UVIC Rocketry

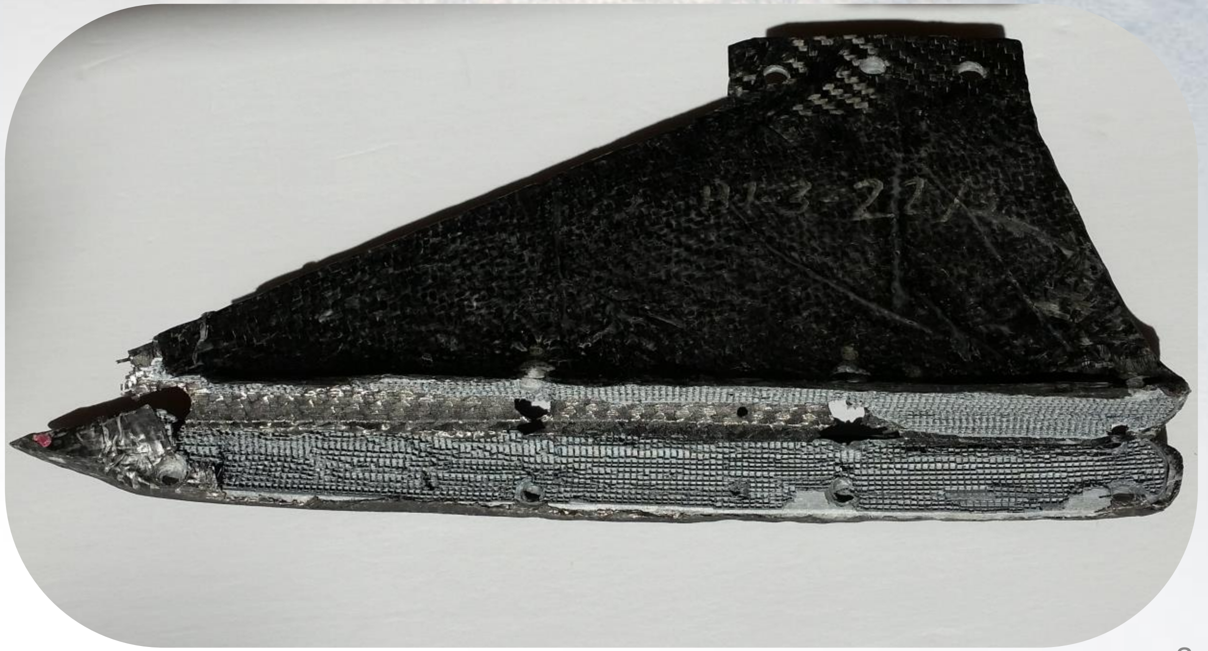
Validation of a detachable fin design for a supersonic sounding rocket

Design

- Detachable Fins
  - Small transporting profile
  - Quick replacement
- Materials
  - 3D printed PLA + carbon fiber
  - Aluminum
  - Foam + carbon fiber
- Manufacturing
  - Cost effective
  - Easy to manufacture
  - Consistent final product

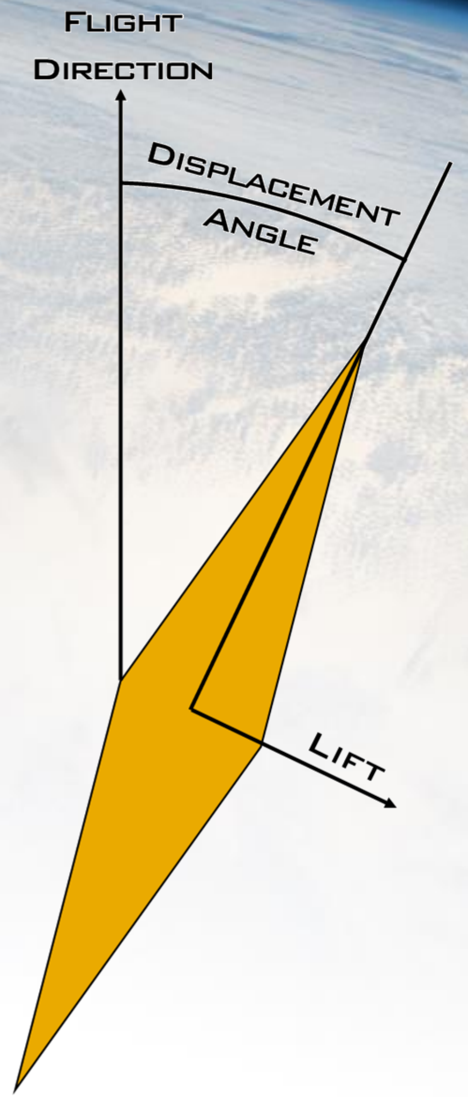
Modes of Failure

- Bending
  - Due to wind gusts and flight path corrections
  - Fin acts as a lifting device
- Flutter
  - Due to relative air velocity
  - Aeroelasticity (aerodynamic and elastic forces)
- Sandwich structure
  - Anisotropic material
  - Properties determined experimentally



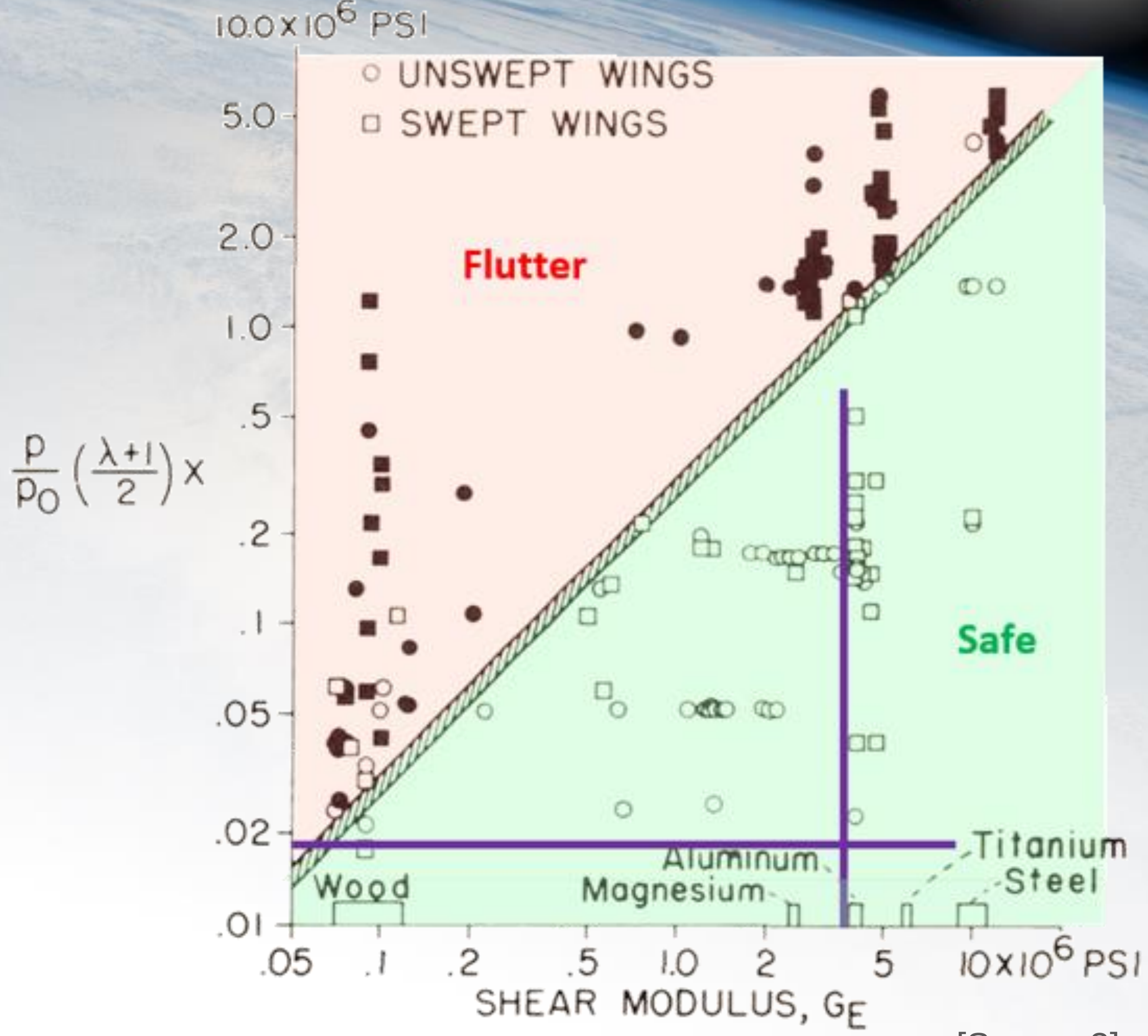
Bending Calculations

- Bending
  - Wind deflects the rocket
  - Fins act as lifting bodies
- Expected loading
  - Wind speed of 6 m/s
  - 341 N at Mach 2
- Highest loading
  - Wind speed of 10 m/s
  - 550 N at Mach 2
- Assumptions
  - Higher velocities are hard to reach
  - Sea level conditions



Flutter Calculations

- Bending-torsion flutter
  - Most common flutter
  - Once started,
    flutter results in failure
  - Effective shear modulus
    from testing
- NACA TN 4197 paper
  - Preliminary design for thin fins
  - ƛ : taper ratio
  - X : geometric flutter factor
  - Critical Mach number is 1.4



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Static Bending Test

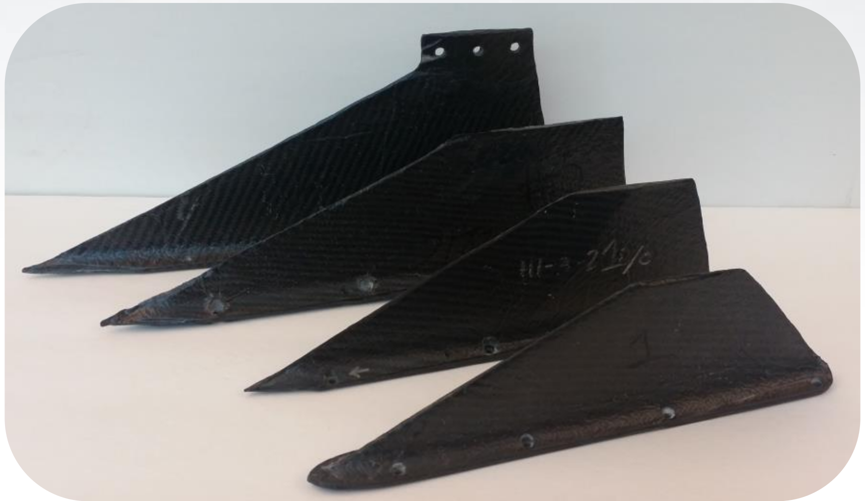
- Fin is tested for bending
- Fin must withstand 570 N (60 kg)
- Weights hang off tip of fin
- Tested for failure

Torsional Stiffness Test

- Torsional stiffness is tested
- Test is non-destructive
- Deflection and loading is recorded
- Shear modulus is calculated to get a flutter safety factor

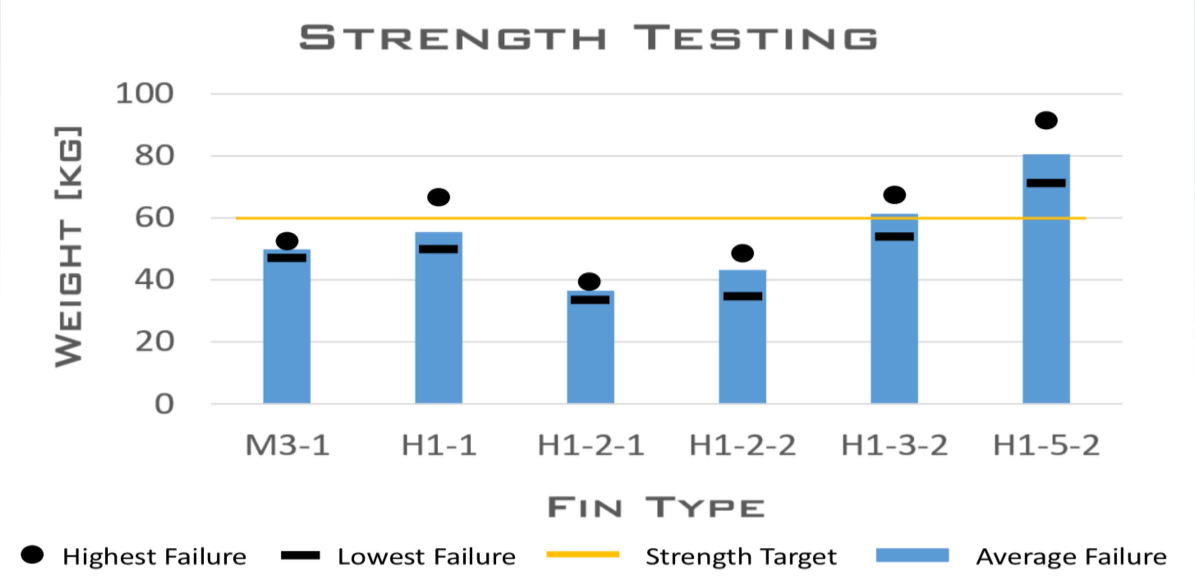
Results

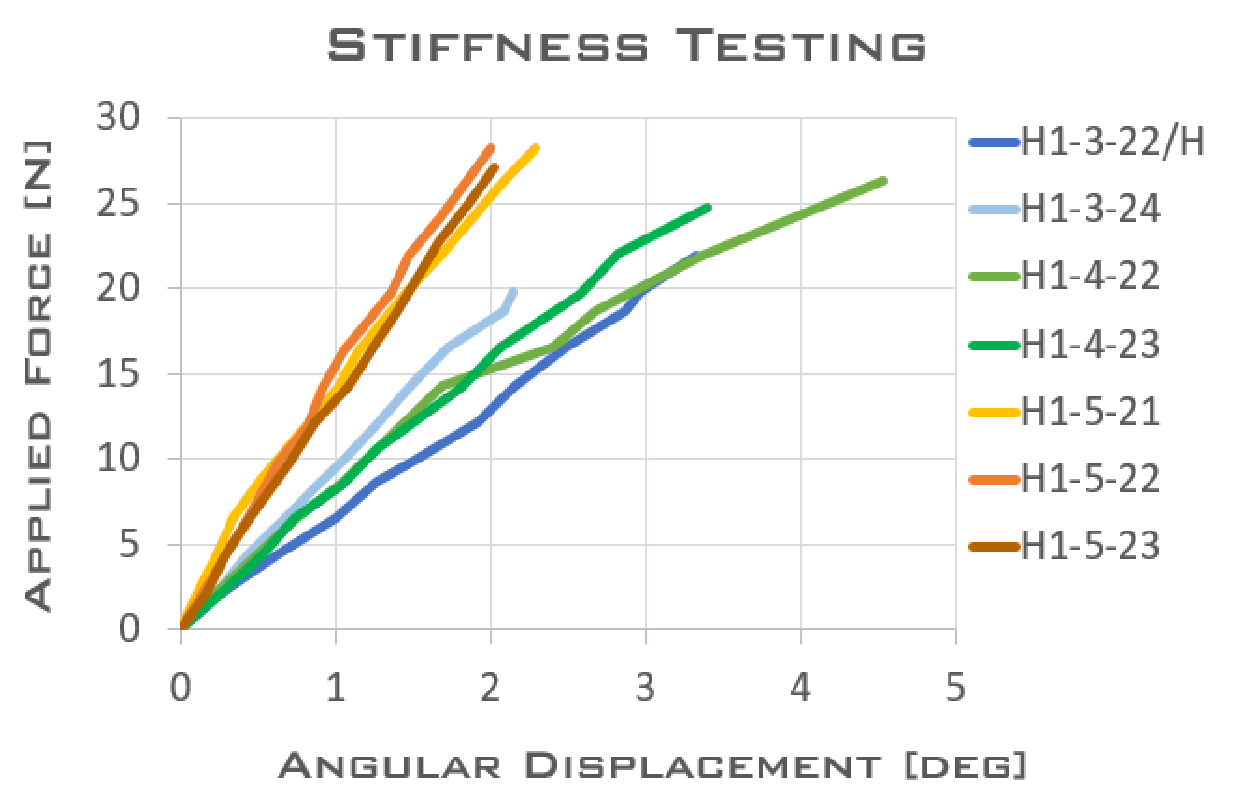
Method	Stiffness	Strength
One layer carbon fiber wrap	Baseline, fins are too weak	
Heat treatment (60°C for 30 min)	Decreased by 40%	No effective change
Two layer carbon fiber wrap	2x stiffer than baseline	40% stronger than baseline
Carbon fiber insert (8-layer plate)	4x stiffer than baseline	60% stronger than baseline



Results

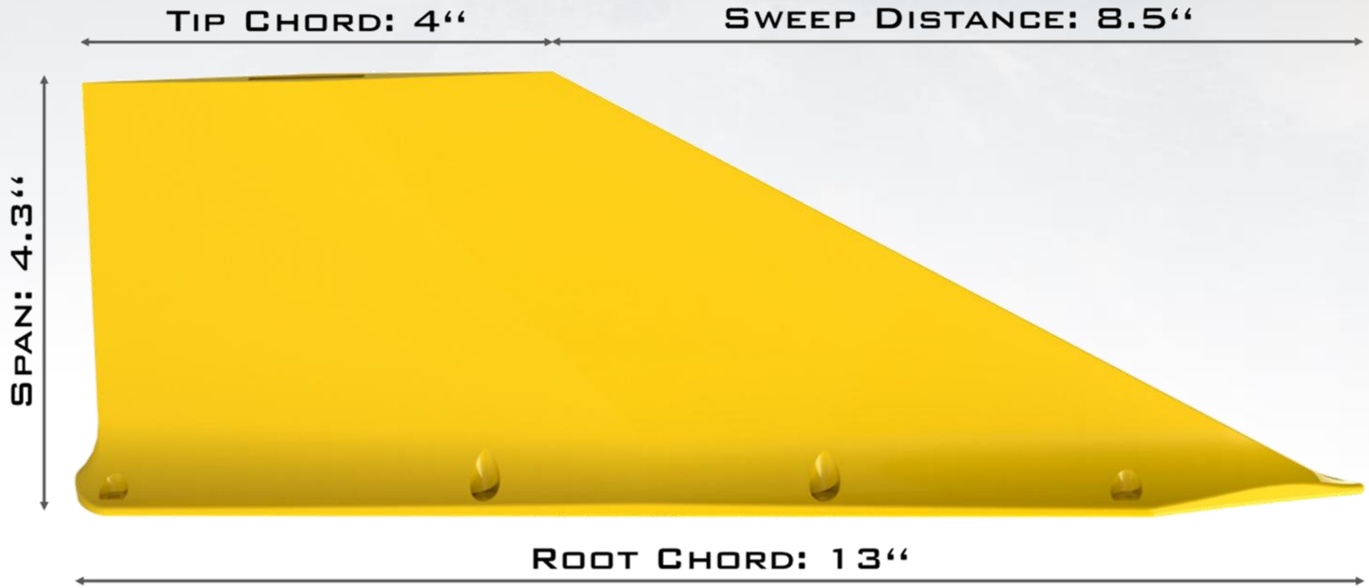
- 24 fins tested
- Carbon fiber insert improves strength and stiffness
- Fastener tear-out only in last fin design
- Last fins were consistent

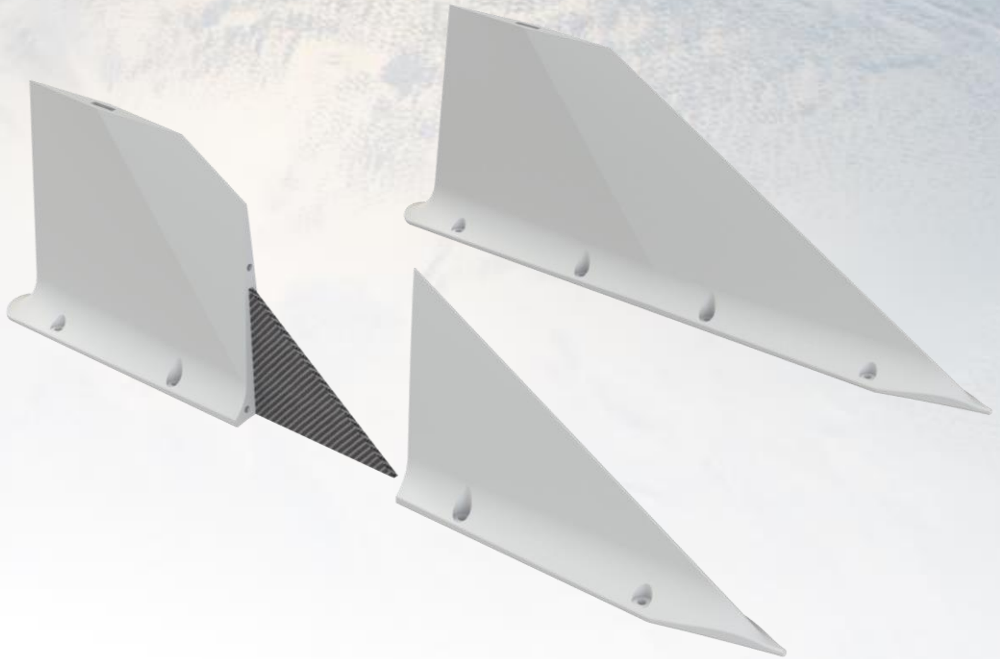




Manufacturing

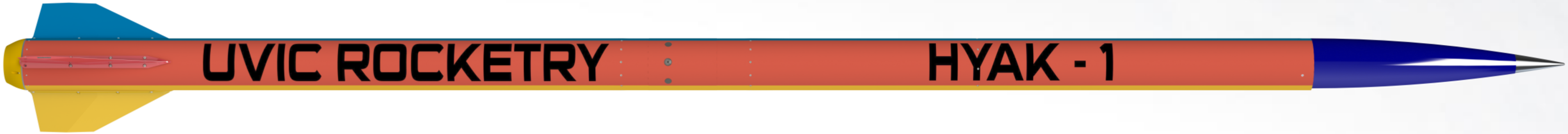
- 2-piece PLA 3D-print
- Carbon fiber insert for extra stiffness
- Overwrapped with 2 layers of carbon fiber
- Low cost for manufacturing
- Surface sanded smooth





Conclusion

- Proof of concept: Detachable fins
  - Perform up to Mach 2
  - Can guide a 28 kg heavy rocket
  - Easy and cheap to manufacture
- Stiffness is driving mode of failure
  - Taper, span and thickness have high influence
  - Length and base radius have least influence
- Launch will give final confirmation
  - Validation of calculations and assumptions



Thank You

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