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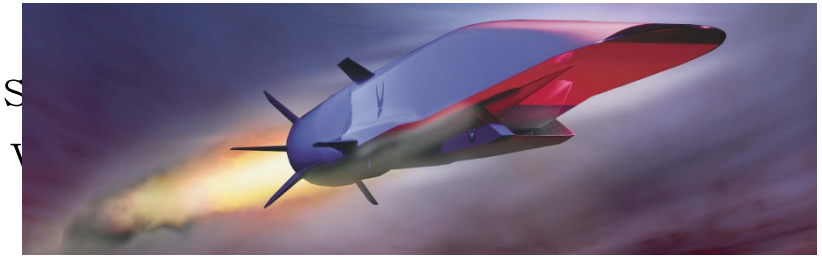
Hypersonics T&E: A University Approach

Dr. Nathan Tichenor and Dr. Rodney Bowersox

NDIA 32nd Annual National Test & Evaluation Conference
March 7, 2016
San Diego, CA

WHY HYPERSONICS T&E?



- The underlying physical processes
high-speed viscous flows are not v
understood.
- Non-equilibrium (Thermal, Chemical, Mechanical) and transition significantly effect hypersonic vehicle design and performance
- Real hypersonic vehicles are composed of curved surfaces and complex geometries
- Modern modeling tools require high-resolution experimental validation data to improve performance and applicability to hypersonic problems

FROM THE UNIVERSITY PERSPECTIVE

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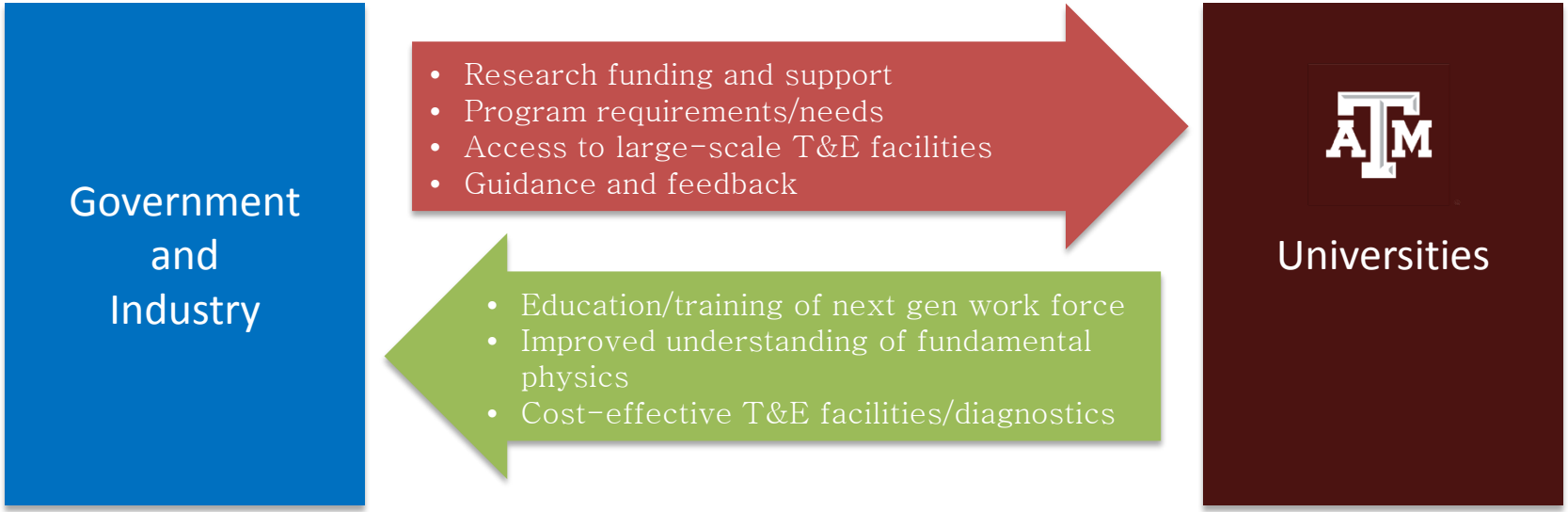
- Universities are a significant partner in hypersonics T&E
  - University research typically compliments and supports industry and government programs



HOW HAS TEXAS A&M RESPONDED?

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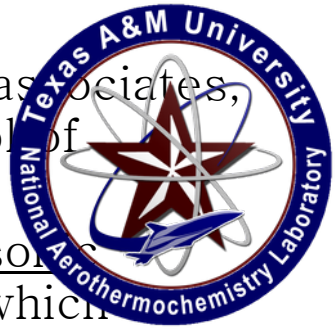
The National Aerothermochemistry and Hypersonics Laboratory (NAL)



- **Mission:** to provide a venue for faculty, students, research associates, and visiting scientists to improve our knowledge and control of high-speed non-equilibrium flows
- The NAL houses a suite of national resource quality hypersonic facilities, instrumentation and numerical methods, most of which are one-of-kind and were developed to address specific problems
- Features a student-driven interdisciplinary culture, where researchers from various disciplines (Aerospace Engineering, Chemistry, Physics and Mechanical Engineering, etc.) work side-by-side to solve complex problems
- The facility has been supported by the AFOSR, AFRL, ARO, NASA, NSF, ONR and Industry

NAL: TRAINING THE NEXT GENERATION

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NAL TEAM FACULTY

R. Bowersox (Founding Director, Aerospace) – Hypersonics, turbulent/transitional flow, thermochemical non-equilibrium, scramjets, facilities & laser diagnostics

R. Miles (Aerospace, NAE) – Hypersonic flight, plasmas, flow control, laser diagnostics

S. North (Co-Director, Chemistry) – Thermochemical non-equilibrium, chemical kinetics & laser diagnostics

H. Reed (Aerospace) – Boundary layer stability and transition simulation

W. Saric (Aerospace, NAE) – Boundary layer stability and transition experiments

E. White (Aerospace, Director LSWT/KSWT) – Transient Growth

D. Donzis (Aerospace) – Turbulence simulation, HPC, thermochemica
non-equilibrium

N. Tichenor (Aerospace) – High-Speed Flow Control, facilities & las
diagnostics

C. Limbach (Aerospace) – Lase

2016 Sounding Rocketry Team
-- 20 Undergraduates

2016 NAL Team
-- 20 Students, 2 Postdoc/scientists

Government and Industry

TEXAS A&M FACILITIES: M6QT

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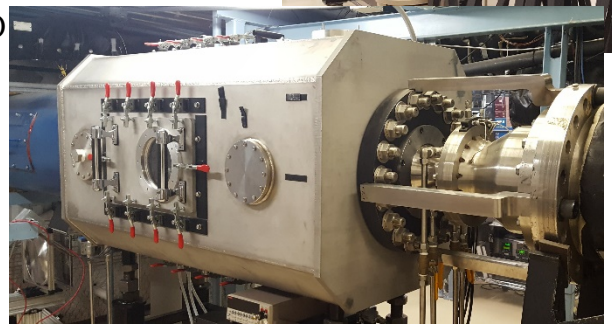
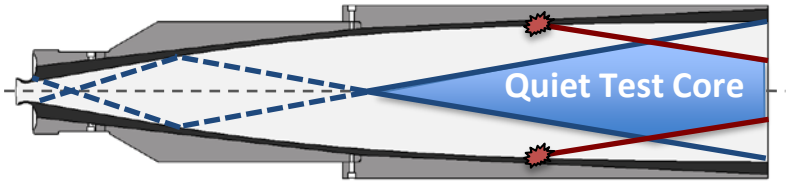
- The Mach 6 Quiet Tunnel (M6QT) is a seminal low-disturbance facility that transitioned from NASA Langley to TAMU
- Research focuses include fundamental studies of boundary layer stability and transition.
- The quiet Reynolds number range is 3.0 – 11.0 million per meter. The nozzle diameter is 0.18 m; the run time is 40 s and the duty cycle is 2.5 ho





TEXAS A&M FACILITIES: HXT

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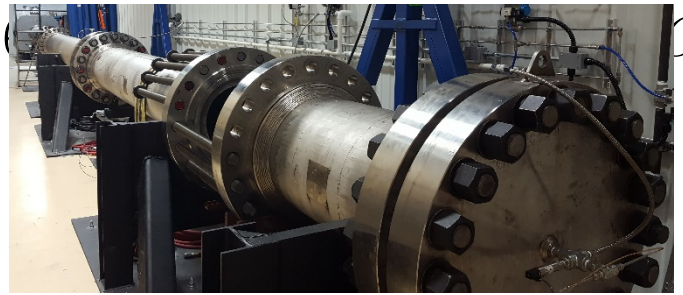
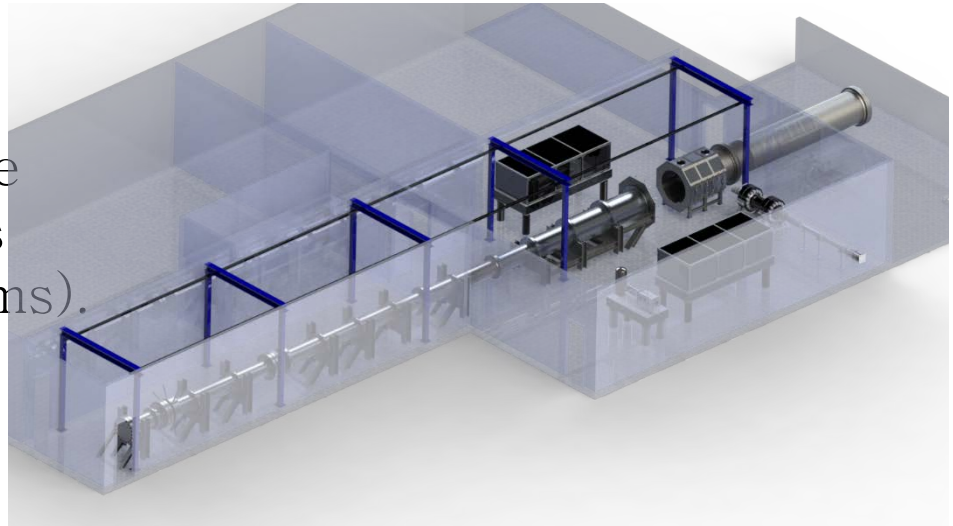
- A large-scale Hypervelocity Expansion Tunnel (HXT) that provides total enthalpies up to 11 MJ/kg is under development.
- The facility tube diameter is 0.5 m and will have 1.0 m nozzle exit.
- The planned nozzle exit Mach numbers are 9.0 and 15.0. The overall length of the facility is 3( )(ms).





TEXAS A&M DIAGNOSTICS: VENOM

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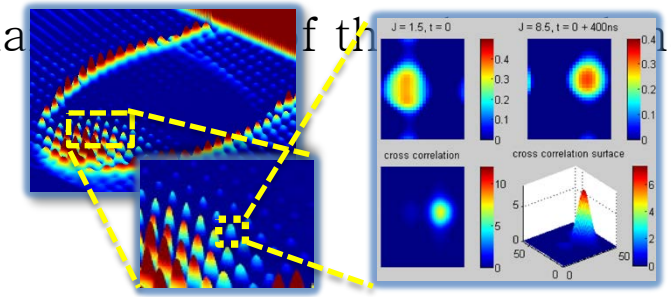
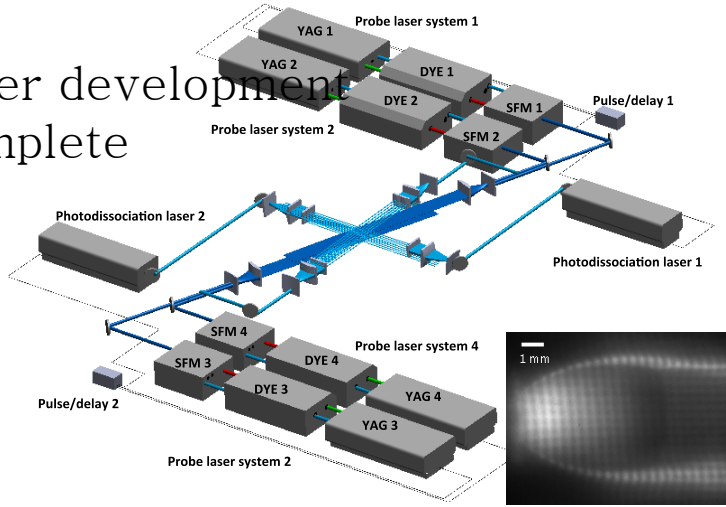
- We have also pioneered a new non-invasive diagnostic for hypersonic (and other) flows
- Vibrationally-excited NO Monitoring (VENOM) combines MTV and 2-line PLIF thermometry to enable direct measurement of the turbulent heat flux.
- A new dual plane system (VENOM2) is under development to provide 3-D velocimetry and a more complete qua f th amic state.





Sanchez-Gonzalez et al, *Optics Letters*, 2012, Hsu et al, *AIAA J.*, 2009.

TEXAS A&M FACILITIES: ACE

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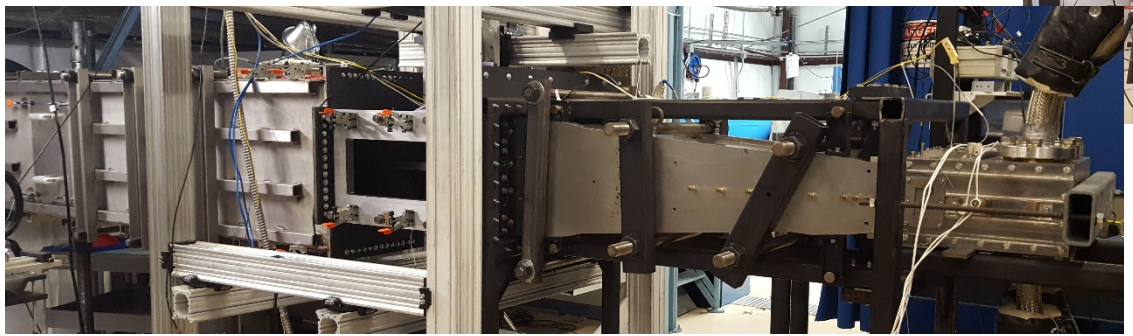
- The Actively Controlled Expansion (ACE) Hypersonic Tunnel is a unique large-scale continuously variable Mach number (5-8) facility
- Research focuses include fundamental studies study turbulent and transitional flows using modern laser diag
- The Reynolds number range is 0.5-10.0 million/meter. The nozzle exit is 0.23 m x 0.36 m; 40 sec run time and 2.5 hr duty c



TEXAS A&M FACILITIES: SHR

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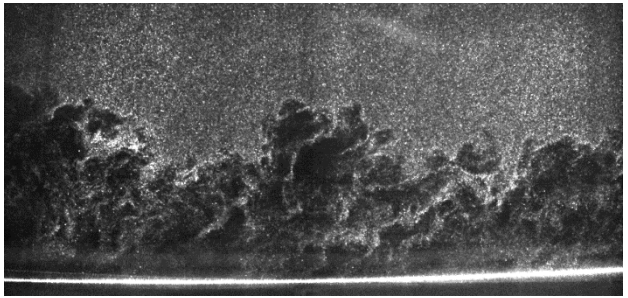
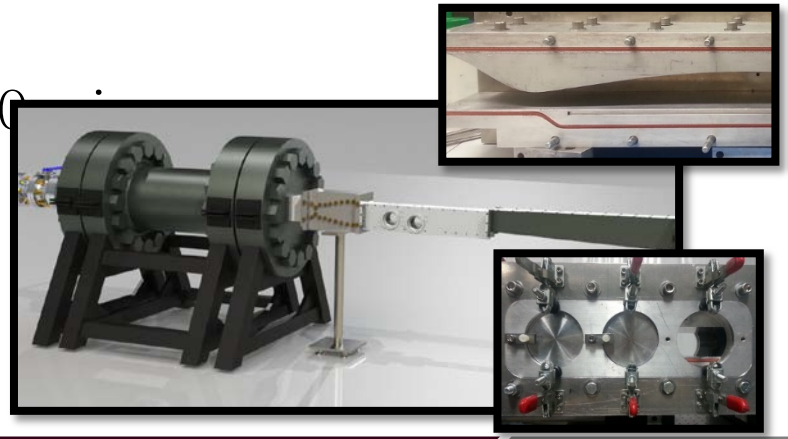
- The Supersonic (M = 2.2, 3.0 and 5.0) High-Reynolds (SHR) Tunnel is a smaller scale high Reynolds number facility (Re/m = 40 – 60 million) developed at TAMU
- Research focuses include fundamental turbulent boundary layer research, scramjet fuel injector studies, diagnostic development, etc.
- 12.7 cm x 12.7 cm nozzle exit with 10 [illegible] run time





TEXAS A&M FACILITIES: PHACENATE

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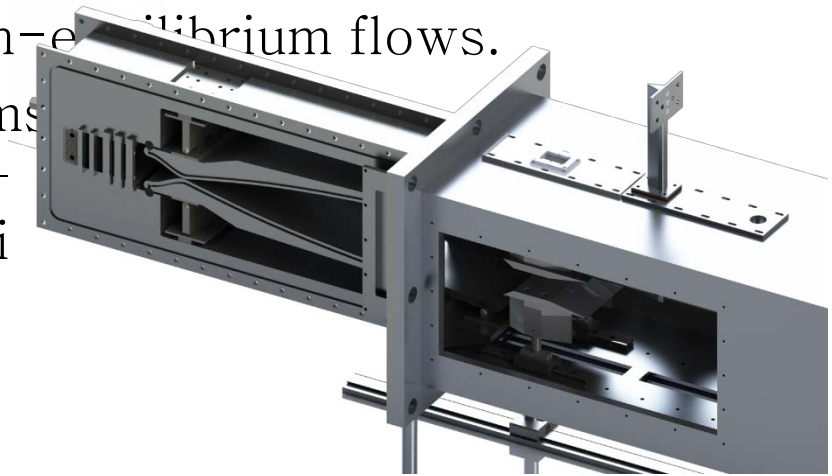
- The Pulsed Hypersonic Adjustable Contoured Expansion Nozzle Aerothemochemistry Testing Environment (PHACENATE) facility is $\mathcal{O}$(10 cm) variable Mach (3-7) facility
- Research focuses include study non-equilibrium flows.
- Produces a continuous train of 30 ms pulses of high-speed flow (M = 4.5- which is synchronized to our Q-swi lasers. The duty cycle is 20 sec.



TAMU AEROSPACE - VISION

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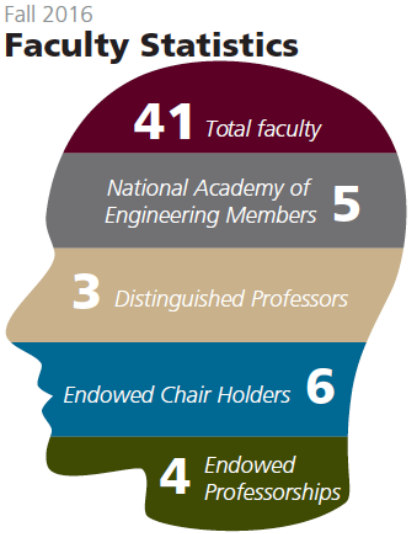
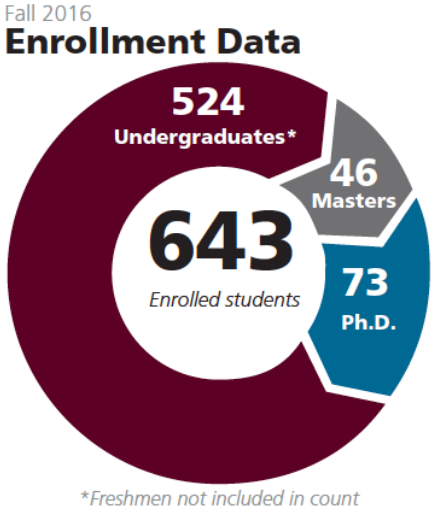
Vision: Aerospace program that attracts top faculty and students, and promotes a passion for providing solutions to the most challenging problems in the field.





TAMU AEROSPACE – CORE COPETENCIES

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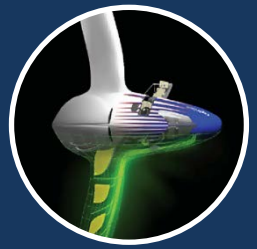
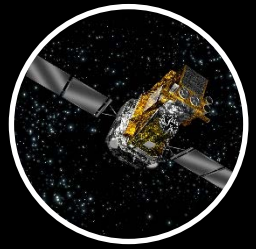
A&P. Aerodynamics, Thermochemistry, Propulsion & Energy



M&S. Intelligent & Extreme Environment Materials & Structures

D&C. Autonomy, Controls, Dynamics, Guidance, & Flight Mechanics



S&D. Aerospace Systems and Design

CORE COMPETENCIES

Basic and Applied Research. Closing the gap between modeling, simulation and experimentation. Developing solutions for system integration, design optimization, and operations.

CONTACT INFORMATION

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We are always seeking industry and government collaborations to advance hypersonics research!

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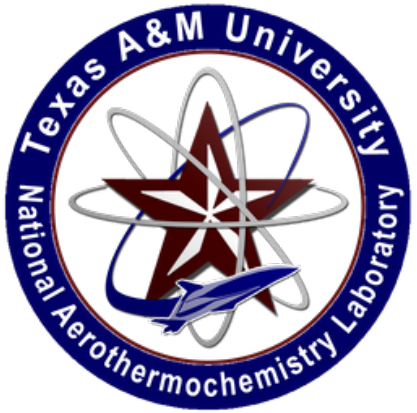

nal.tamu.edu