A Modular, 3D-Printed Low-Speed Wind Tunnel as a Versatile Platform for STEM Education and Outreach

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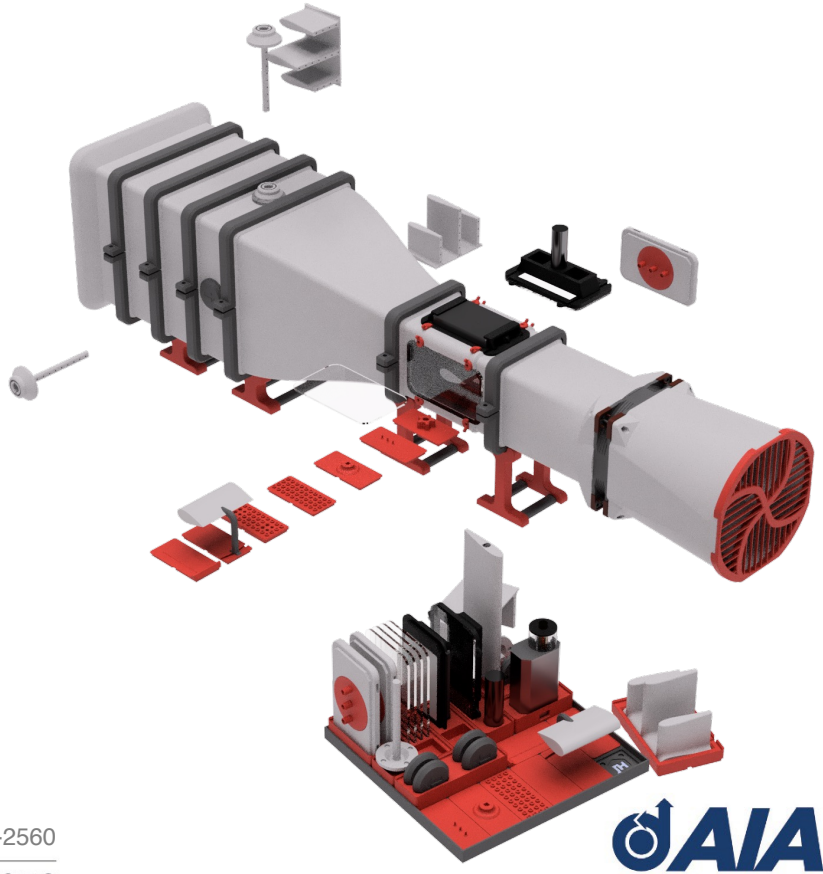
Overview

- Background, from two perspectives
- Project overview
  - Goals
  - Configuration and Options
  - Diagnostics
  - Test Articles and Lab Packs
  - Future Work
- Use cases and opportunities



(A Noble, Though Revisionist,) Background

- "DIY" / hobbyist wind tunnel plans abound, but cost, complexity, documentation, and build quality vary wildly
- Modern advancements in mid-size **3D-printing technology** and affordable accessibility motivate a carefully-designed "print-and-play" alternative
- Potential applications are myriad
  - STEM play and guided instruction/demo
  - Homes, Makerspaces, Schools/Univ., Museums
  - Commercial use – recruitment, trade shows

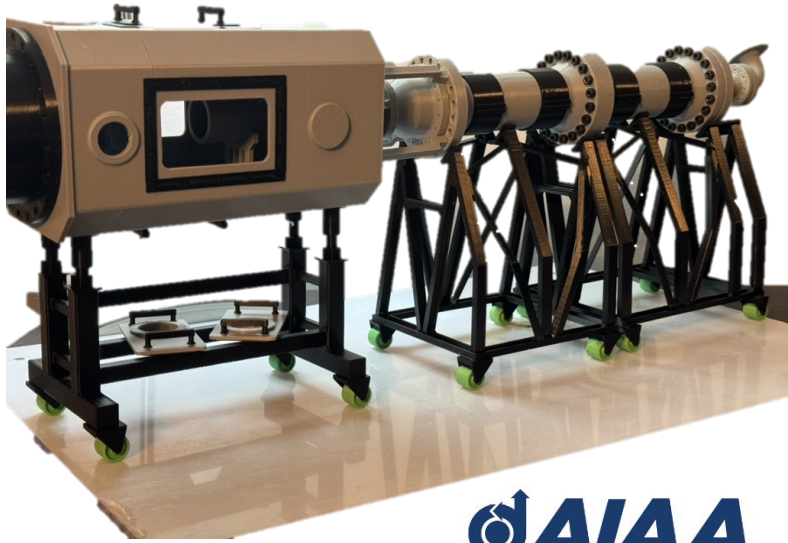
(The actual, chronological,) Background

- A project born *accidentally* that then snowballed dramatically
- 3D-printing hobbyist lifecycle…

  …out of *"functional parts"* to build, and, bored of trinkets…
- Printed a 10% scale model of Texas A&M Mach 6 Quiet Tunnel from grad school, to display and show my daughter
- Her reply:

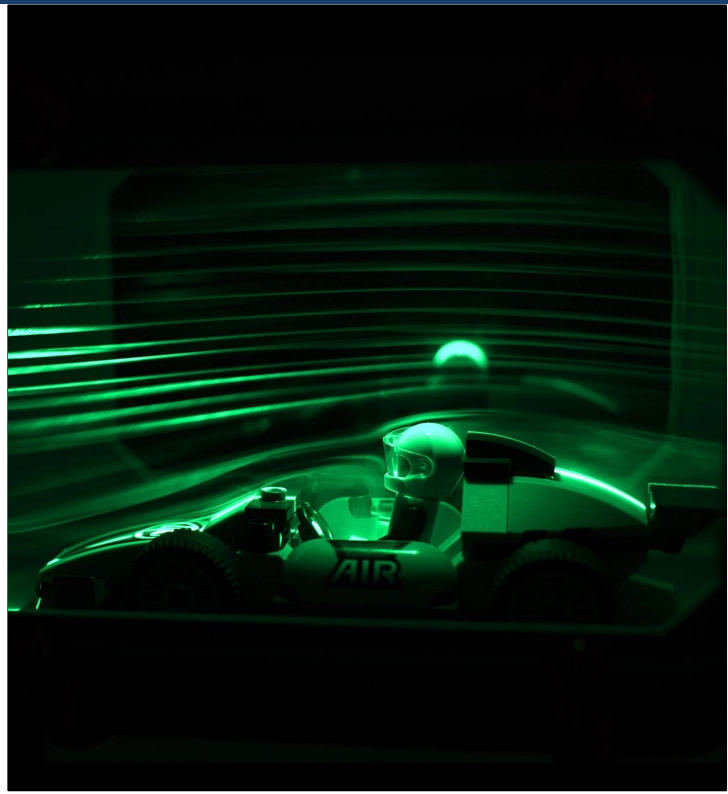
  "That's cool, Dad,…
  …but can we build
  one that works?"

  – Eleanor, 7

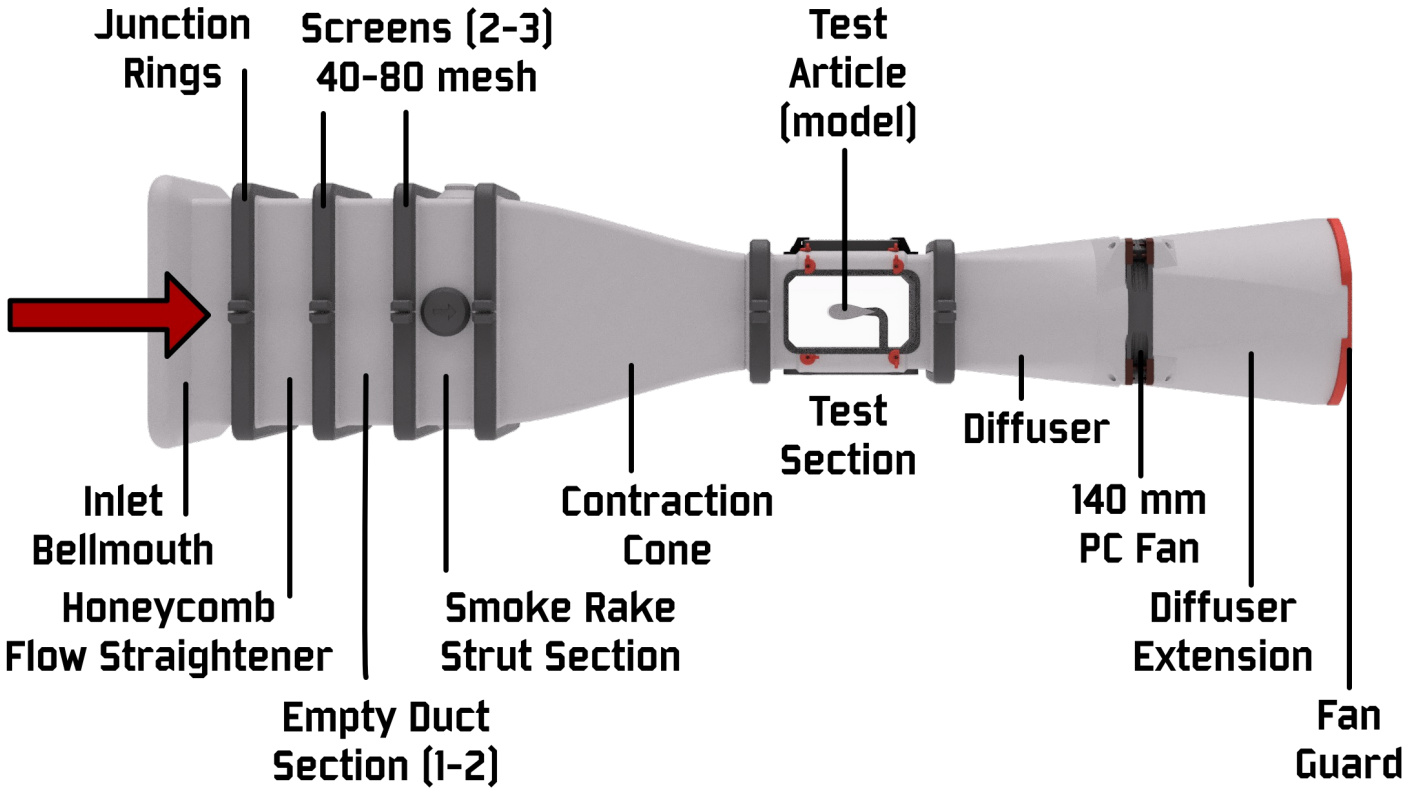


Project Goals

- **Easily, affordably producible** using a wide variety of available hobby-grade 3D-printers
- **Modular architecture** enabling incremental production, flexible reconfiguration, and component or subsystem upgrades
- **Optimized for flow-visualization** and other simple diagnostics
- **Support for varied test articles**, both educational and purely entertaining
- **Safe and easy to operate**, even by small children.



Baseline Components



Overall length:
1.1 m

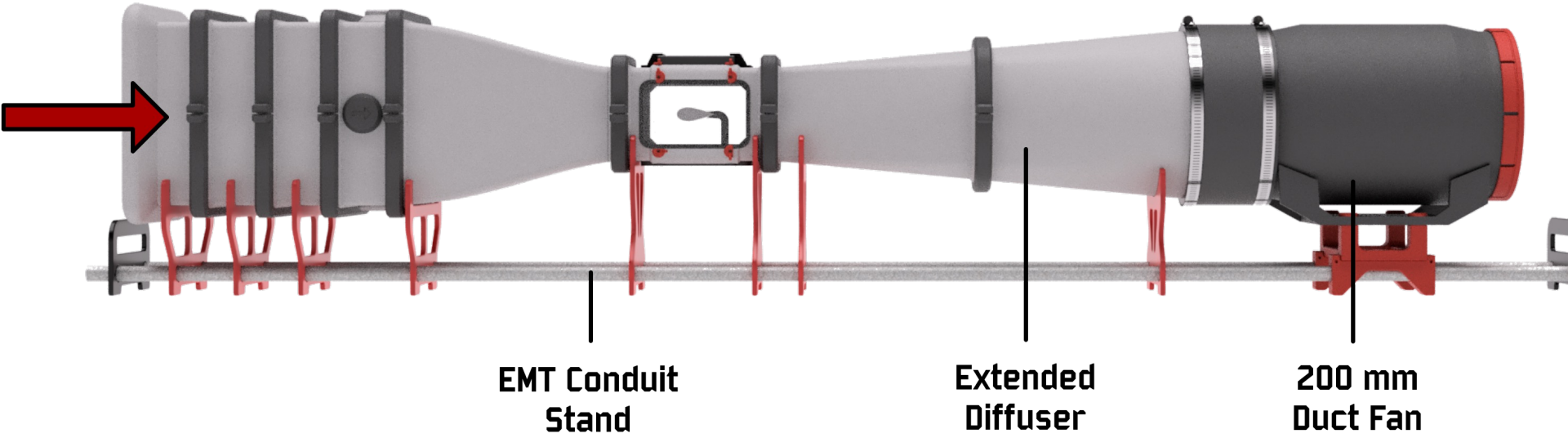
Test section:
102 × 102 mm

Max velocity:
4.0 m/s

Upgrade Options

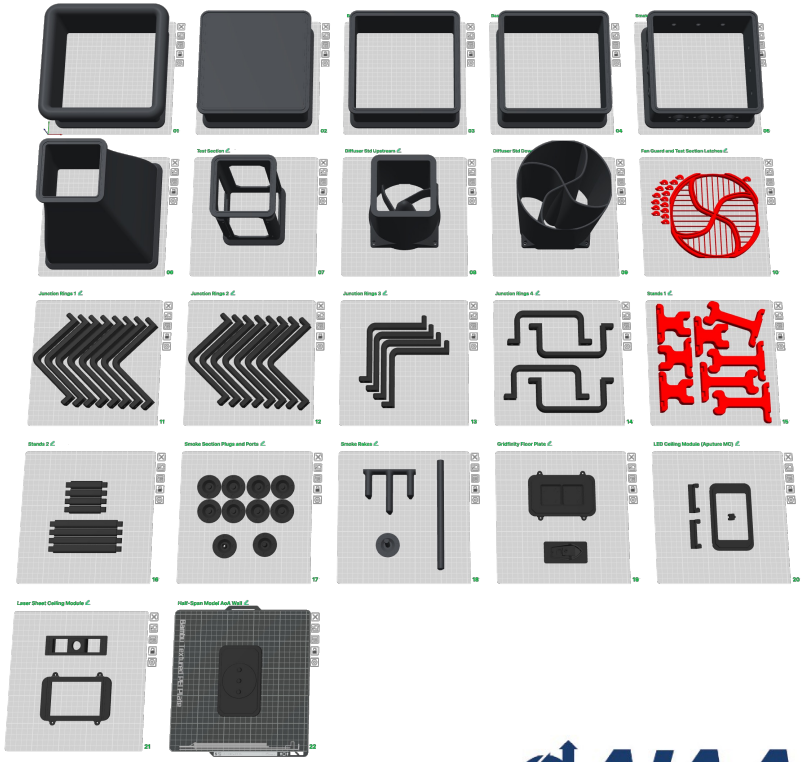
Max velocity:
15 m/s

Overall length:
1.6 m

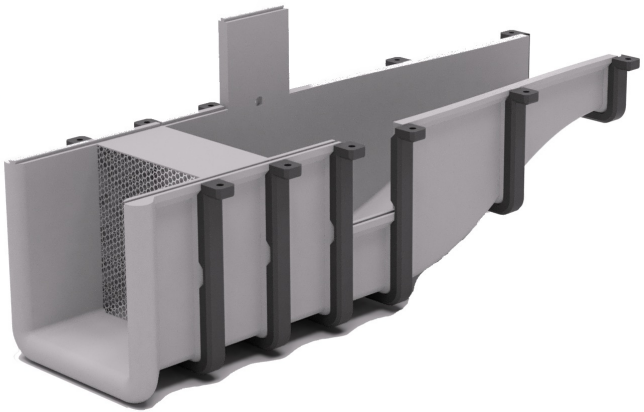


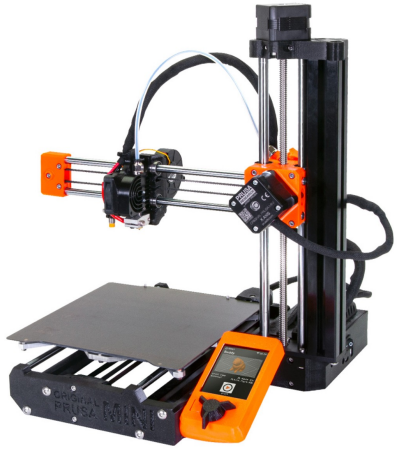
Fabrication Details

- Standard configurations print on FDM printers with **256×256 mm** bed size.
- Baseline materials (≈ $250 total)
  - 5 to 6 kg of filament (PETG / PLA)
  - 140 mm PC fan and driver
  - Fasteners, threaded inserts, magnets
- Recommended equipment (≈ $200)
  - LED panel and/or laser line generator
  - Handheld smoke generator



Small-Printer Compatibility

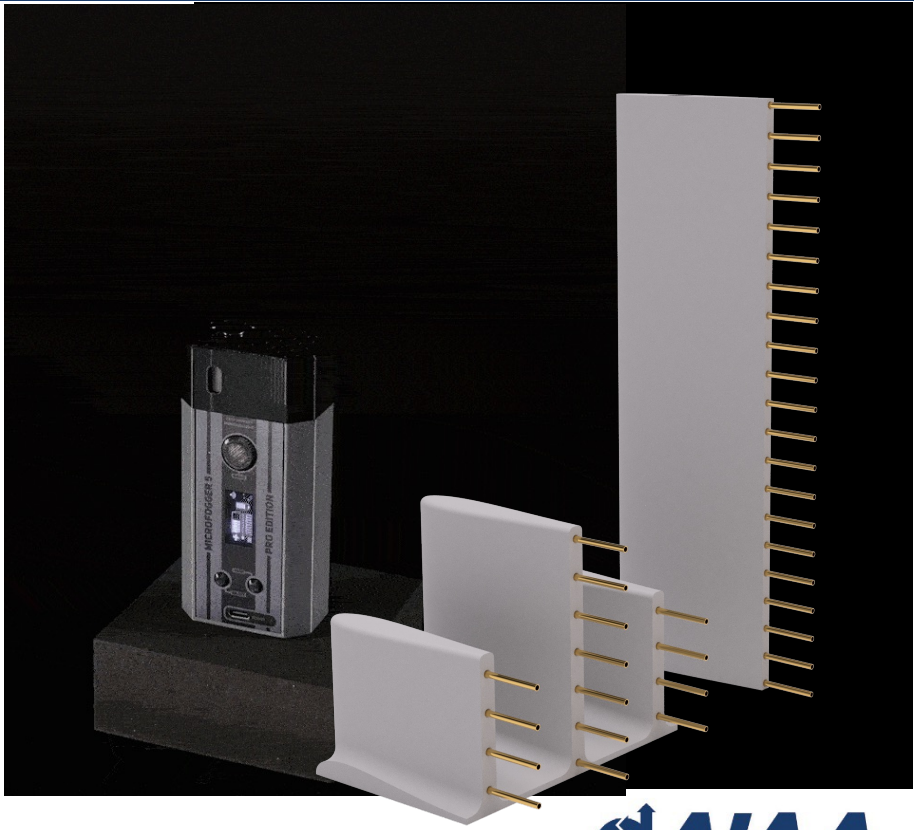




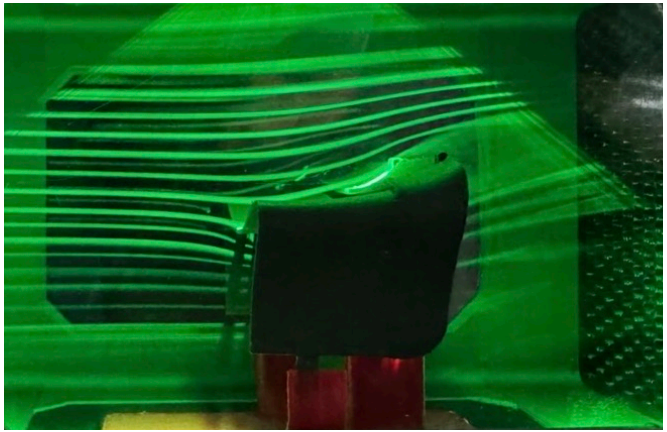
- Alternate split design for upstream sections: inlet, honeycomb, contraction cone.
- Reduces max bed-size requirement to **180 × 180 mm.**
- Full tunnel build is accessible to even entry-level home 3D printers.

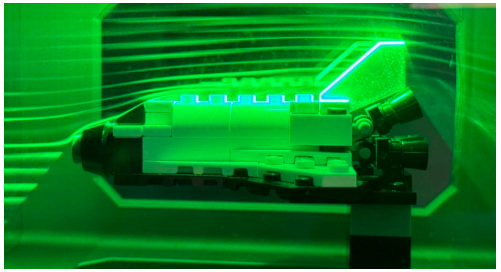
Primary Diagnostic: Smoke Flow Visualization

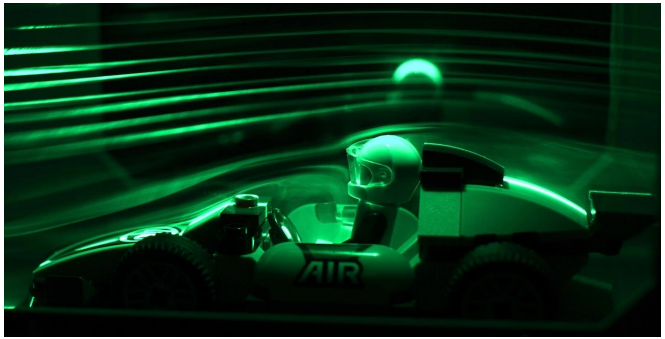
- Handheld miniature smoke machine for photography / videography
  - Small reservoir with a vegetable glycerin / propylene glycol mix
  - Battery power, DC heater coil
  - Small vibratory pump / fan
- Various 3D-printed rake probes with brass-tube inserts
- LED panel or construction-grade laser-sheet illumination

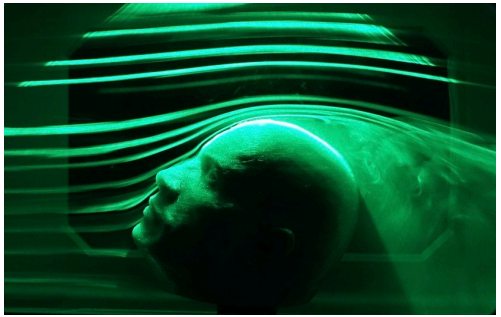


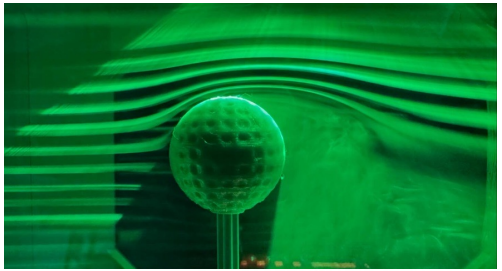
Smoke Flow Visualization and Example Models





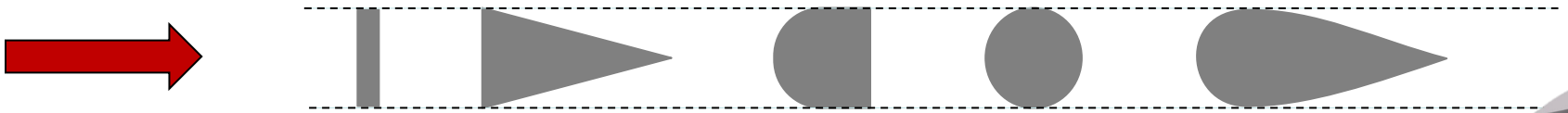




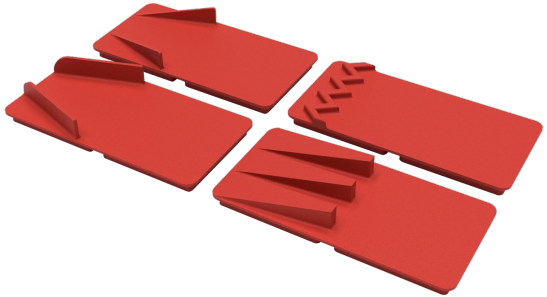


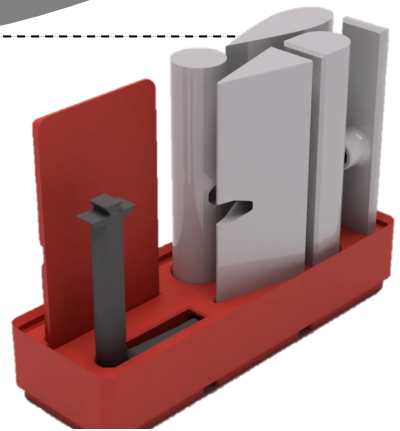
Example Lab Kits

- Effect of shape on aerodynamic drag – wakes and streamlining



- Vortex generators

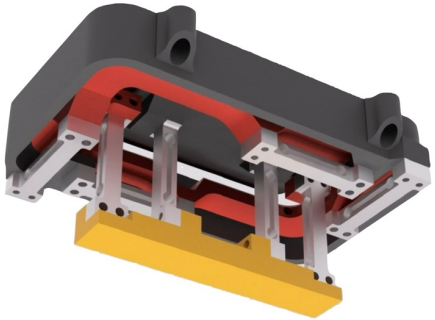




- Velocity measurement
- Principles of lift
- Parts of the wing
- Formula 1 aerodynamics

Roadmap / Future Additions

- **Control and display console** – Arduino / touchscreen control of motor speed, smoke, and lighting
- **Instrumentation and velocity control** – Pitot-static probe and pressure sensor, velocity measurement and closed-loop control of velocity
- **Force and moment balances** for high-velocity tunnel configuration
  - 2 DoF – Lift and drag only
  - 6 DoF?



Select Use Cases

- Routine **STEM play** – compatibility w/ LEGO, 1:43-scale cars, paper airplanes etc.
- Successful **interactive demonstrations**
  - Girl Scout badges for “STEM Career Exploration” and “Think Like an Engineer”
  - Exhibited at Tennessee Maker Fest – fantastic response from all ages
- Known university applications:
  - As platform for “Engineering Experimentation” **coursework**, in development
  - As outreach to local **high school science labs**, with accompanying CFD and curriculum
  - As platform for an undergraduate summer **internship project**: *build, characterize, improve*
  - As a recruitment aid, i.e. at **trade-show** and **recruitment fair booths**
- Prospective applications:
  - Adaptation as design/test aid for programs like Pinewood Derby and “F1 in Schools”
  - **Science fair projects**
  - Interactive **museum exhibits** and **makerspaces**

Axiometrix / IMC Test & Measurement

Concluding Thoughts

- New modular low-speed wind tunnel design is **affordable and approachable** for home & small-institution.

- Varied use cases demonstrated in first 6 months of availability; highly promising for **STEM play and education** and as an **aero outreach platform**.

- **Broad potential** is *currently limited by my personal bandwidth.*

  Open to partnerships and collaboration regarding:

  - Unique applications
  - Accompanying curriculum / pedagogy
  - Social promotion
  - *Possible transition to community-driven model*, open-source contributions

Acknowledgments

- My family
  - Eleanor (8) – Inspiration, design input, quality assurance, co-presenter and facilitator at TN Maker Fest.
  - Evelyn (4) and wife Jacqueline

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Thank You! Q&A and Project Link

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