USD(R&E)

2025 Undergraduate Hypersonic Flight Design Competition

Webinar and Q&A

Joint Hypersonics Transition Office
University Consortium for Applied Hypersonics 18 April 2025

Controlled by: Dr. Lori M. Stiglitz lori.m.stiglitz.civ@us.navy.mil

Agenda

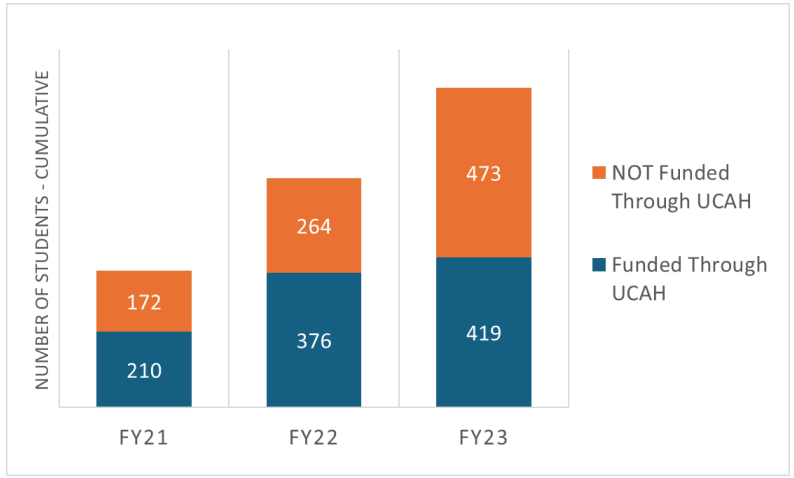
- Welcome & Introductions
- The Importance of the 2025 Undergraduate Hypersonic Flight Design Competition
- Panel Discussion
  - Army Research Laboratory
  - CUBRC
  - Boeing
  - University Consortium for Applied Hypersonics
- Questions & Answers

Introductions

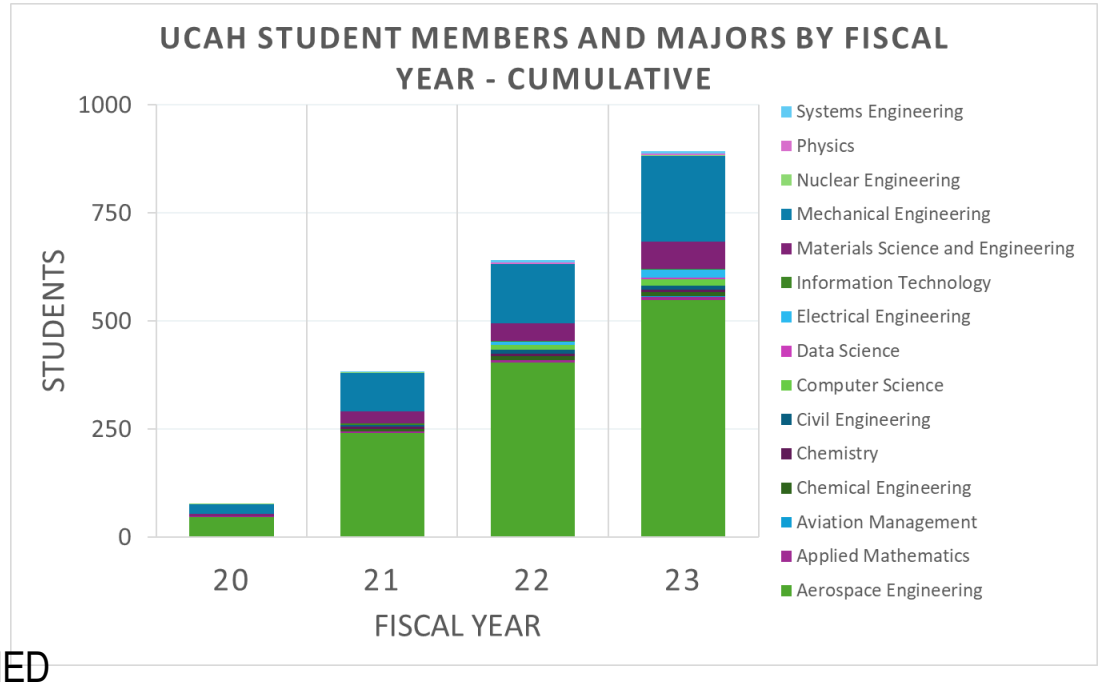
- Mr. Mark Glenn, JHTO Director
- Dr. Lori Stiglitz, JHTO WFD Lead
- Dr. Rodney Bowersox, UCAH Consortium Manager
- Dr. Joseph D. Vasile, U.S. Army Research Laboratory
- Mr. Tim Wadhams, CUBRC
- Dr. Kevin Bowcutt, Boeing

UCAH Student Participation

- 419 Students funded
- 473 Students not funded
  - Highly-educated, screened individuals available for internships/capstone projects
  - Funding limitation



- Top 3 Student Majors
  - Aerospace Engineering: 549
  - Mechanical Engineering: 198
  - Materials Science and Engineering: 64



2025 Design Project - BLUF

- The 2025 UCAH Design Competition is focused on an unpowered, high lift-to-drag, hypersonic projectile for low altitude operation.
- The winning concept will be eligible for ground-based gun-launched flight experiments with the Army Research Laboratory and/or wind tunnel tests within the 48-inch LENS Tunnel at CUBRC.
- The competition is open to all UCAH membership universities.
  - Formal classroom design teams (e.g., senior capstone) and university club organization are encouraged to participate. Multi-university teams are allowed.
  - Although not required for participation in the competition, the UCAH website provides contact information for potential industry and national laboratory members of UCAH to serve as advisors.
  - Faculty, student, and industry advisors must also be approved participants within UCAH.

Competition Rules

- All UCAH member universities and participants are eligible and encouraged to participate.
  - If you are not a member or participant in UCAH and wish to join, see https://hypersonics.tamu.edu/membership/.
- The key dates for participation are listed in Table 1.
- To be eligible for the competition, a notice of intent (NOI) is required with a list of faculty advisors.
  - Students are encouraged to submit a request to join UCAH near the beginning of the semester to be eligible to participate in the wind tunnel or flight test activities.
  - Reviews can take up to 60 days for processing.
  - External UCAH industry and national laboratory advisors must also be approved participants in UCAH and must be disclosed to TEES prior to their participation on the project.

Table 1 Key Dates

MILESTONE	DEADLINE
Project Announcement	28 March 2025
Q&A Webinar	18 April 2025
University Notice of Intent	31 July 2025
Student Request to Participate in UCAH	01 September 2025
Design Report Submission	10 Dec 2025
Selection of Semifinalists*	05 Jan 2026
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Gun Launch Flight Test (ARL)	Spring/Summer 2026
Team Presentations – 2026 UCAH Forum	July/August 2026

**Virtual Presentation to Review Panel*

Competition Rules

- University design teams, including 1 or 2 semester senior capstone design courses or university club organizations are encouraged to participate.
  - Universities may have additional requirements to meet curriculum requirements for graduation.
  - The submitted designs must be the work of the students, but guidance may be provided by a faculty advisor, which should be acknowledged.
  - The recommended maximum team size is 15.
- The top design teams will be acknowledged at UCAH Technology Exchange and Forum events. Universities may submit multiple designs.

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Mission Requirements – Unpowered Low-Altitude Projectile

- Maneuvering a projectile at hypersonic flight conditions (M = 5 – 8) at low altitude operation introduces many design challenges, such as high heat flux and large mechanical loads.
  - Through modern simulation and design tools, it may be possible to design highly maneuverable hypersonic systems for low altitude operation that can be economically manufactured using modern fabrication technologies, such as additive manufacturing.
- The goal of this project is to explore the design space, identify an optimal set of system specifications that optimize a free flying (unpowered) system for range and affordable manufacturability – and then design a concept that optimally achieves the specifications.
  - The project will entail geometry/configuration definition using a CAD system, discipline analysis such as aerodynamics, aerothermal, structural sizing, mass properties, stability & control, and conclude with vehicle sizing to meet mission requirements.
  - The projectile will be launched at speed from an independent source.
  - On board propulsion is not required.
  - It can be assumed that flight control can be achieved through aerodynamic surfaces, reaction control jets, or a combination thereof.

Mission Requirements – Unpowered Low-Altitude Projectile Continued

- The requirements for the design include:

  - Mach: 5 – 8
  - Aerodynamically Stable and Thermally Survivable
  - Optimized for Maximum Range and Affordable Manufacturing (Minimum Cost)
  - Max length: 1.0 m
  - Max Diameter: 0.1 m (including fins)
  - Max mass: 10 kg
  - Minimum Maneuverability: 15g turn
  - Minimum Volume Efficiency ($\eta = V^{2/3}/S_{planform}$) ≥ 0.12

  - To validate the design, students may use CFD analysis to assess aerodynamic forces and moments predicted using engineering methods and will verify mission performance using flight trajectory analysis and optimization with inputs derived from discipline analyses.
  - Teams may also perform wind tunnel tests at their university.

Deliverables

- The Design Report should be submitted in pdf format to UCAH_Design@TAMU.EDU
- No more than 25 (total) single-spaced typewritten pages (11 pt Times font, including graphs, drawings, photographs, and appendices) on 8.5” x 11” paper. Larger (11” x 17” max) CAD schematics are allowed/encouraged.
- The following is a list of information should be included in the final report.
  1. **Requirements Definition** – Summarize the mission and design requirements of the vehicle system
  2. **Concept of Operation** – Demonstrate vehicle design meets mission requirements
  3. **Trade Studies** – Describe how trades studies leading to final design (pro and cons)
  4. **Design and Fabrication** - Discuss the design, integration, and manufacturing concepts for all subsystems
  5. **Methods and Tools** – The report must clearly describe all tools and methods utilized for the system and subsystem design
  6. **Mission Summary** – A summary table of resource requirements should be included
  7. **Test and instrumentation plan** – Gun launch and wind tunnel experiments
  8. **CAD drawings of wind tunnel and gun launch test articles** (not included in the 25-page limit)
  9. **A concise, 2-page “Executive Summary”** (not included in the 2-page limit)
  10. **Bibliography** – All references should be cited at the end

Evaluation Criteria and Contact

- **EVALUATION CRITERIA**
  - The team reports will be evaluated on the quality of the following: (i) technical design including approach, analyses, and trade studies, (ii) concept of operation, (iii) manufacturability/cost analysis, (iv) test and instrumentation plans, and (v) final report.
- **CONTACT**
  - Questions should be submitted to UCAH_Design@TAMU.EDU

ARL HYPERVELOCITY EXPERIMENTAL RESEARCH PLATFORM

Experimental Laboratory Platforms:

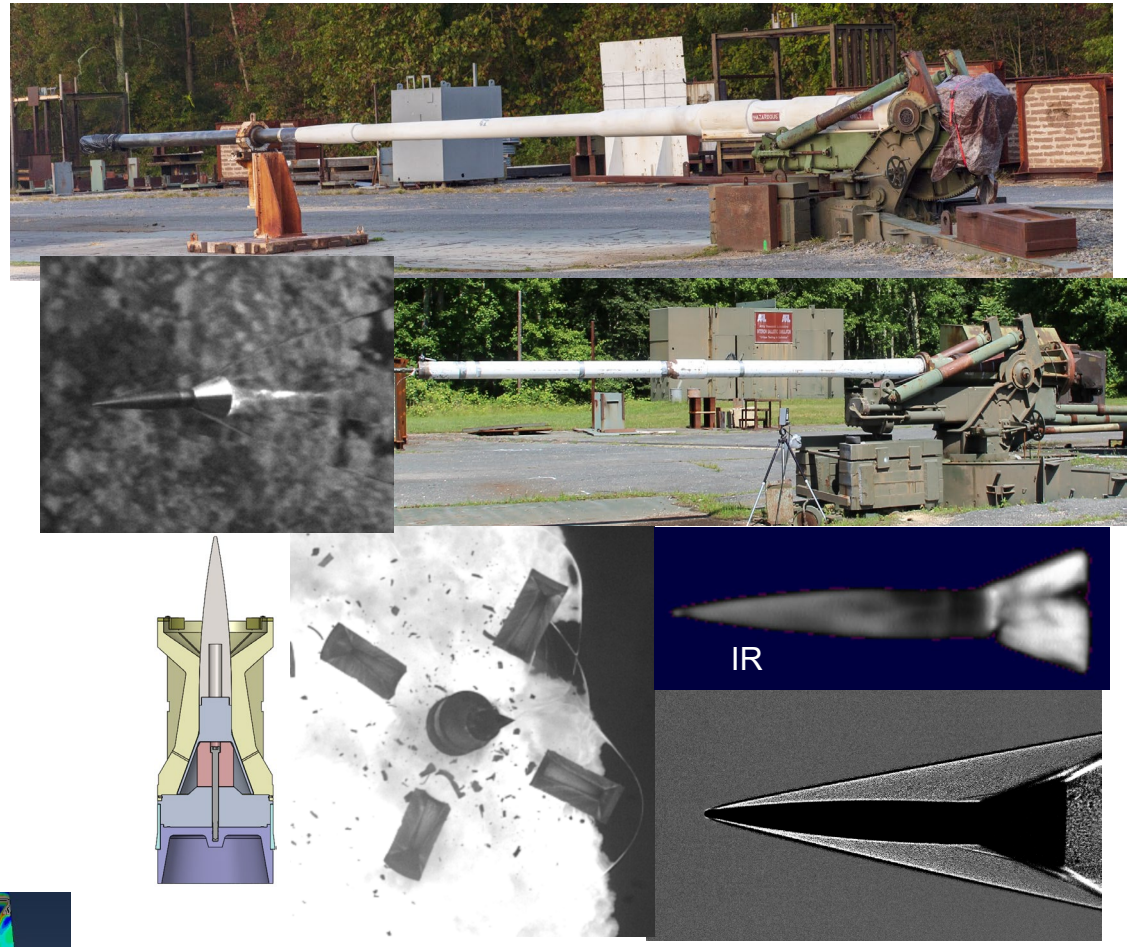
- Double travel powder guns capable of reaching muzzle velocities greater than Mach 5

Approach:

- Subscale ballistic launch and flight platforms for hypersonic experimentation
  - Ballistic modelling, launch package and projectile development, live-fire experimentation, novel instrumentation, thermal material proofing

Capability:

- Custom design and development for charge, launch package, munition, capture
- Ability in house to characterize and develop all aspects of experimental gunfire for hypersonic applications



Conduct quiescent flow, high-enthalpy, free-flight experiments to obtain flow fields and temperature distributions on high-speed vehicles at foundational lab-scale cost

Approved for public release; distribution is unlimited.

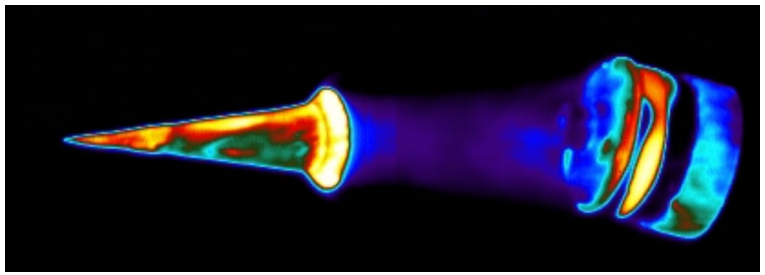
DIRECT VIEW AND IR FLIGHT FOLLOWER

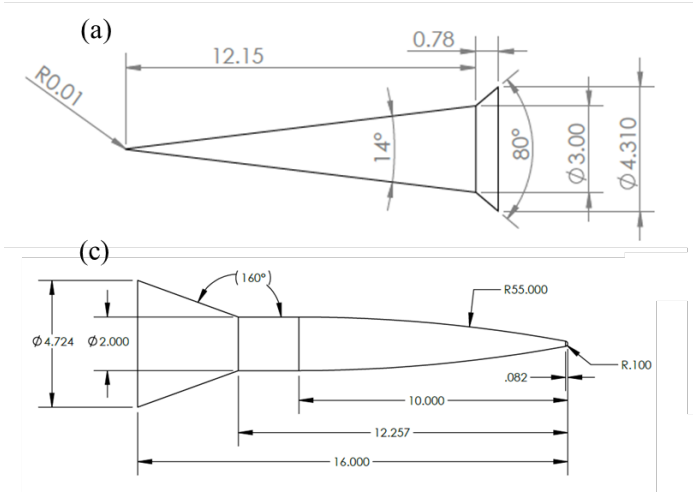
Aluminum Slug

CUBRC 7°/40°Cone Flare

HARV Ogive Flare

CUBRC Double Cone





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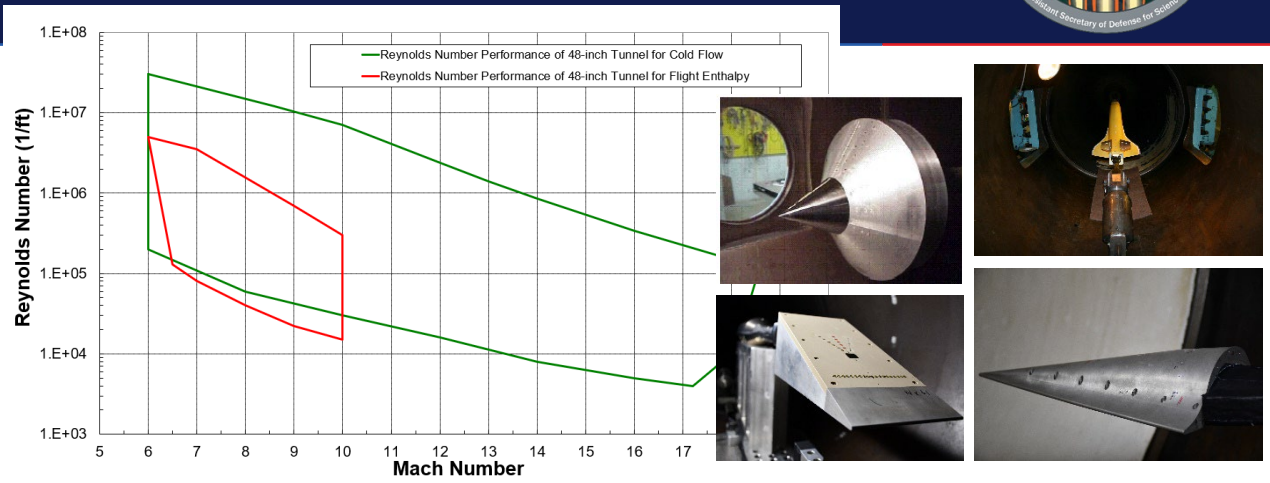
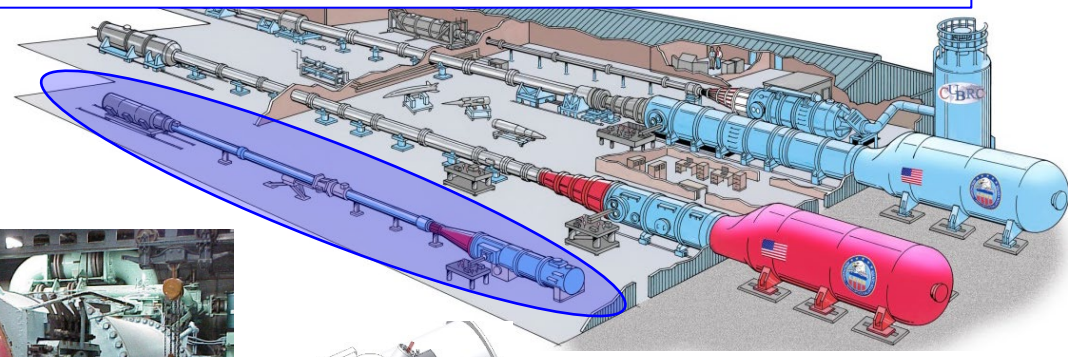
High-level Overview of the CUBRC 48-inch Tunnel

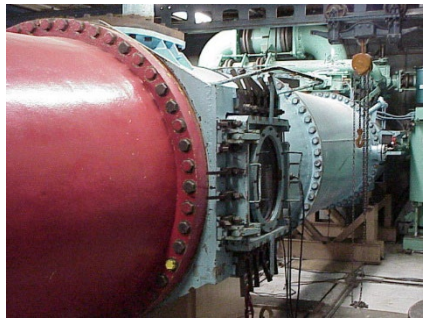
- Commissioned in the mid 1950s as the worlds first true wind tunnel to employ a shock tube to generate flight enthalpy test conditions with 20k+ tests completed to date
- 2024 saw the most tests completed in the facility in a calendar year - increased need obtain hypersonic R&D and S&T class ground test data
- Testing for UCAH, AFOSR, ONR, and Industry IR&D
- Dedicated and experienced team of CUBRC engineers, scientists, and technicians to work with you to design and execute testing.

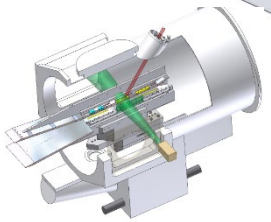


Mach Number and Reynolds Number Test Space

The CUBRC LENS Family of Hypersonic Wind Tunnels







Listing of 48-inch Tunnel Reference Test Conditions

Nominal 48-inch Tunnel Flight Freestream Conditions

Mach Number	Reynolds Number	Velocity	Pressure	Temperature	Density	Run Time	Flow Lengths
-	(1/ft)	(ft/sec)	(psia)	(deg R)	(slugs/ft^3)	(ms)	(ft)
6.5	1.40E+05	6521	4.40E-02	426	7.90E-06	8	52
6	3.40E+06	6562	1.17E+00	493	1.97E-04	8	52
7	7.80E+04	7000	1.80E-02	407	3.70E-06	10	70
7	2.60E+06	7000	6.60E-01	430	1.30E-04	10	70
8	3.10E+04	8000	6.00E-03	415	1.27E-06	10	80
8	3.80E+06	8000	3.00E-01	442	5.70E-05	10	80
9	1.50E-04	9000	3.00E-03	423	5.60E-07	8	72
9	6.20E+05	9000	1.10E-01	399	2.20E-05	8	72
10	1.10E+04	9000	1.20E-03	300	3.30E-07	5	45
10	4.70E+05	9000	5.90E-02	338	1.46E-05	5	45

Nominal "Cold Flow" 48-inch Tunnel Freestream Conditions

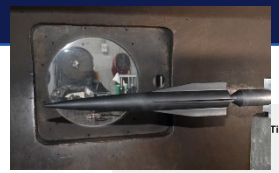
Mach Number	Reynolds Number	Velocity	Pressure	Temperature	Density	Run Time	Flow Lengths
-	(1/ft)	(ft/sec)	(psia)	(deg R)	(slugs/ft^3)	(ms)	(ft)
6	1.00E+06	3225	5.00E-02	100	4.08E-05	25	81
6	3.00E+07	3225	1.00E+00	100	8.16E-04	25	81
8	3.40E+05	3950	8.00E-03	100	6.80E-06	25	99
8	1.20E+07	3950	3.30E-01	100	2.70E-04	25	99
10	9.40E+04	5015	1.80E-03	100	1.15E-06	20	100
10	4.70E+06	5015	9.40E-02	100	7.55E-05	20	100
12	3.50E+04	5900	5.50E-04	100	4.62E-07	15	89
12	1.70E+06	5900	2.70E-02	100	2.31E-05	15	89
14	1.40E+04	6840	2.00E-04	100	1.64E-07	10	68
14	7.40E+05	6840	9.70E-03	100	8.19E-06	10	68
16	7.00E+03	7675	7.80E-05	95	6.80E-08	8	61
16	3.00E+05	7675	3.90E-03	95	3.40E-06	8	61
18	4.00E+03	8420	3.46E-05	90	3.19E-08	5	42
18	2.00E+05	8420	1.70E-03	90	1.59E-06	5	42

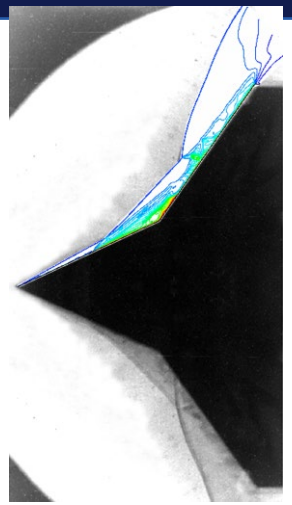
"Hot" vs "Cold" Flow:

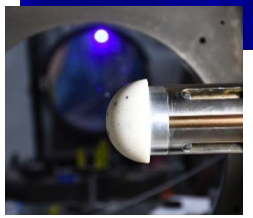
-Refers to the velocity (enthalpy) of the freestream test gas

-Hot conditions imply a match of flight velocity

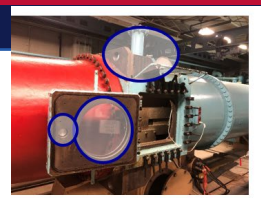
High-level Overview of the CUBRC 48-inch Tunnel

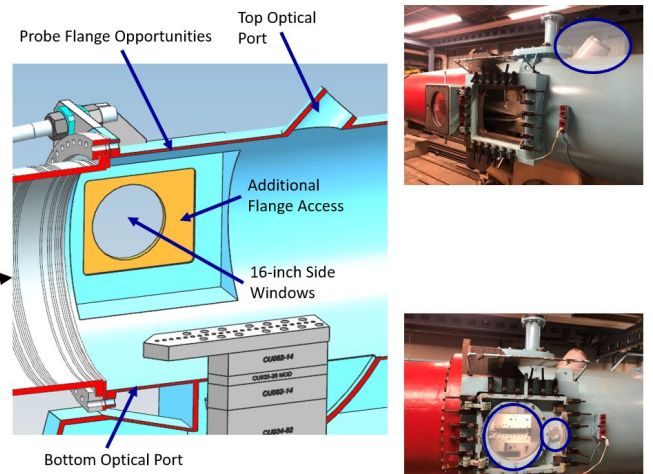






Test Videos





48-inch Tunnel Floor and Optical Access

- The winners of this capstone challenge will be given access to and work with the CUBRC technical team to take the winning project design from paper to test
- This includes direct participation during the test event at CUBRC
- At the completion of the test the winners will have obtained a unique and very relevant set of experiences in the design and execution of a hypersonic ground test
- These experiences can be directly translated to a career in the area of hypersonics – Good Luck!

References:

- Holden, Michael S. and Wadhams, Timothy, P., "Code Validation Study of Laminar Shock/Boundary Layer and Shock/Shock Interactions in Hypersonic Flow Part A: Experimental Measurements," AIAA 2001-1031, 39th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, January 8-12, 2001.
- Naibo, J., Bruzzese, John, Patton, R., Sutton, J., Lempert, W., Miller, J., Meyer, T., Parker, R., Wadhams, T., Holden, M., Danehy, P., "NO PLIF Imaging in the CUBRC 48" Shock Tunnel, AIAA 2011-928, 49th Aerospace Sciences Meeting, Orlando, FL, January 4-7, 2011.

Questions & Answers

Backup Slides

Key Dates

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- The winning concept will be eligible for ground testing funded by JHTO
  - Gun-launched flight experiments with the Army Research Laboratory
  - Wind tunnel tests within the 48-inch LENS Tunnel at CUBRC

DEVCOM ARMY RESEARCH LABORATORY

UNIVERSITY CONSORTIUM FOR APPLIED HYPERSONICS

CUBRC Advantage through technology