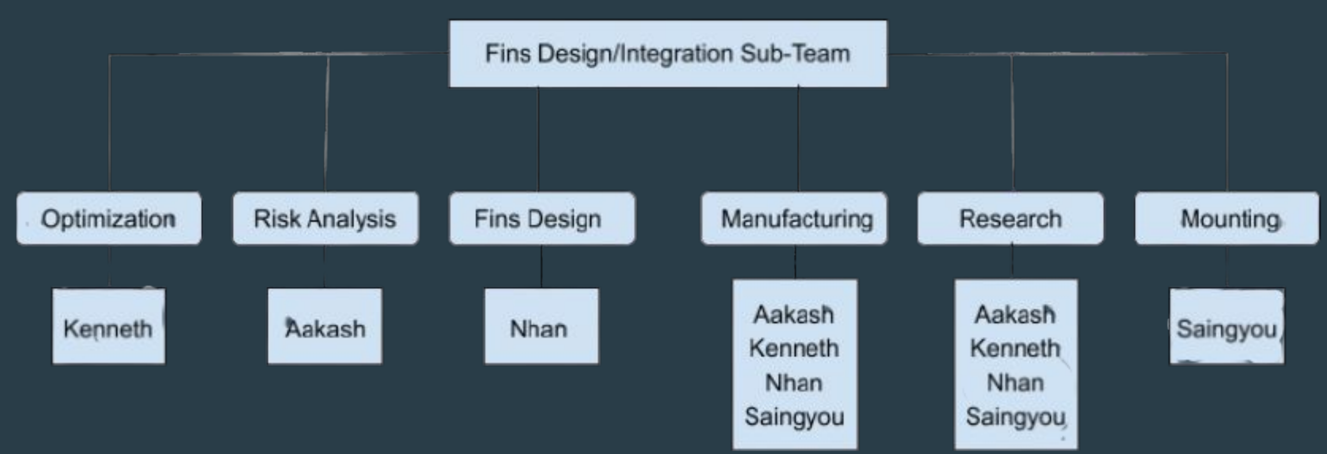
Executive Summary

The UCI Rocket Project requires the fins component on the Preliminary Test Rocket in order to achieve a successful launch in spring of 2021. The UCI RP Fin Design and Integration team has researched and designed a structurally sound fin that will be secured mounted to the strut of the rocket. The primary objectives of the project includes **secure attachment of the fins**, a **minimal to 'no movement' flight experience**, and a **lightweight fin** that would not not hinder the mission objective of the rocket.

Project Goals

- Fins mounting withstands a lifting pressure of 71 kPA
- Flutter velocity should stay 15-20% greater than instantaneous velocity
- Maximum weight of each fin should be 3kg
- Manufacturing covers 3-5 days
- Position of center of pressure needs to be 1.5 caliber aft of center of gravity location
- Fins withstand maximum flight temperature and stagnation pressure of 120 Celsius and 1.72E5 Pascal, respectively

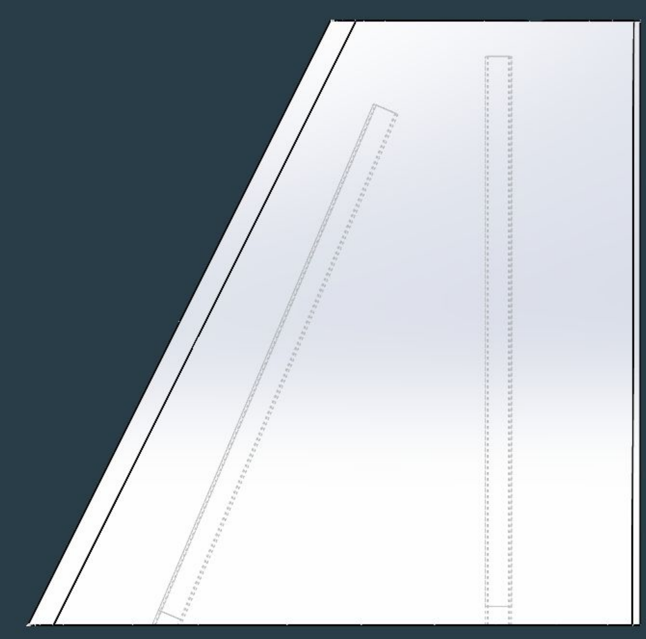
Team Formation / Prior Work



- **Fins preliminary design was completed last quarter**
  - Fin planform: Clipped Delta
  - Fin cross section: Airfoil
  - Preliminary CAD of fin
  - Preliminary Bill of Materials
- **Fin ANSYS analysis and simulations**
  - Test fin selection for: temperature, velocity, pressure, drag force & drag coefficient values
- **Fin flutter velocity MATLAB code tool was completed last quarter**
  - 15-20% Margin of error above instantaneous velocity
  - Utilized the fin flutter velocity equation
- **Barrowman's Equation for center of pressure MATLAB code tool was completed last quarter**
  - Input variables of fin dimensions & rocket dimensions into tool to calculate CP.
- **Research and sources for fin manufacturing for this quarter.**

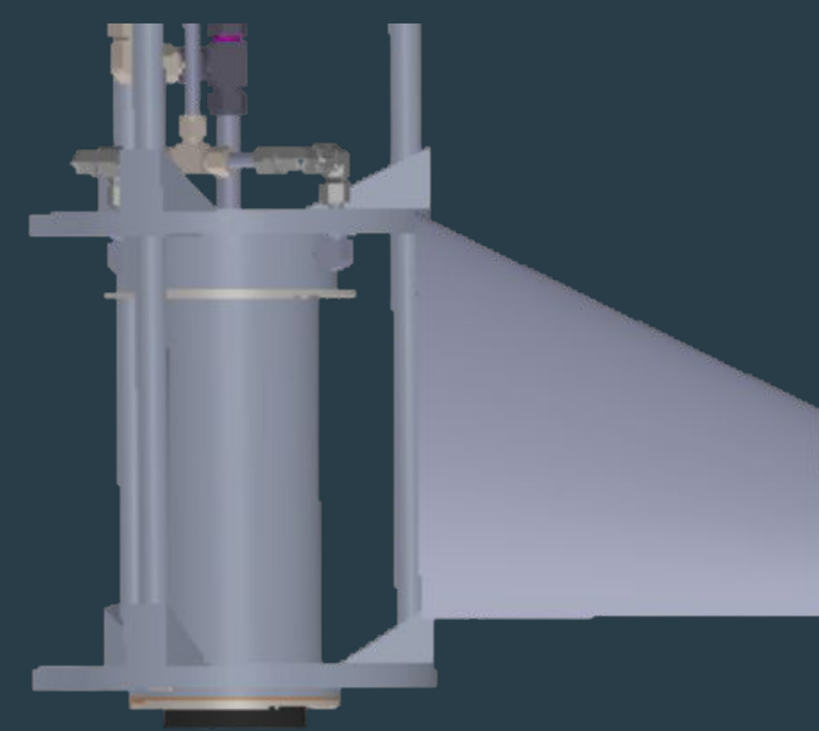
Fin Structure Design

- Fins will have an airfoil profile with a clipped delta planform
- Fins will be made out of a low density foam
- 2 carbon fiber spars will inserted into the foam for structural integrity
  - One spar will run normal to the rocket while the other one will run at an angle to the rocket
- A 3D printed 'leading edge' will replace the foam at the leading edge to protect it from high stagnation pressure



Fin Mounting Method

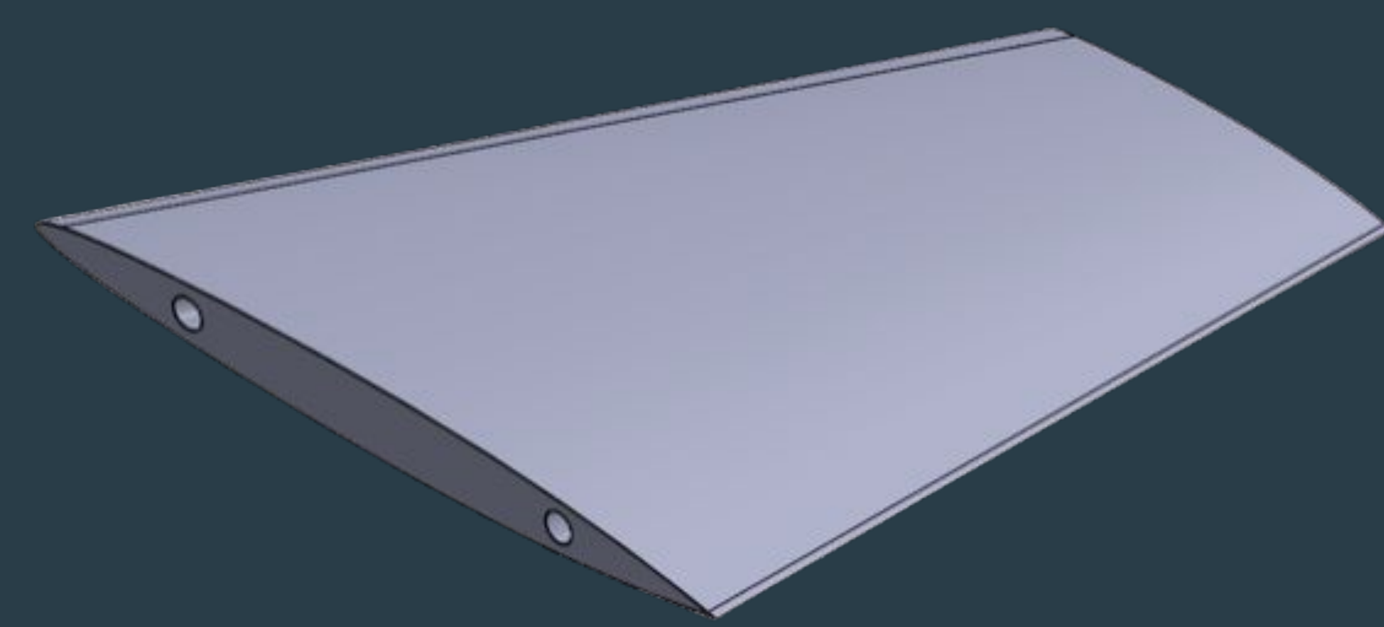
- End of both spars will line up at the flat surface of each fin
- Skin of the rocket will have a cut for each fin's location prior to its attachment on the rocket
- Composite wrap method will be implemented using a fiberglass cloth and resin
  - Wet cloth will be wrapped around the entire fin with the corresponding strut
  - Once resin is cured after 2 hours, the rocket's skin will be installed by sliding down to fit the location of fins
- Tip to tip layup of carbon fiber will be applied to all of the fins



Fin attachment without skin installation

Fin Structure Analysis

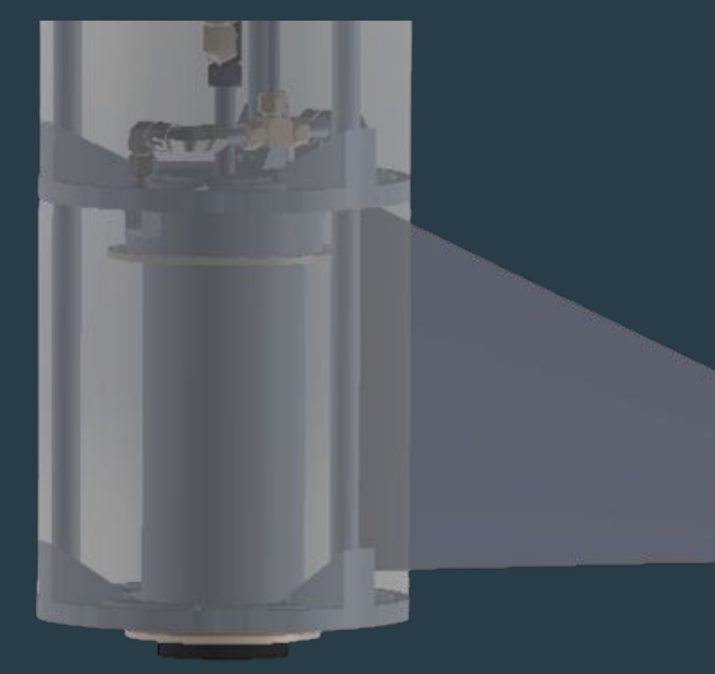
- A prototype of the fins will be made for testing
- A 3-point-bend testing on the fins following ASTM D7250 and ASTM C273 standard using an Instron machine
- The procedure will give us the shear modulus of our fins which we can then use to verify our flutter velocity requirements



Fin Mounting Analysis

A physical test must be performed in order to analyze the final design.

- Conduct installation on a strut and foam
  - Use wet fiberglass cloth to wrap strut and foam
  - Add resin and cure for 2 hours
- Once resin is cured, place test materials in Instron test machine (or similar machine at UCI)
- Conduct a test on the example fins and strut
  - Set load to 70 kPa



Fin attachment after skin installation

Future Improvements

Risk Assessment Matrix				
Probability/Severity	Catastrophic	Critical	Marginal	Negligible
Frequent				
Probable				
Occasional				
Remote		Risk 1	Risk 4	
Improbable	Risk 5, 6	Risk 2	Risk 3	
Eliminated				

Risk 1: Fins flutter

Risk 2: Spars fracture inside fins

Risk 3: LE alignment failure

Risk 4: Fins placements failure

Risk 5: Spars to strut adherement failure

Risk 6: Fiberglass wrap failure (resin fracture)

- Adherement
  - Additional research and analysis is needed to provide a firm conclusion on composite wrap and fiberglass strength to support fin mounting
- Fiberglass Wrap
  - High stagnation pressures in flight can cause fiberglass fracture
  - Further case studies need to be performed regarding fiberglass wrap performance at high speeds

Acknowledgements / References

The UCI RP Fin Design and Integration Team would like to acknowledge the guidance of the team's advisor Professor Mark Walter, as well as the Launch Vehicle co-leads of UCI Rocket Project, Arthur Weng and Cliff (Ching-Hao) Yu.

References:

- "Design, Manufacturing, and Integration of Fins for 2017-2018 OSU ESRA 30k Rocket" by Emma Renee Fraley
- "The Jarvis Illustrated Guide to Carbon Fiber Construction" by Jim Jarvis
- "Handbook of Model Rocketry" G. Harry Stine
- "Prediction of Forces and Moments on Finned Bodies at High Angle of Attack in Transonic Flow" William L. Oberkampf
- "Development of Composite Fin to Improved Orion Rocket" Petter Ekman
- Various newsletter by Apogee

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