

Wind Tunnel Testing Process

IREC Aerosciences

Previous Revisions:

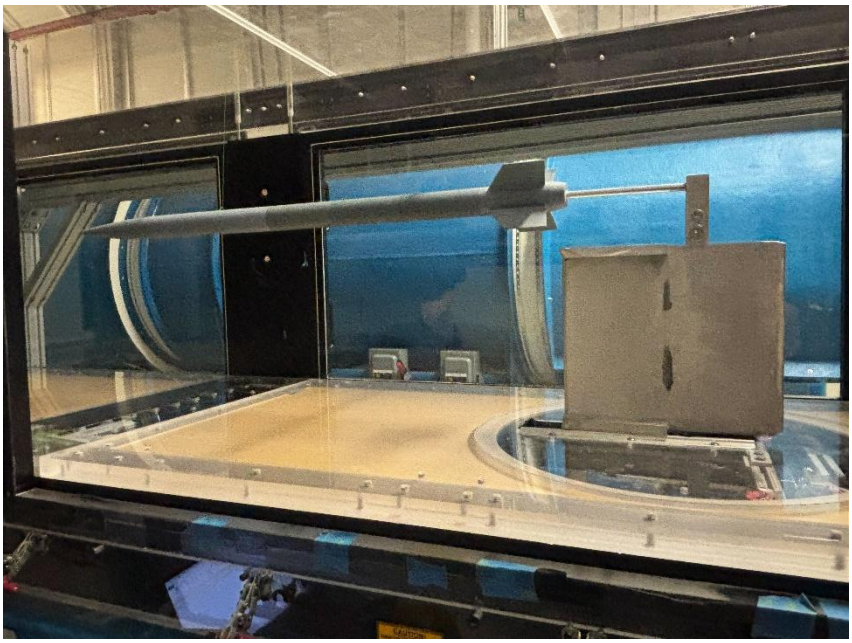
No previous official documentation on this process.

University of Florida
Swamp Launch Rocket Team
Revision 1
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Expected Results

Purpose: This document walks you through how the current wind tunnel setup was designed, built, evaluated, and analyzed. This includes: Data processing scripts, design criteria, scaling laws, lessons learned, testing procedure, pictures, and details about the design.

What fidelity to expect: We used this process on the simplified rocket geometry we used for verification 2025-2026. The wind tunnel testing gave a $Cd = 1.794 \pm 8\%$ at a speed of 10.089 m/s and a $Re = 585{,}387$. I don't know if this is accurate or not because I have never run a sim that slow. Furthermore, the 8% error is based on $2 * \sigma$ only, not accounting for other sources of error (which definitely existed). Best possible ~5% could be up to ~30%.



Warnings

- The whole setup was unstable until we added the giant airfoil and used strings to support the nose. So the results are questionable.

Next Steps

- Fix wind tunnel setup
- Do Y+1 Ansys analysis of the simplified rocket geometry to see if the Cd value we got was reasonable.
- Do more testing with this geometry or with models that have protrusions.
- READ THE LESSONS LEARNED SECTION

How the Design was Determined/Analysis decisions

Scaling Laws

Match Re number and keep the same flow regime. We found that the max size following 1/10 rule of diameter sizing would give us a ¼ scale rocket. Using the max wind tunnel speed you can find the Re number of the wind tunnel rocket. If you then use that Re number for the full scale rocket you can solve for the equivalent speed.

Rocket/Model Manufacturing

Resin or 3D print? We chose resin printing to reduce the effect of layer lines on the flow. You want the surface roughness to scale with the rocket aka $k_{testing} = k_{full} \cdot scale$ Ex: $k_{testing} = \frac{3e-5}{4}$. Furthermore the rocket was printed in about 6 inch pieces, JB welded together with conical fittings, then sanded with 220->330 grit sand paper. This method worked very well.

Design Idea for Load Cells/Rig in general

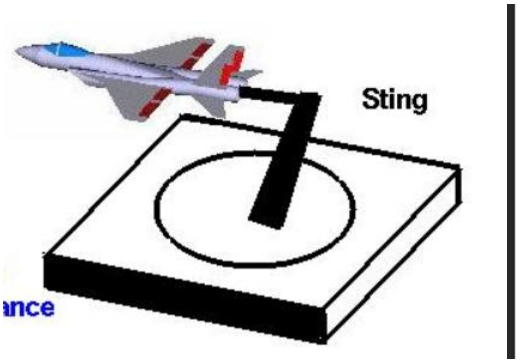
The general design concept for this came from a paper which claims a low cost solution for 4% average accuracy on a sphere Cd:

Paper: https://peer.asee.org/a-low-cost-adaptable-system-for-lift-and-drag-measurement-in-an-educational-wind-tunnel

Estimation of Errors Related to Rig

Ideally the rocket would be magically suspended like it is in flight. However, that is not possible so we need to minimize the effects of the Rig on the flow field. There are many ways to attach the rocket model to the load cells but the chosen method was using a sting which was estimated to have negligible error if kept to 30% of rocket diameter based on this paper:

https://digital.library.unt.edu/ark:/67531/metadc63751/m2/1/high_res_d/19930089881.pdf



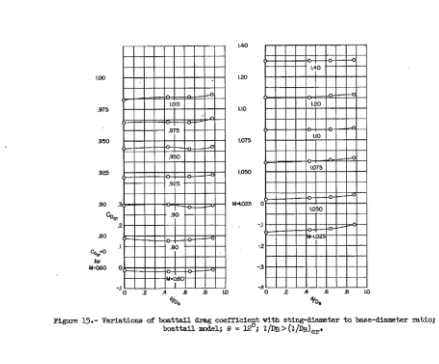


Figure 15.- Variations of boattail drag coefficient with sting-diameter to base-diameter ratio; boattail model; $\theta = 12^{\circ}$; $l/D_b > (l/D_b)_{cr}$.

Another issue is that the sting may sag causing an effective AOA so deflection calcs were done to make sure this would not be a problem. Deflection calcs were done assuming

Deciding Sting Diameter and Length

$$E = 68.9\ GPa \text{ (from lowes cart and matweb)}$$

$$I = \frac{1}{4}\pi r^4\ D = 3/8"\ from\ lowes = \frac{1}{4}\pi(0.0047625)^4 = 4.0405E-10m^4$$

$$W_{bar} = 1.03N \text{ (just add to F as worst case)}$$

$$\delta = \frac{FL^3}{3EI} = \frac{(12.45N)(0.5461m)^3}{3 * 68.9E9 * 4.0405E-10m^4} = 0.02427m$$

$$\Delta AOA = \tan^{-1}\left(\frac{\delta}{L}\right) = \tan^{-1}\left(\frac{0.02427m}{(0.5461m)}\right) = \mathbf{2.54\ deg = \Delta AOA}$$



Should be less in actuality due to I increase of rocket

Final Decision: $\boldsymbol{L = 6in\ D = 3/8"}$

Note: Actually calculated using excel sheet below:

Deflection Calculation.xlsx

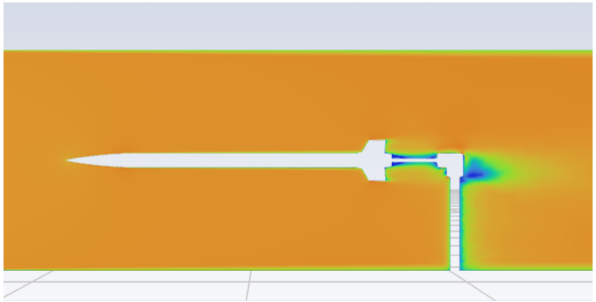
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CFD Analysis of Setup

The domain caused an increase in drag that was due to increased velocity in the free stream which would be negated if the velocity is measured in the center because it will adjust free stream velocity so this error is negligible. Thus rig error is around 6%.

Domain causes increase in drag sting decreased drag so **error is somewhere <6% possibly less than 1%**

	wind tunnel domain with no sting	wind tunnel domain with sting	infinite domain with no sting	
On rocket:	1.7676527 N	1.674 N	1.66365 N	
On Sting:		4.98 N	1.6779 N	(3 million cell mesh that got corrupted but good as a mesh ind case
	6.2516049 % error	0.62225 % error		

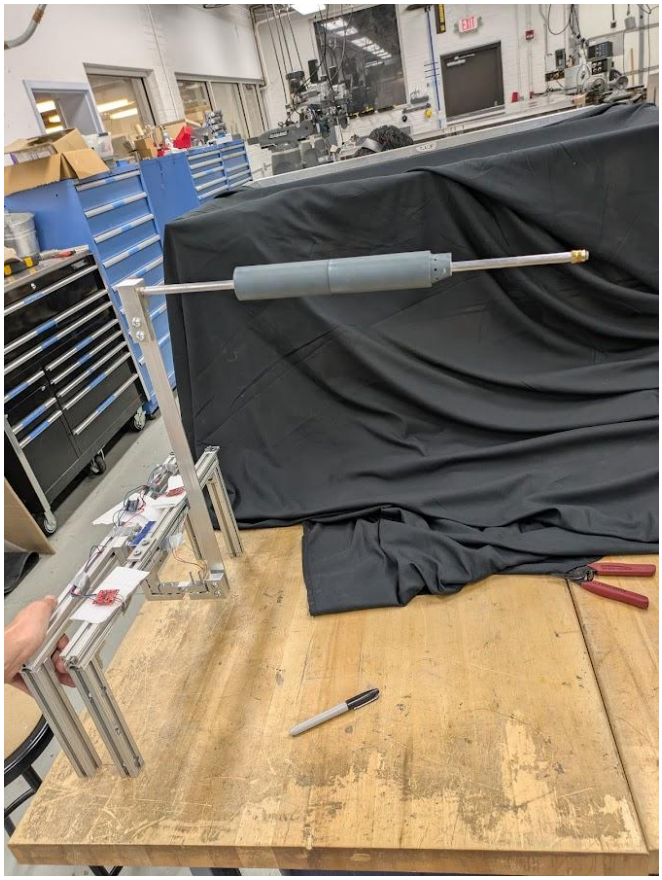


Results and Process.xlsx

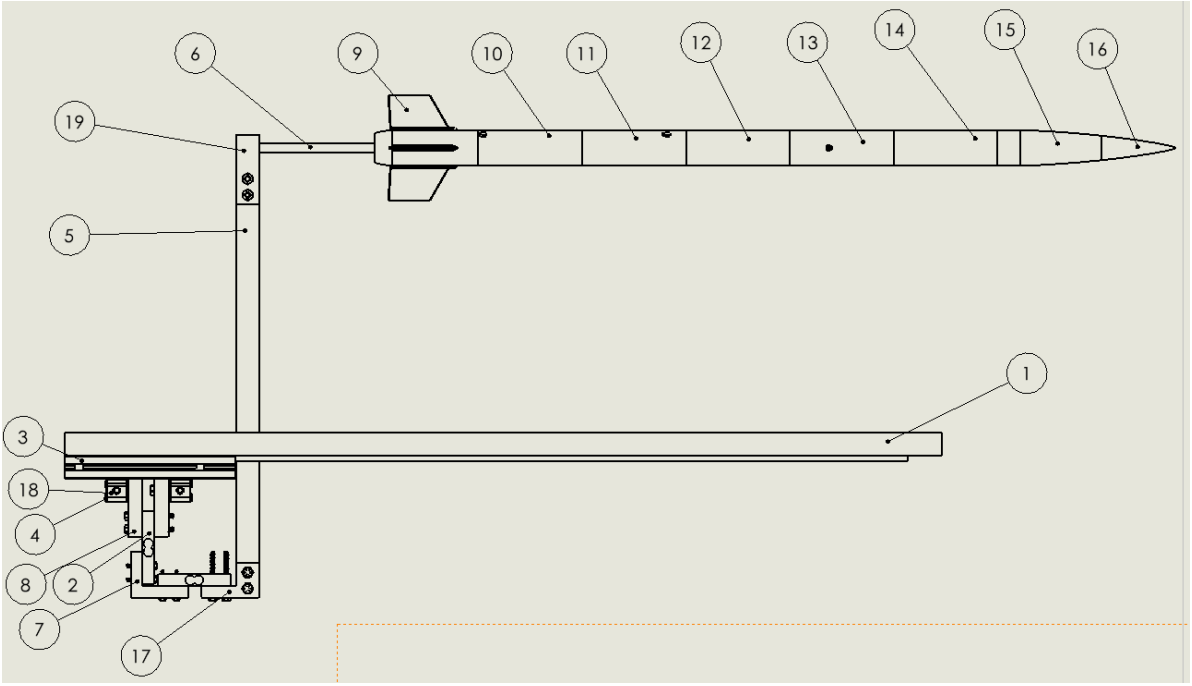
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Manufacturing Rig

Now that the general idea was established 80-20 was used to mount the load cells to the bottom of the wind tunnel and 6061-T6 aluminum pieces were used to connect the sting and the rest of the pieces together.



Note: The rocket threads into the sting using a threaded insert. The 80-20 pieces are also in a different config right now. This is the right config.



Lessons Learned and Future Changes

Wind tunnel debrief 5/5/26:

Biggest issue is a lot of oscilations in beam which caused rocket to move side to side (because of bar) as well as front to back caused by general looseness in system

1.5 degree AOA measured with level for rocket post-test pre test it was around 0

Looseness in 20" parallel 80-20 beams

Was able to limit deflection by accounting for it, adding airfoil to brace (reactionary force), adding strings

System must be calibrated at stiffness so can not just add airfoil otherwise no strain to measure

Use hex head instead of phillips head or flat head so you can properly torque things down

Was able to get up to 25m/s with minimial oscillations

Rocket sanded by 220 dry->330 wet

you should calibrate right before the test and verify during test

See teams for what is recorded (velocity, temperature) ->30.04inHg

Callibrated with 2 100g weights from mom lab weighed with mom lab scale

JB weld works great to fill and sand rocket

The shear clacs were correct (at least it did not fail)

Screws were generally way too loose which added in vibrations to the system

The deflection calcs for the sting itself and the entire system underneath were wrong possibly due to assumption errors.

Future changes:

In future designs calculate vibrations/stability and avoid large cantilevered masses

Change thickness of bar or shape of bar (could add airfoil) so it doesnt wiggle as much

Change bar to steel to limit deflection

adding dampening into the system itself like some sort of rubber

HAVE TO MAKE SURE NO MATTER WHAT WE DO THAT STRAIN STILL EXIST AT STRAIN GAUGES AND STILL CALIBRATABLE OUTSIDE OF WIND TUNNEL