Fabrication and Wind Tunnel Tests of High Speed Swept-tip Tilt-rotor Blades

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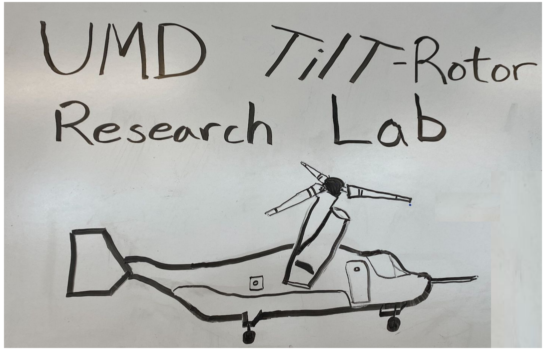
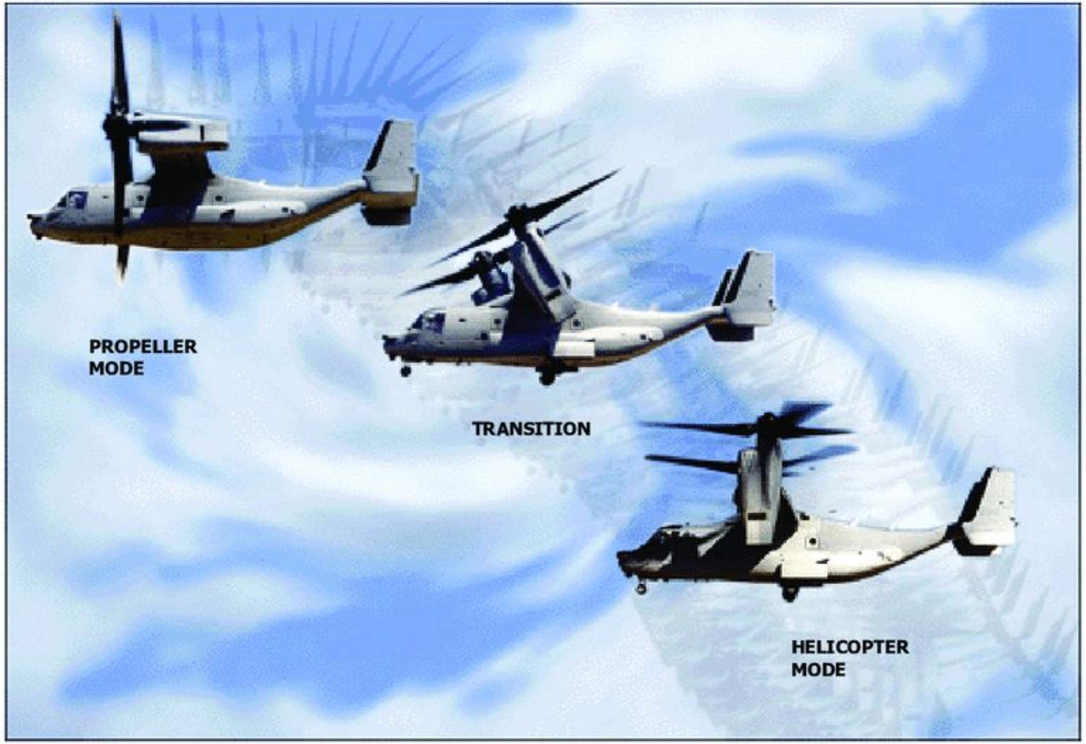


What is a tiltrotor?

- Unique aircraft
- Hovers like a helicopter
- Cruises like an airplane



Why are tiltrotors important?

Goes where no other aircraft can

Civil

Military

V-22 Osprey

Vision for Future: Very High-speed

- Current speed 250 knots
- Future vision 500 knots
- DOD's vision for Future Vertical Lift

AW60

V-22

Path to the Future

1. Advanced Blades
2. Advanced Hub
3. Advanced/Thinner Wings

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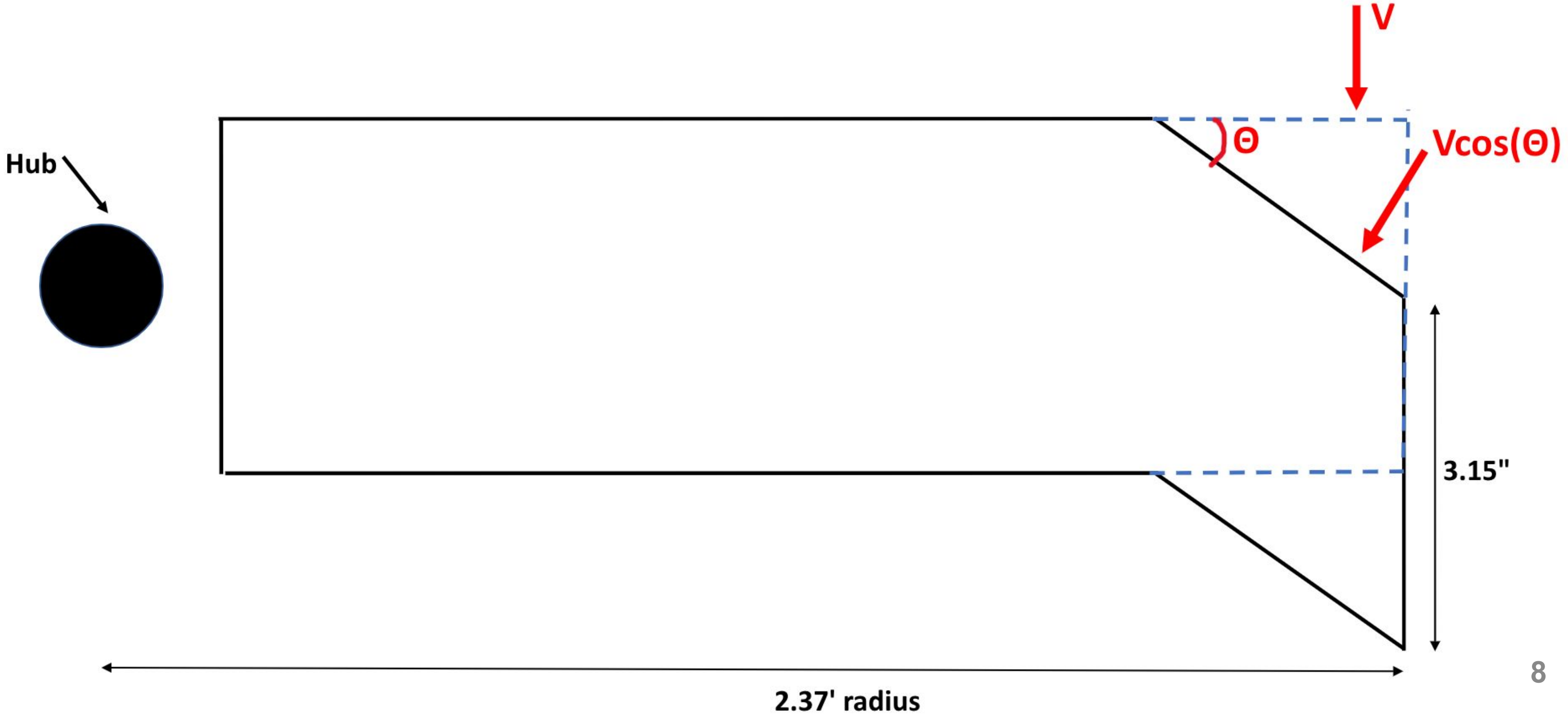
Technical Approach of My Internship

1. Fabricate advanced swept-tip tilt rotor blade
2. Integrate on the Maryland Tiltrotor Rig (MTR)
3. Test at high speeds in Glenn L. Martin Tunnel

Why Swept Tip?

Reduces the speed at which air hits the tip, prevents approach to speed of sound.

Speed of sound leads to shocks, breaks blades, spikes drag, creates deafening noise.



What is Aeroelastic Scaling?

Build blades to have same dynamics as real aircraft

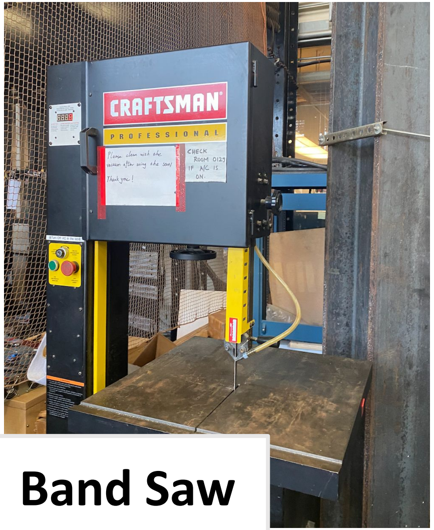
XV-15/NASA precursor to V-22

Scale-Factor
Real rotor R = 12.5 ft
Model rotor R = 2.375 ft
12.5/2.375 = 5.26

Major Equipment

Curing Oven

4 axis CNC



Band Saw

Power Tools

Eclectic Wrench

Dremel

Drill

Many Other Tools

Filers

Allen Keys

Pliers

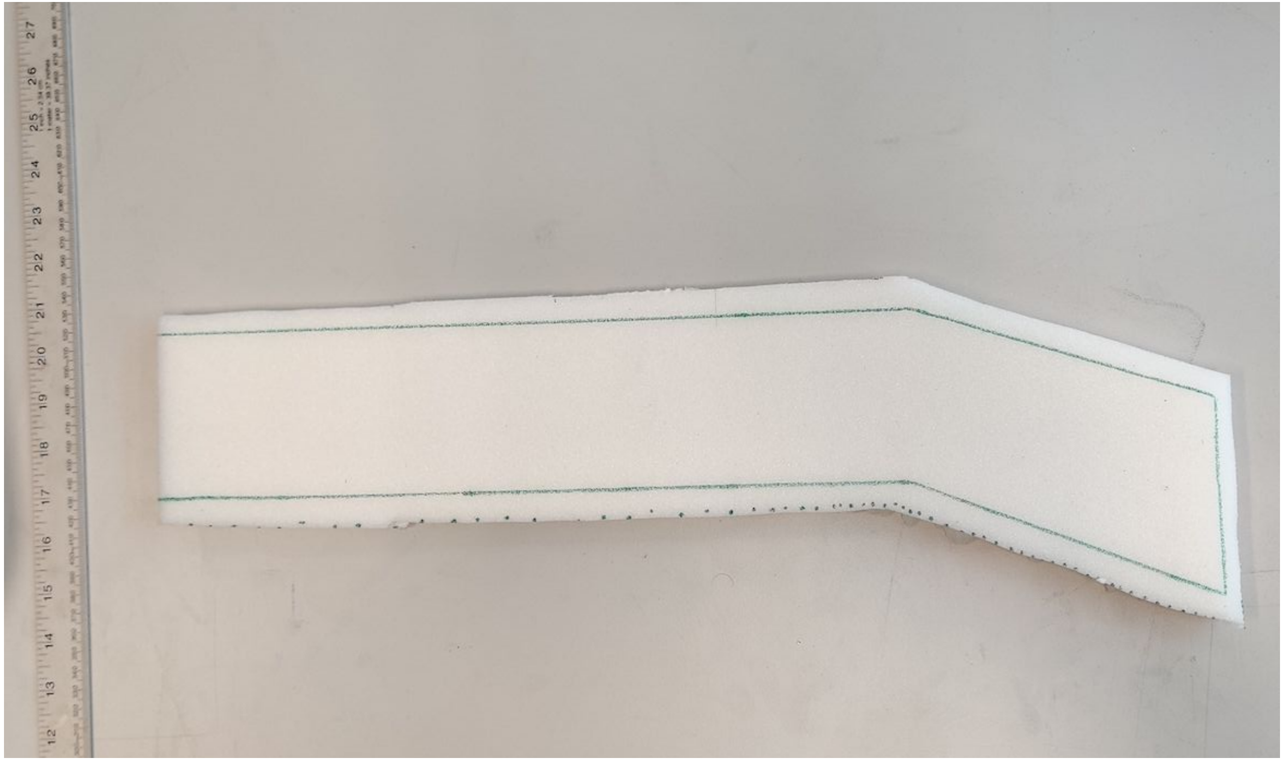
X-ACTo Knife

Hammer

Wrench

Step 1: Trace foam from template and trim

Rohacell foam



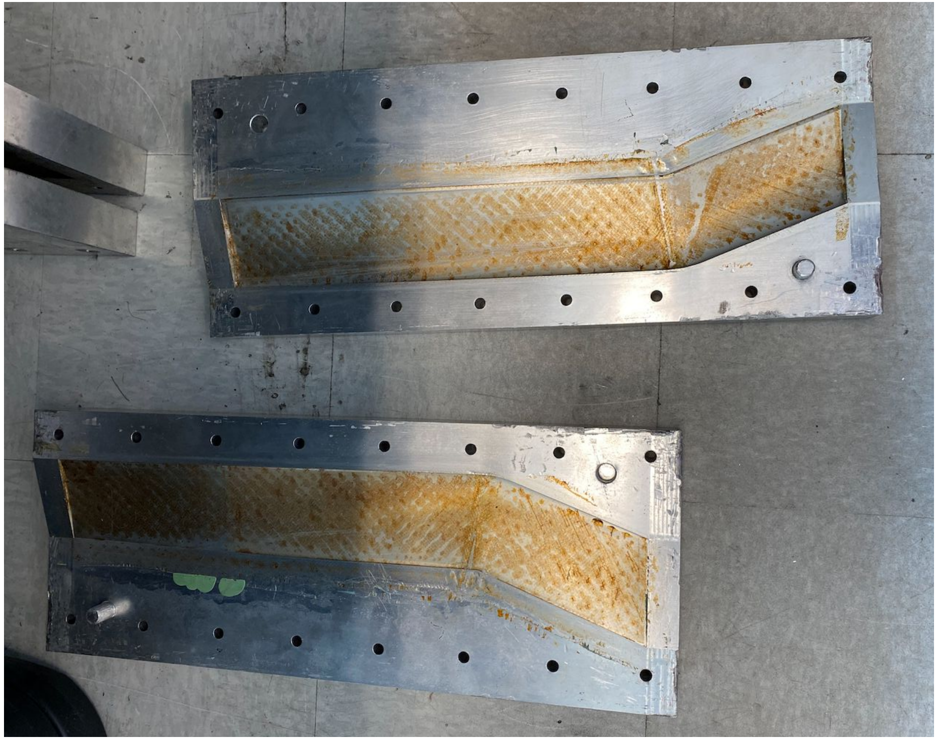
Materials

Material	Designation	Density	Modulus	Source
Foam	IG-31	0.00116 lb/in³	0.0360 GPa	Rohacell
Adhesive	EA 7000 AERO Epoxy Film Adhesive			Loctite
Aluminium	Root insert 6061	0.0975 lb/in³	68.9 GPa	
	Blade Grip 7075	0.102 lb/in³	71.7 GPa	
Carbon Fiber	IM7/8552		10.3 GPa	Boeing

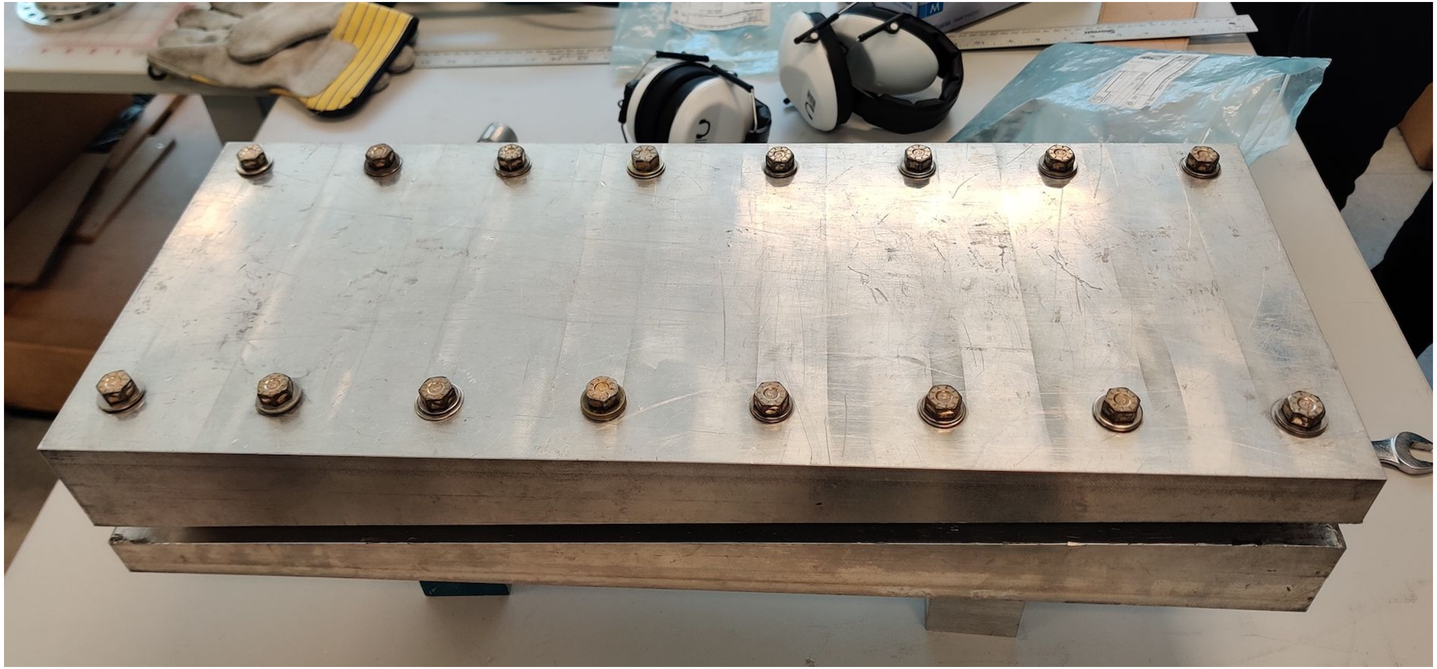
Use Aluminium Mold of Same Shape

Top mold

Bottom mold

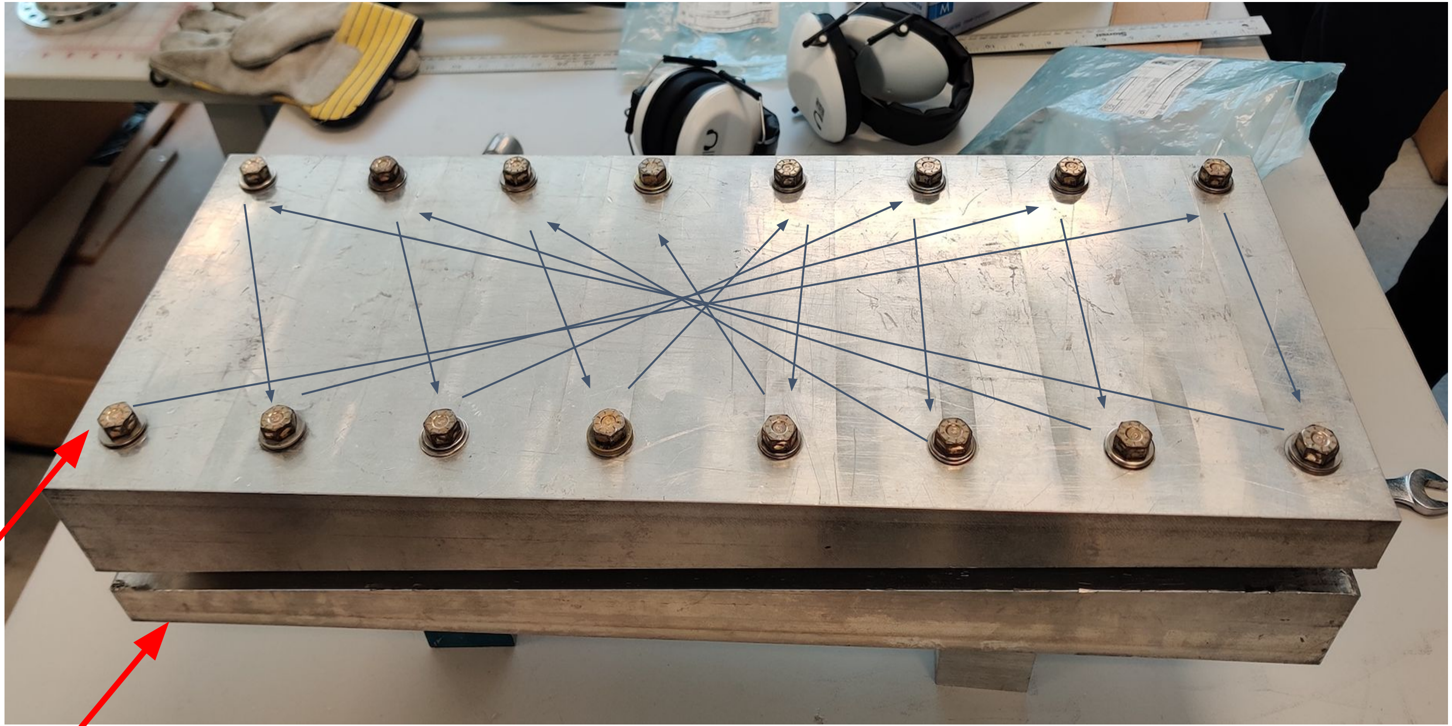


Step 2: Put foam in mold



Foam must be aligned so it covers the full area

Step 3: Tighten screws in star pattern



2 washers

3 washers

Step 4: Cure in oven for 90 minutes at 350℉

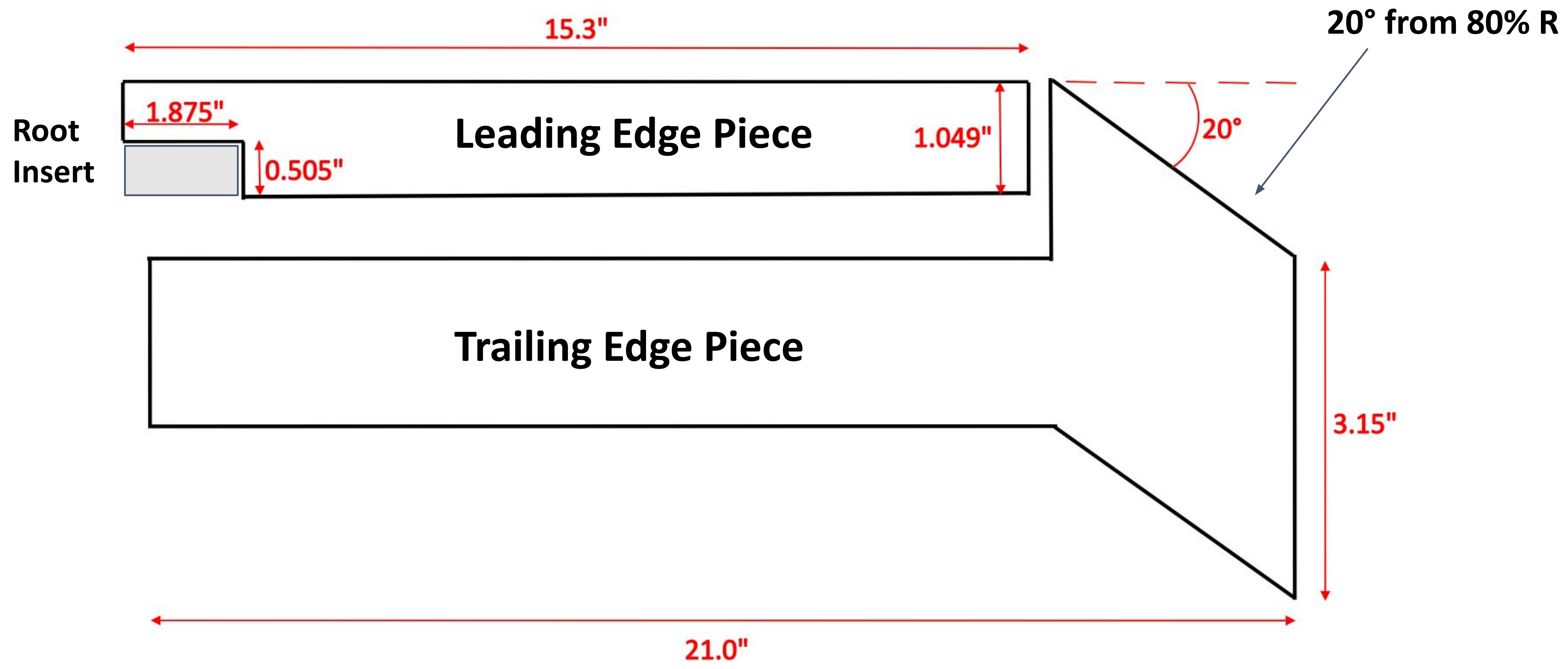
Curing Oven

After curing is over

Step 5: Trim the foam and sand it down

Before sanding and trimming

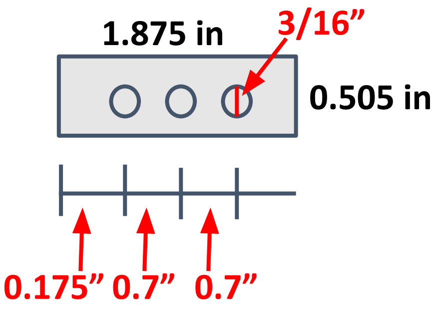
Strategy for Fabrication: Build in Two Parts

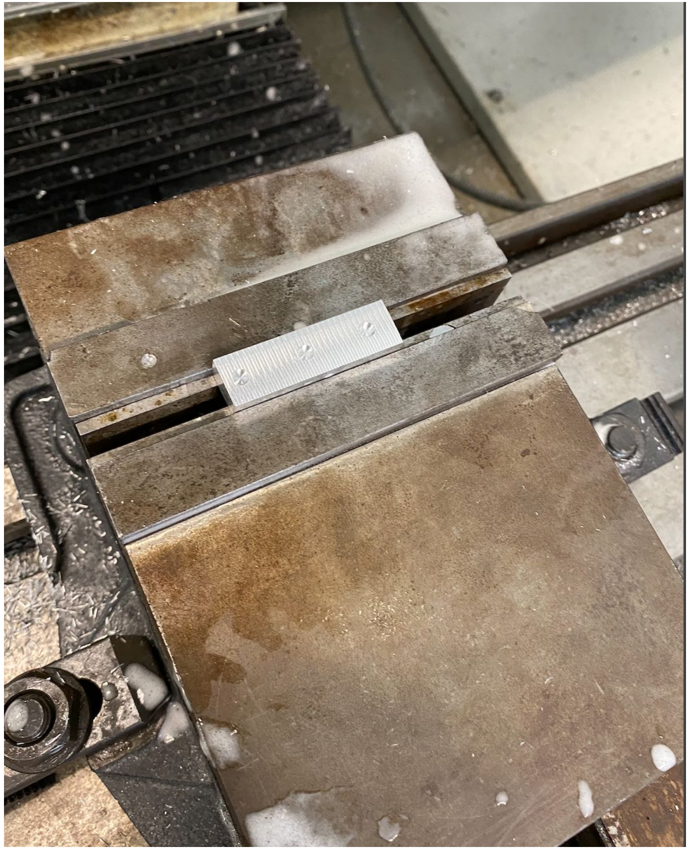


Step 8: Cut out root insert space and spar

Must align foam so it is straight

Step 6: Create divots in root insert using CNC





Root Insert made of Aluminium

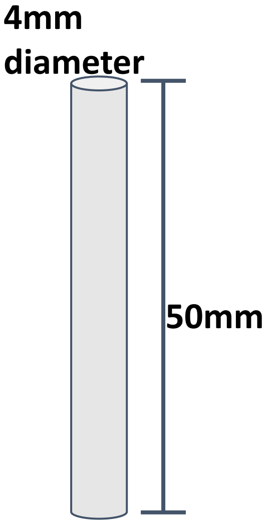
Step 7: Drill through using CNC

13. Wrap root insert in adhesive

9. Cut leading edge weight slots

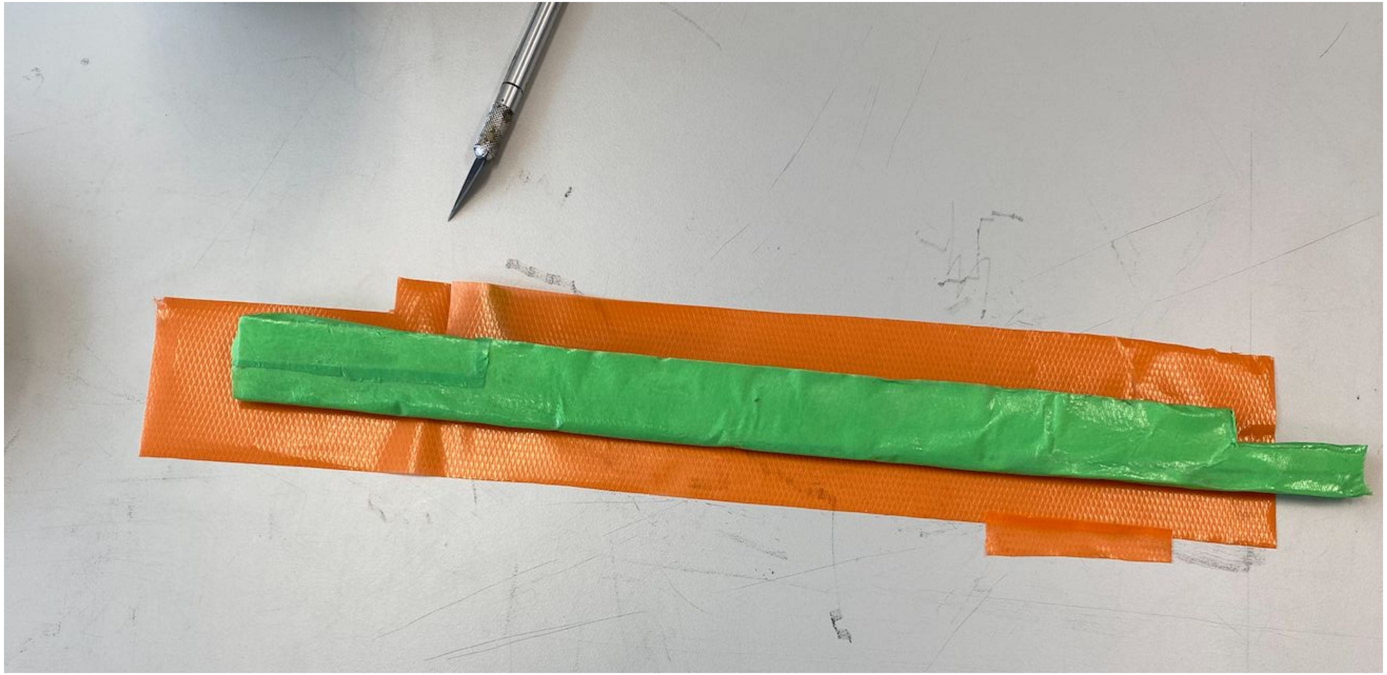
7 slots, 50mm in length cut using g-code

10. Wrap leading edge weights in adhesive



11. Insert leading edge weights

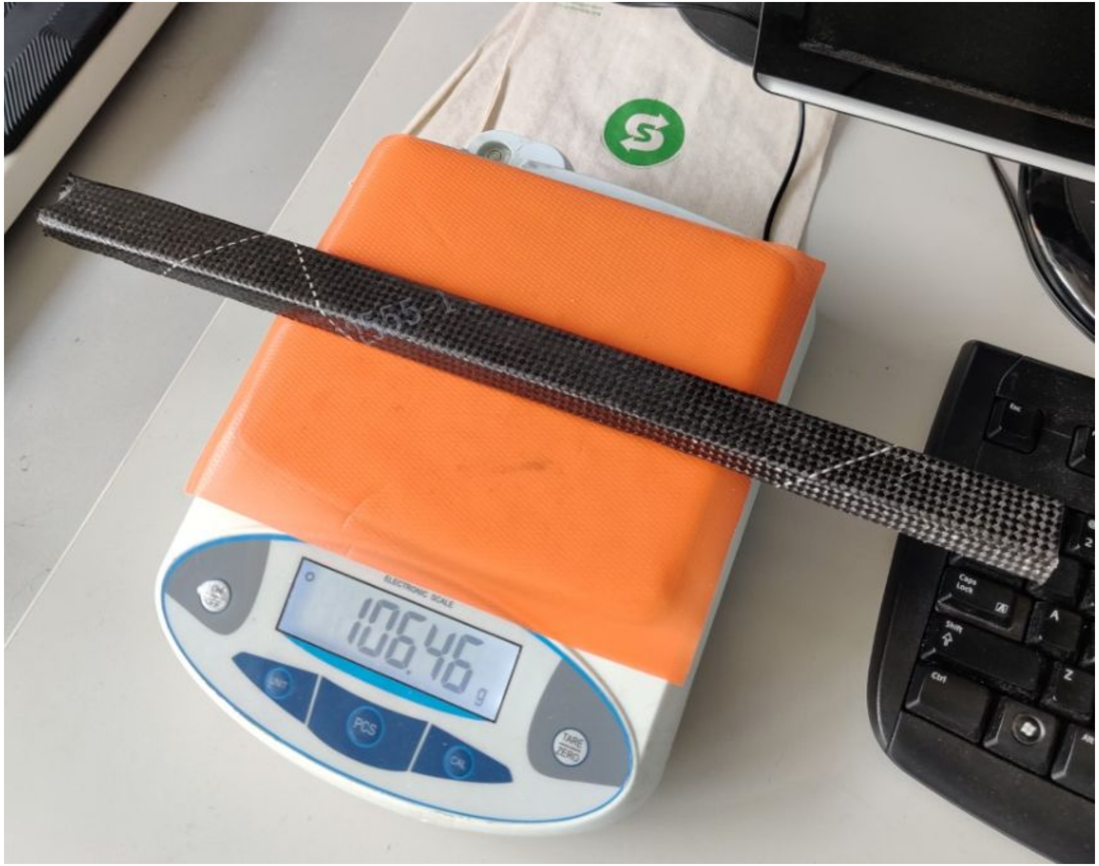
12. Wrap Spar in adhesive



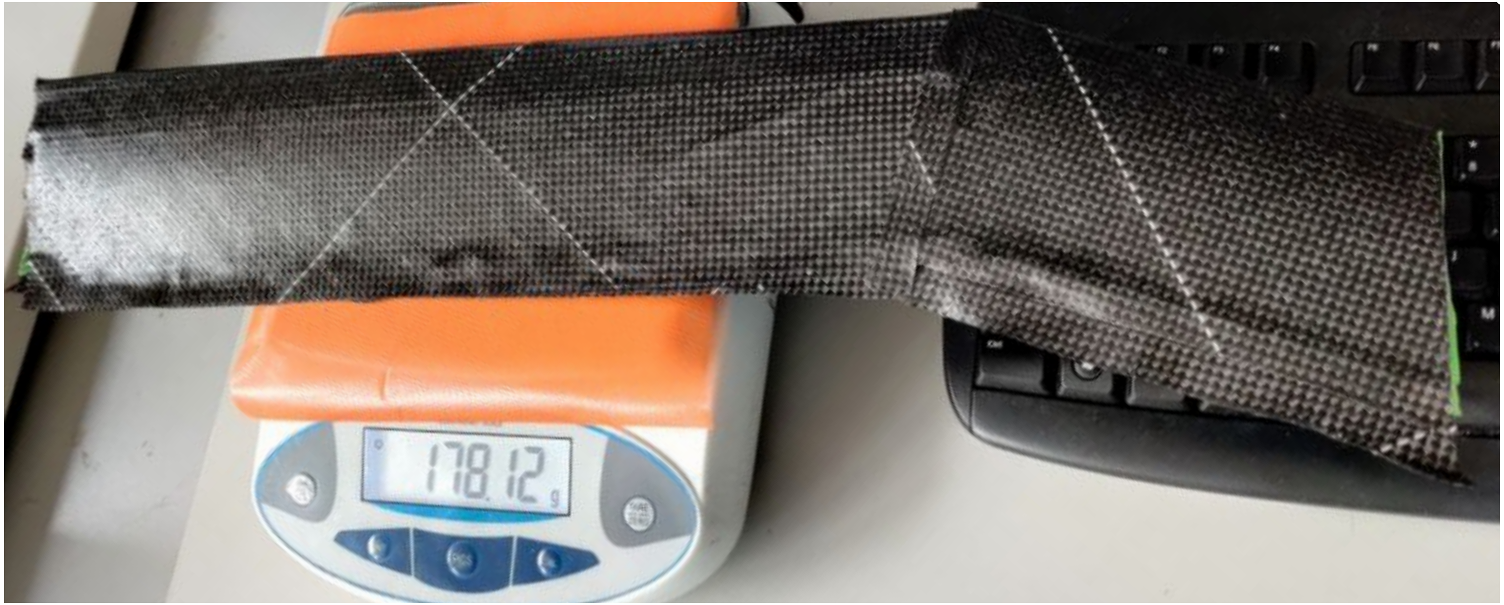
14. Wrap Trailing Edge in adhesive

15. Wrap spar in carbon fiber twice

IM7/8552 Carbon Fiber from Boeing

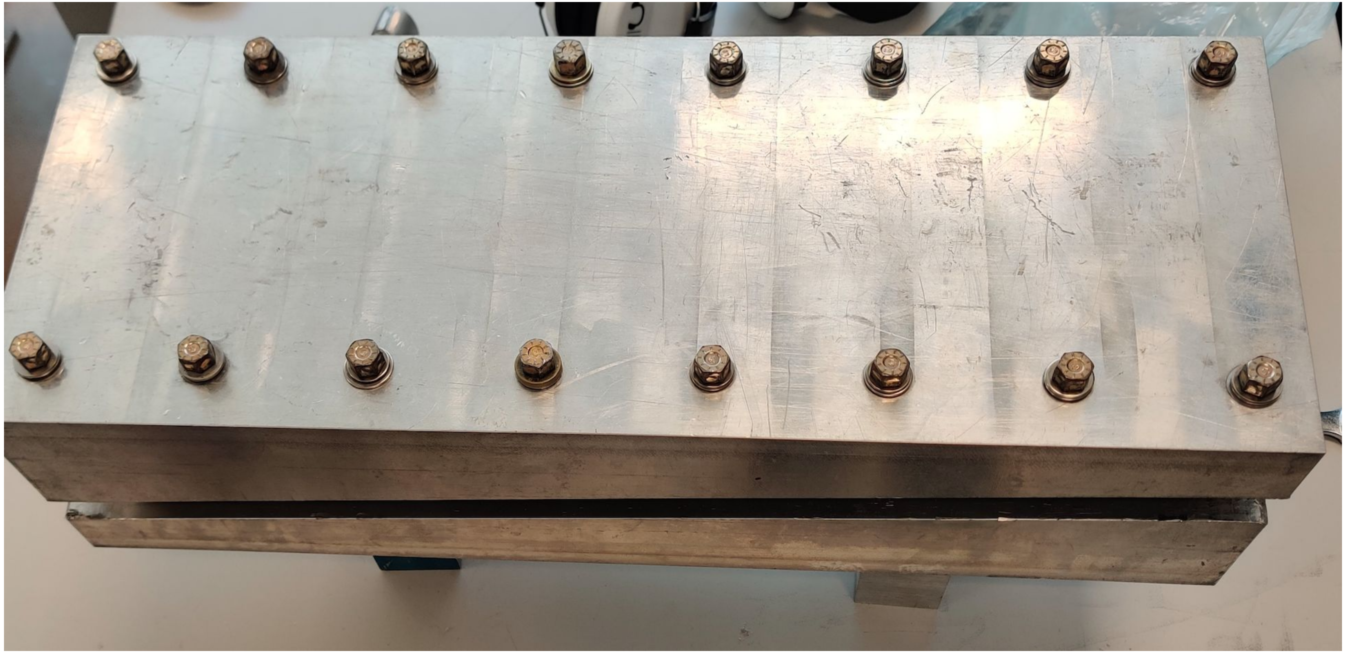


16. Wrap everything in carbon fiber once



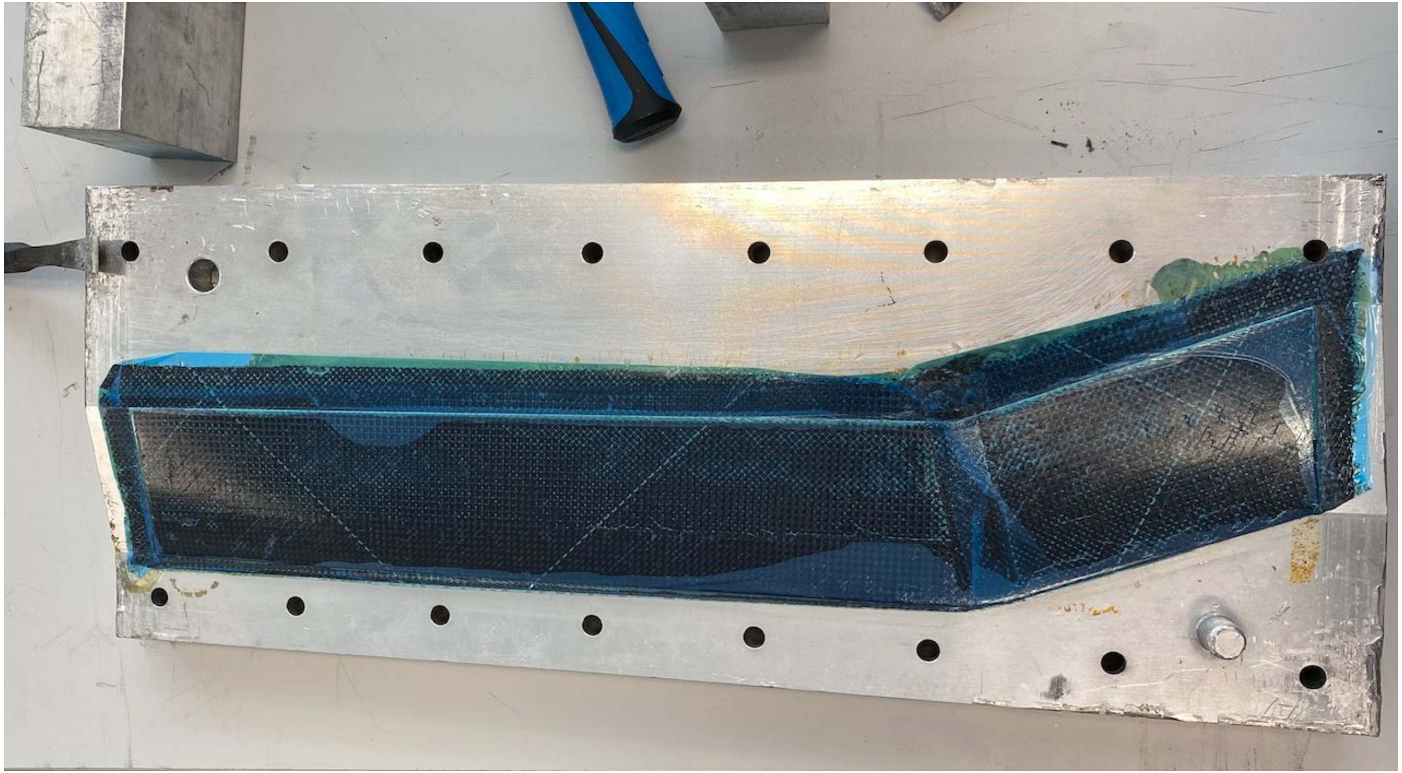
17. Put wrapped blade in mold

Cure in over for 90 minutes at 350℉

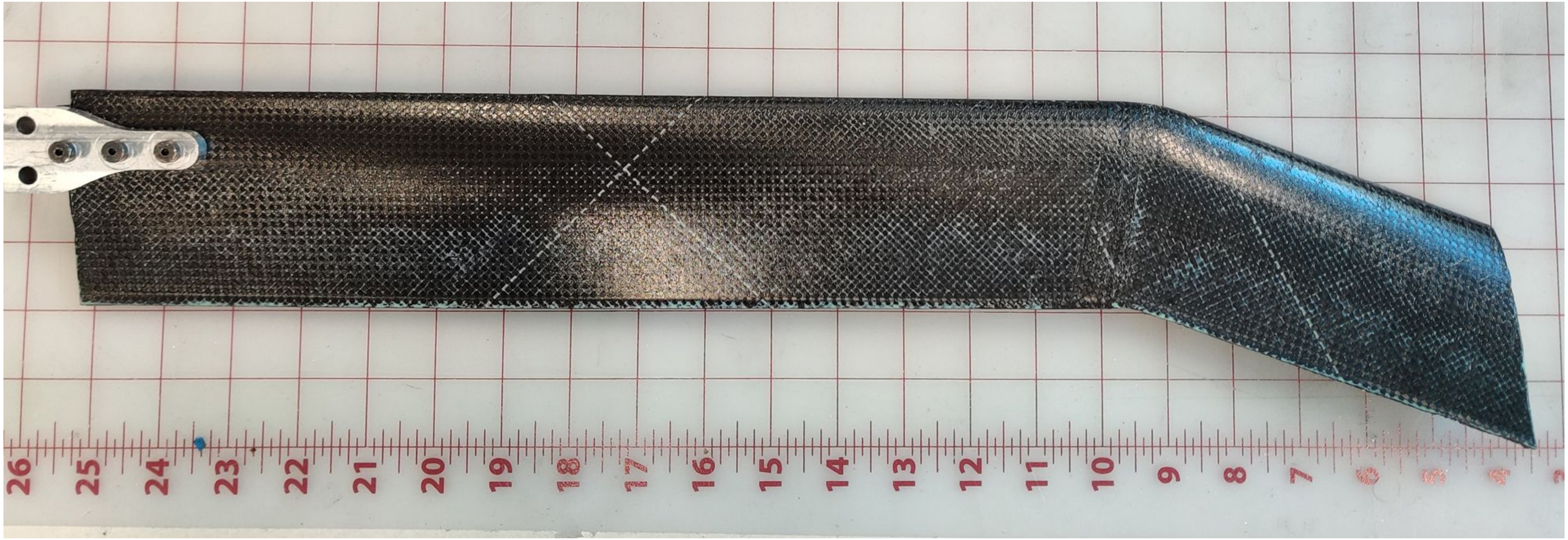


Peel-ply wraps around blade before it is put in mold

18. Take blade out of mold



Final Blade



Finished blade without grip adapter: 174.19g

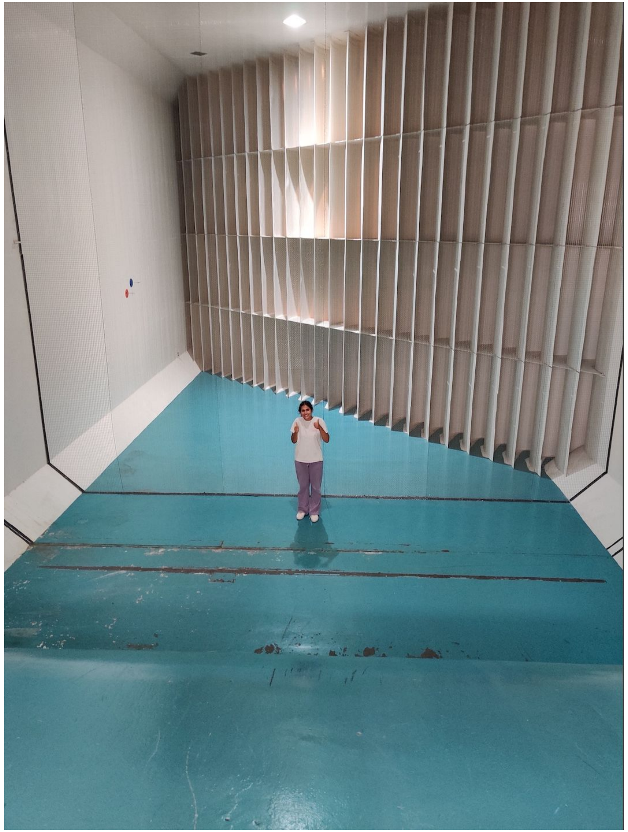
Intricate Integration of Blades on MTR

- Mechanical
- Electronic
- Computer System for data

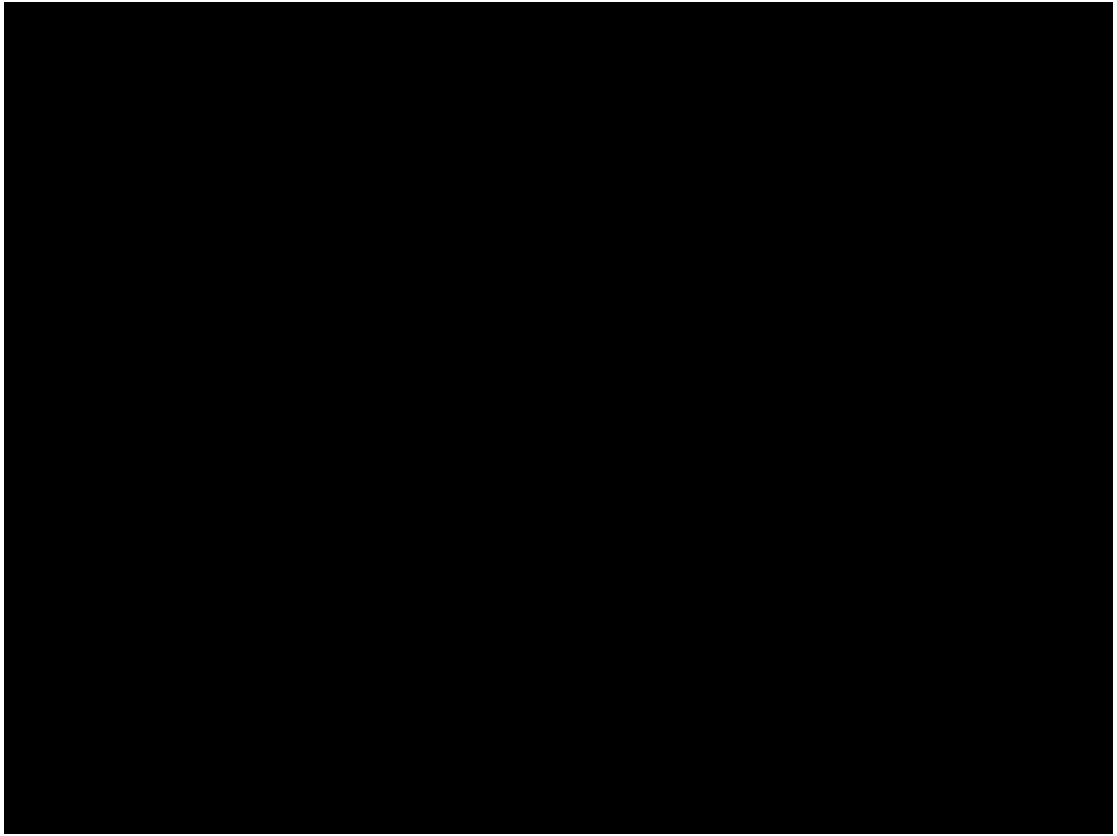
Wind Tunnel Testing

1 Week in UMD Wind tunnel

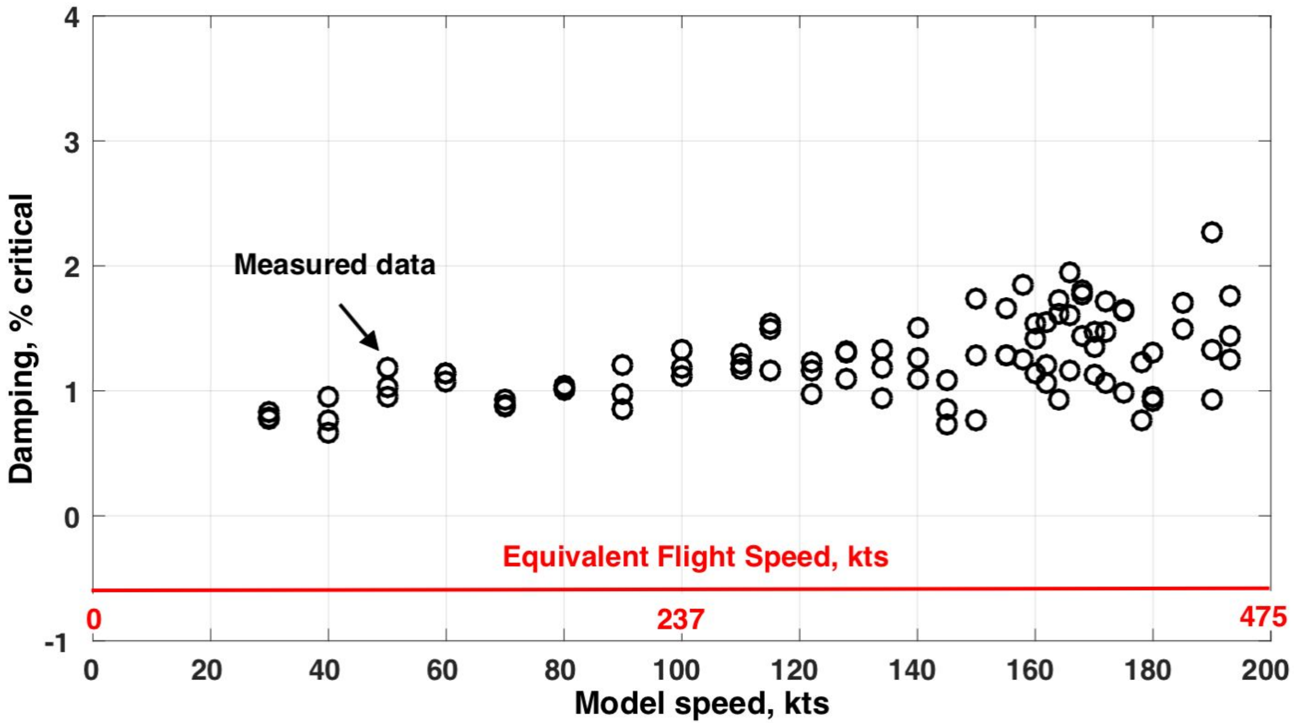
- 30 ft. High, 20 ft. Wide
- Settling Chamber



200 Knot Testing on August 5



Data/Results



Summary/Conclusions

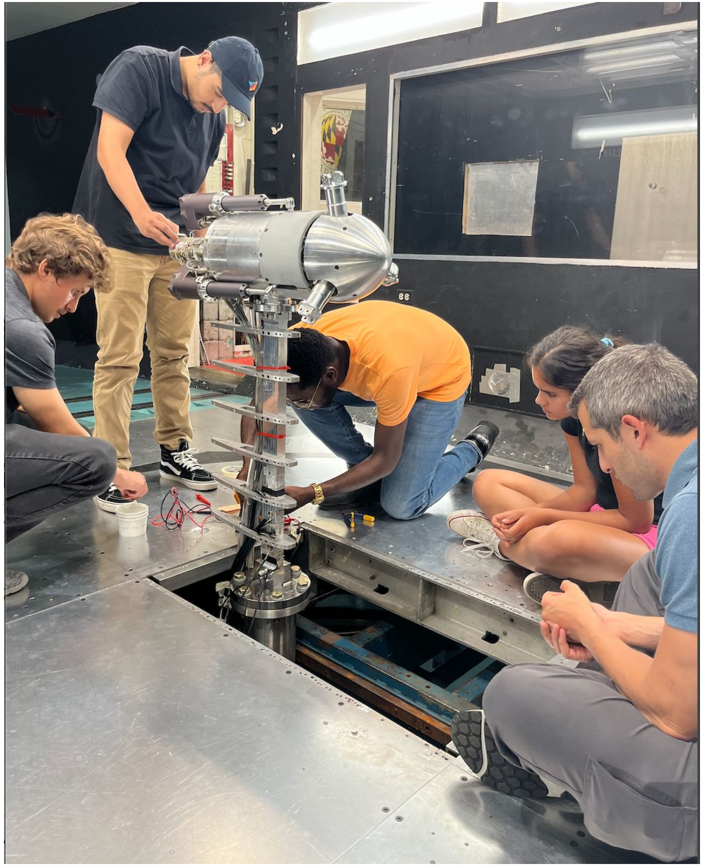
- Swept-tip blades tested at historic speeds up to 200 knots equivalent to 475 knots full-scale
- Blades proven to be stable
- Rich data set acquired on stability & loads at more than 200 tests conditions to guide future engineers

Conclusions

- Froude scale models can be used to predict a full scale aircraft
- Proper engineering equipment and exact aircraft materials are needed
- Must be precise with each step

Lessons Learned

- Engineering is teamwork
- Crucial to have a plan
- But do not expect to go 100% as planned
- Be prepared for contingency
- Perseverance is important in engineering
- If you do not fail, sometimes, you are not trying hard enough



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