NEW MEXICO STATE UNIVERSITY HYPERSONICS RESEARCH CENTER (HYPRC) INITIATIVE FROM 2022 TO PRESENT

Speaker: Dr. J.I. Frankel*, R.G. Myers Endowed Professor and Dept. Head

Drs. A. Gross, F. Shu, Y. Wang, Q. Liu, F. Torres-Herrador, S. Mohammadshahi

Advancing U.S. hypersonics through
the facilities, integration of modelling and analysis,
computations, instrumentation, sensor
design and workforce development.

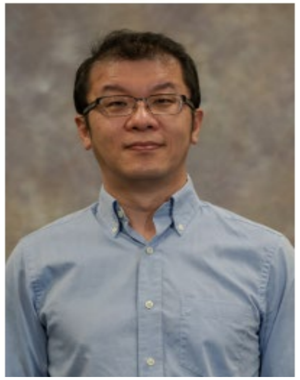
DEVELOPING "LEAP-AHEAD CAPABILITIES" AND TRANSFORMATIVE SOLUTIONS

MEET THE GROWING HYPERSONIC'S TEAM

Dr. Fangjun Shu, D. and A. Chapman Endowed Associate Professor: *Experimental fluid mechanics (PIV, FLDI, FLEET, high-speed flow visualization); hypersonics; flow control; development of flow diagnostic methods*.
Ph.D.: Purdue University

Dr. Andreas Gross, F. Mooney Endowed Professor: *Computational fluid dynamics; large-eddy simulation; Reynolds-averaged Navier-Stokes; aero-thermodynamics; aero-optics; linear stability theory; reduced-order modeling.*
Ph.D.: University of Aachen

Dr. Qiong Liu, Assistant Professor: *Computational fluid mechanics, modal and non-modal analyses (global instability analysis; resolvent analysis; data-driven approaches), passive and active flow controls, particle-laden high-speed flows and machine learning.*
Ph.D.: Universidad Politécnica de Madrid, Spain



Dr. Yanxing Wang, Assistant Professor: *Computational fluid dynamics; multiphase thermal fluid dynamics in supersonic and hypersonic environment; microscale particle and droplet dynamics; fluid-particle/droplet interaction; anisotropic heat and mass transfer in multiphase flow.*
Ph.D.: Pennsylvania State University.

Dr. J.I. Frankel*, Department Head and R. G. Myers Endowed Professor: *Heat transfer (theory to benchtop experiments, mathematical physics), heat flux sensors, physics based data reduction ((parameter required and calibration).*
Ph.D.: Virginia Polytechnic Institute & State University (Virginia Tech, "Society of Distinguished Alumni")

Dr. Francisco Torres-Herrandor, Assistant Professor: *Materials with hypersonics application; pyrolysis and gas-surface interactions; carbon composites and thermal protection systems.*
Ph.D.: Universities of Brussels and Ghent

Dr. Shabnam Mohammadshahi, Assistant Professor: *Experimental fluid mechanics; superhydrophobic surfaces; non-intrusive optical diagnosis.*
Ph.D.: Pusan National Universities University of Massachusetts Dartmouth

Significance

-Place for Space-

Workforce Development
(Regional and National Reputation)
(SNL, LANL, companies)

Research Grants and Contracts
(Research Reputation)
(Attractor for top faculty and students)

NMSU MAE-Hypersonics

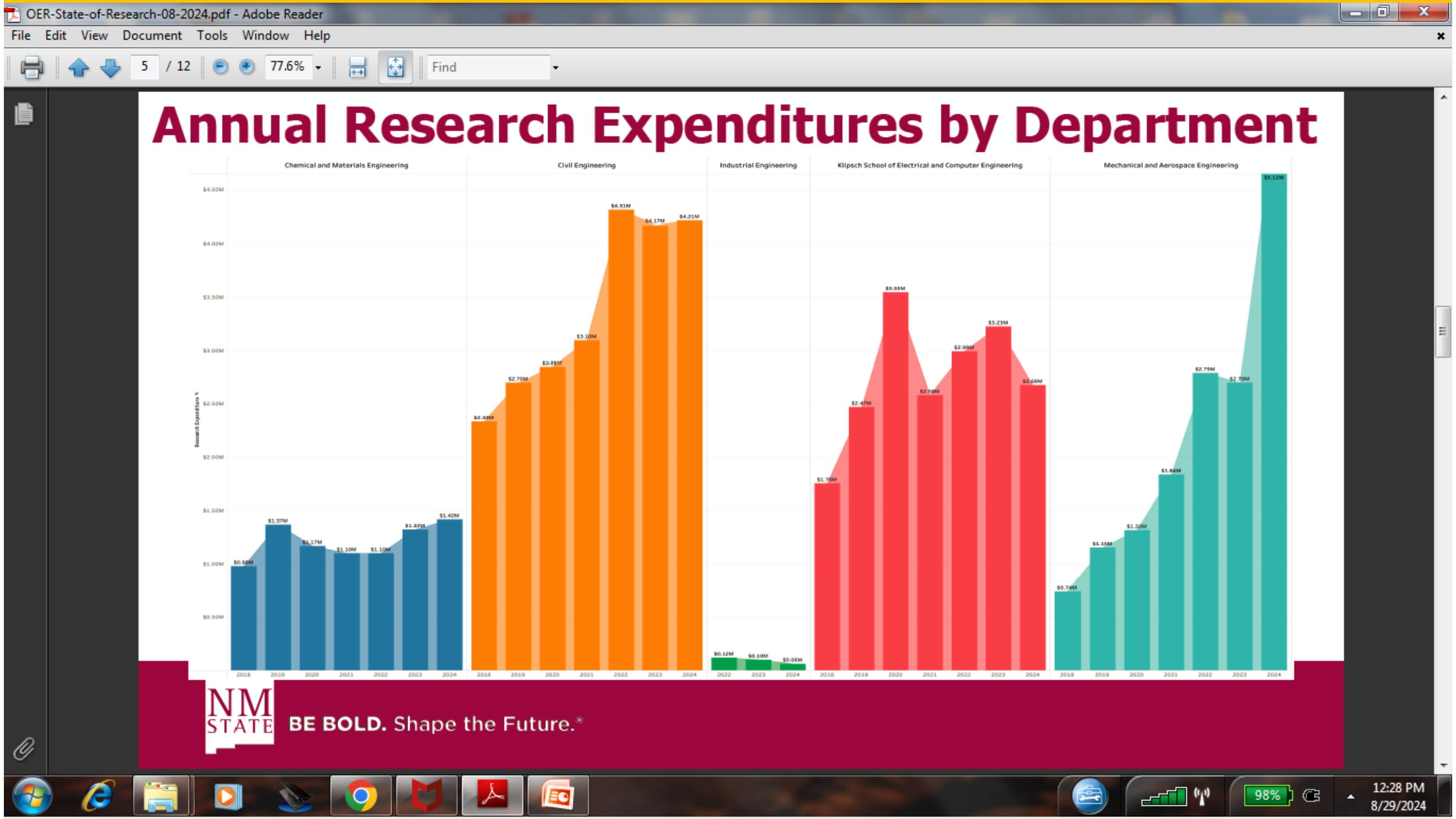
Service (internal and external)
Tutorials, Workshops, Short Courses
Conferences.
Strengthens NM standing in Hypersonics

Modernizing **UG** and Grad Labs
(Instructional Reputation)
UG and Grad laboratories will have unique experiments involving hypersonic tunnels, and lasers! This excites students!

Payback

Attractor for start-up companies while promoting relocation of aerospace companies (and families) due to the four (4) boxes above. Already worked with Spaceport America on an international relocation case.
Availability of test and evaluation (T&E) facilities at NMSU are an immediate benefit to companies for minimizing initial start-up costs, reducing delay times, and removing maintenance costs. We expect an increase in both UG and Grad enrollments and increase in national ranking.

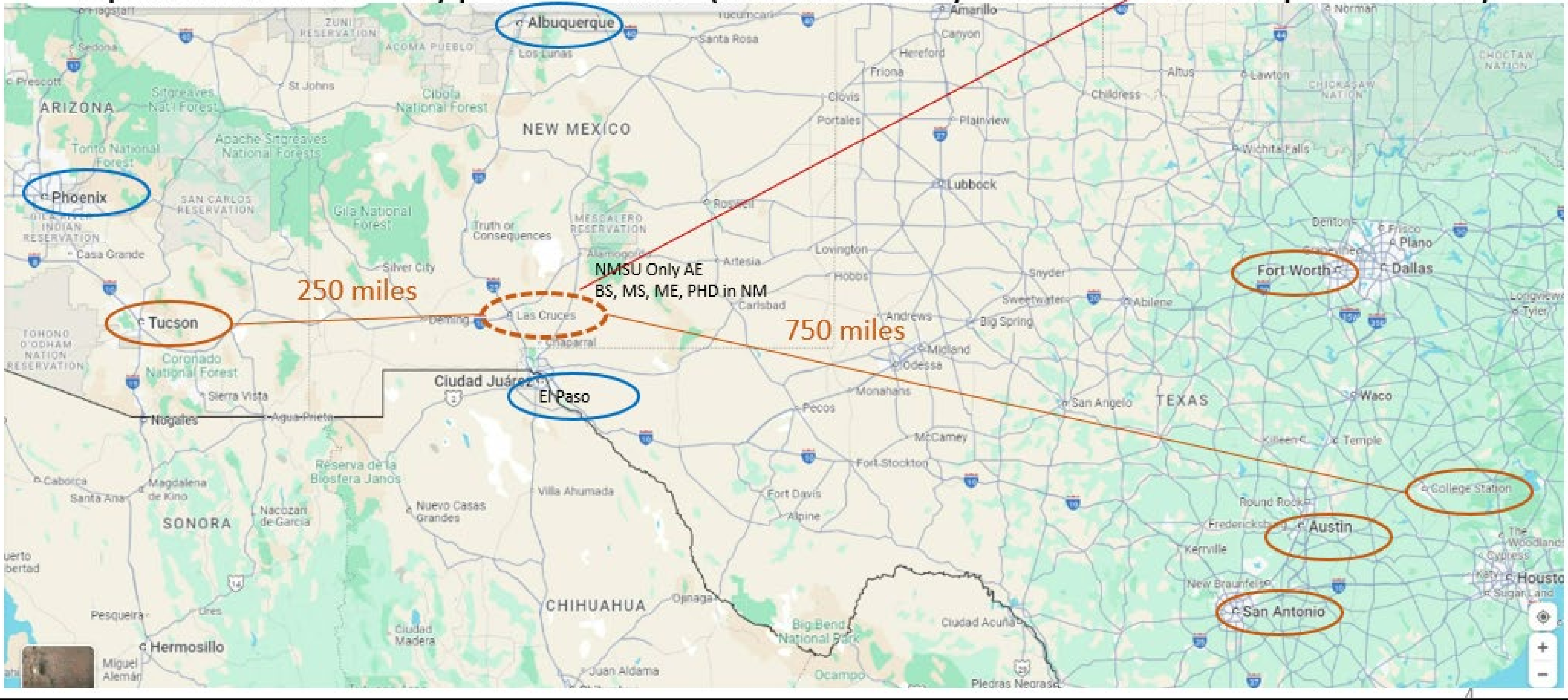
Research in MAE Dept-Development since 2020



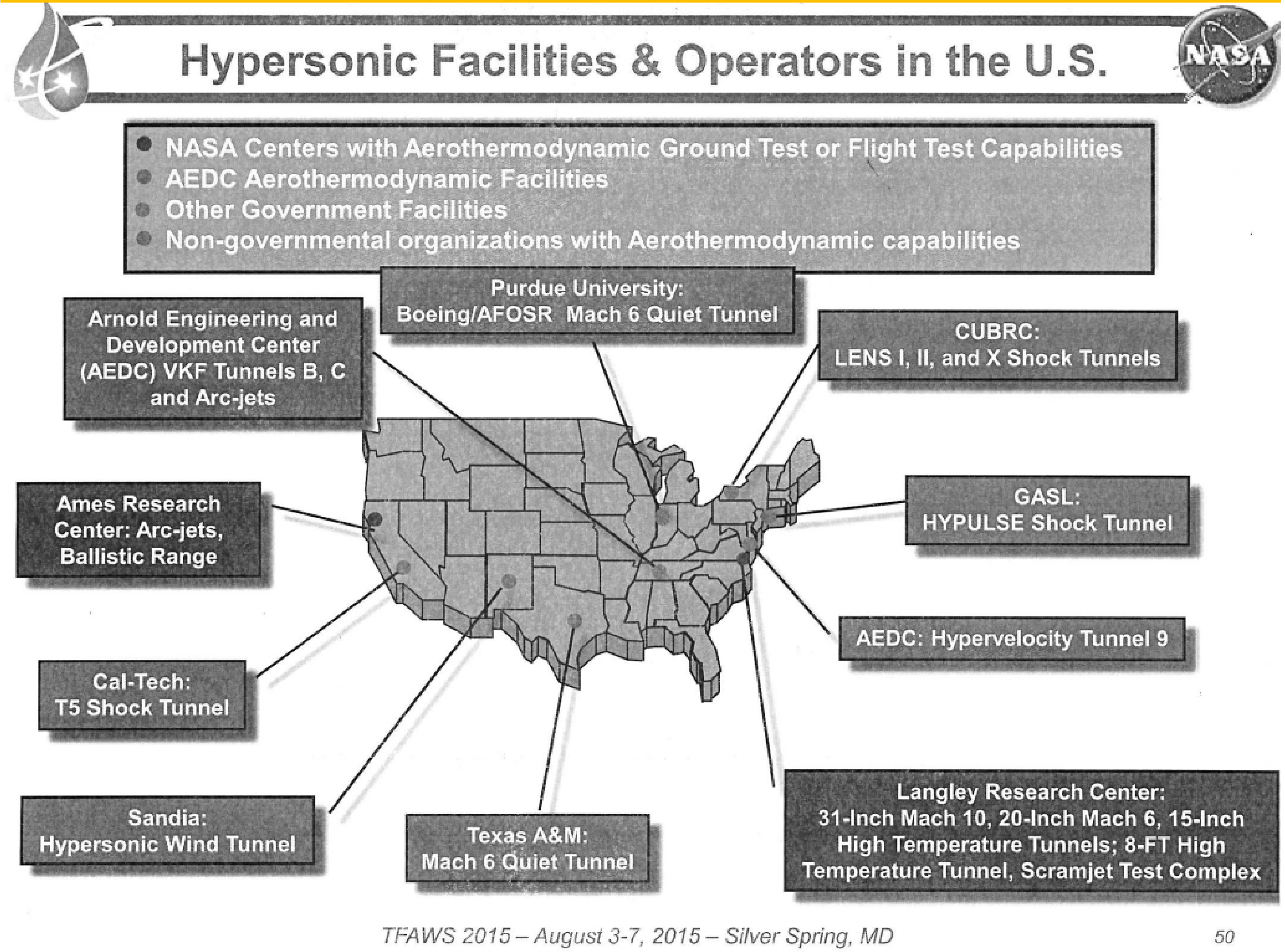
Epicenter of activity

Purdue, 1441 miles (N/S)

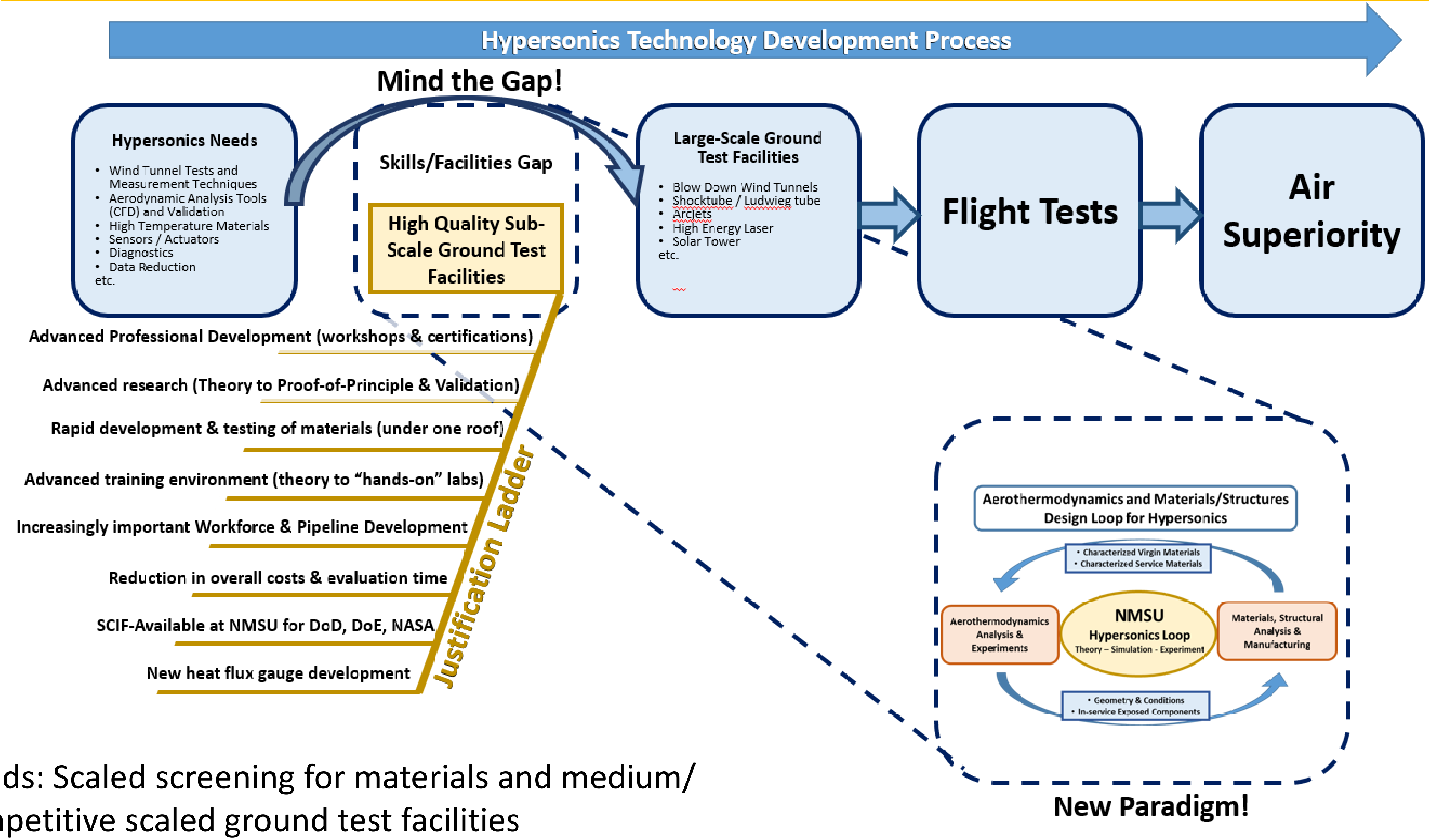
Where:
Epicenter of Hypersonics (University Tunnel Competition)



DoD & NASA (NMSU has good connections)

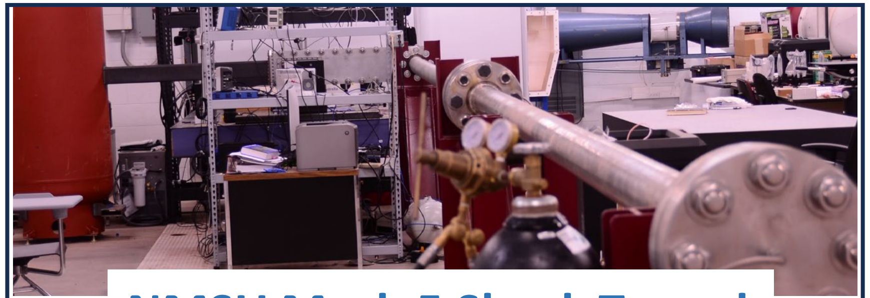


Our technical vision

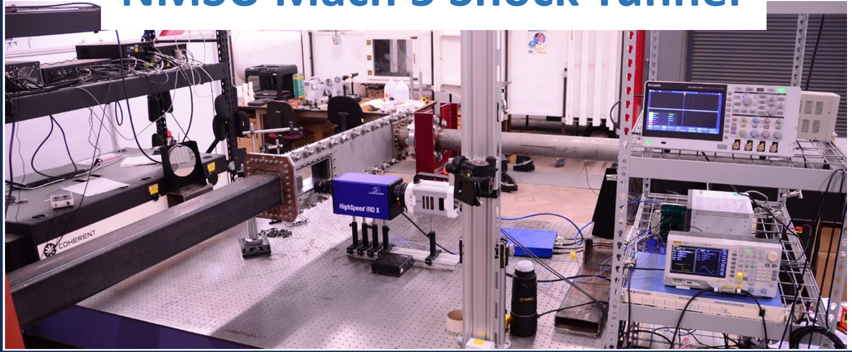


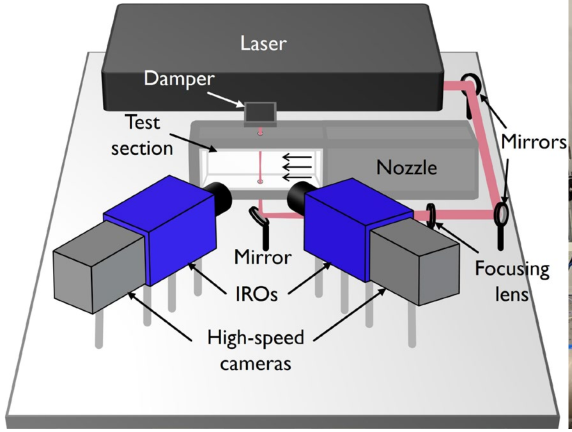
Needs: Scaled screening for materials and medium/ competitive scaled ground test facilities

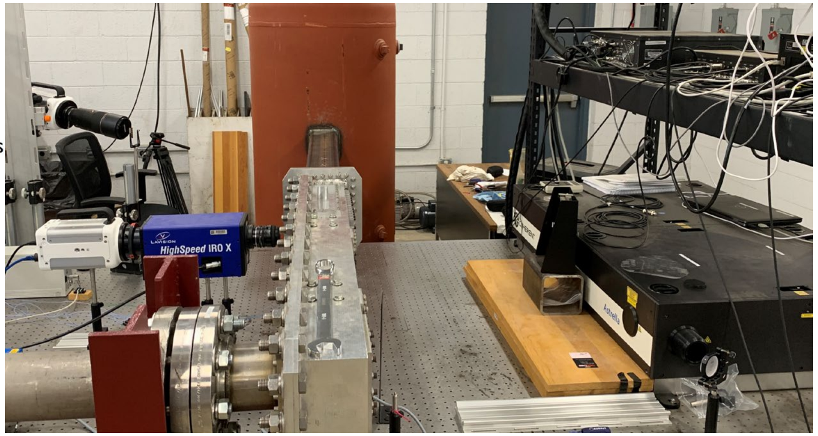
Facilities and Major Equipment (gifts, contracts)



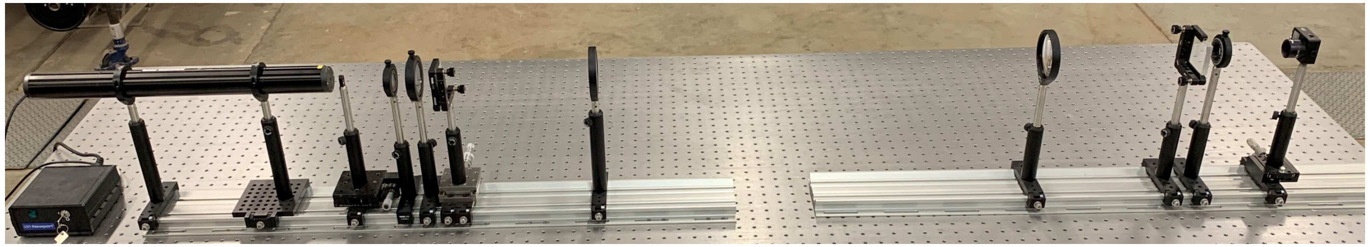
NMSU Mach 5 Shock Tunnel



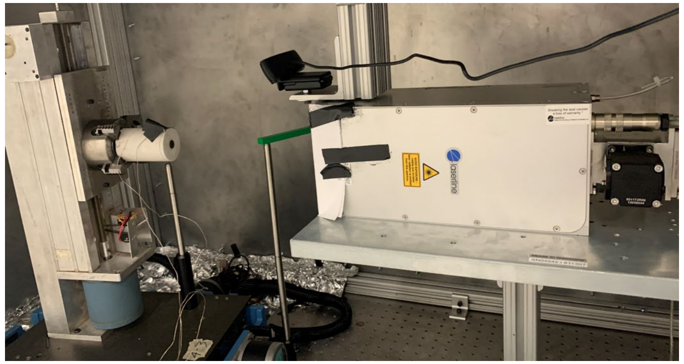




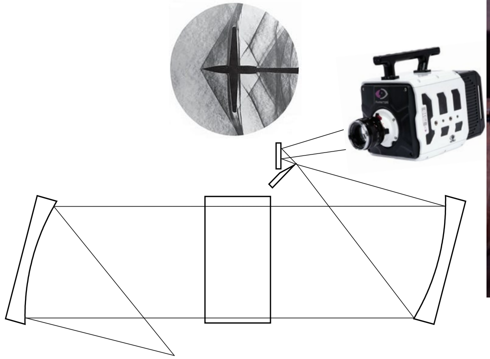
Stereo-FLEET Velocimetry System (Sponsored DoD, DURIP 2022-2024)



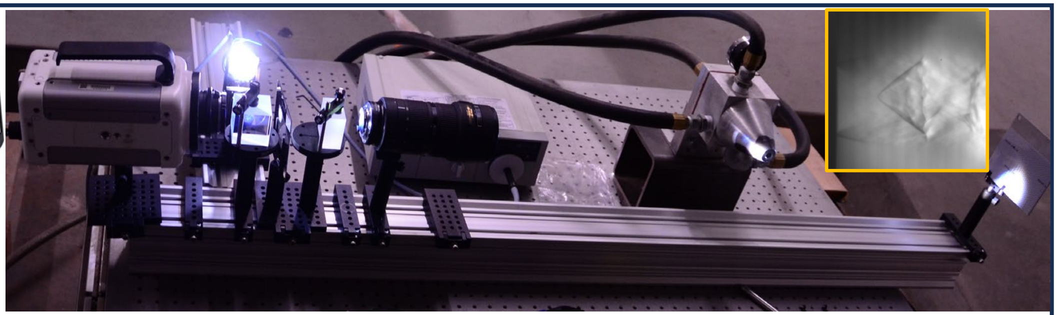
Focused Laser Differential Interferometer



1.5 kW CW Near IR Diode Laser



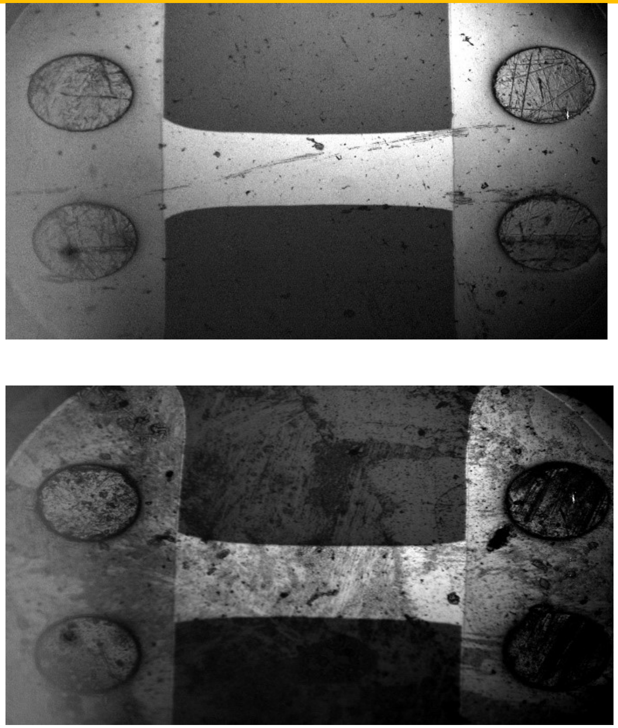
High-Speed Schlieren System



Focused Schlieren System
(sponsored by DoD, DEPSCoR, 2022-2025)

NMSU Test Facilities

Present tunnel instrumentation include FLEET, FLDI, Schlieren, Focused Schlieren, Co-axial TC's, TFTG's



New sensor (top) and sensor after 5 tests in the NMSU Mach 5.1 shock tunnel. **This sensor is not intended for debris existing flows.** Used to demonstrate static calibration drift.

NMSU 1.5 kW Laserline diode laser
(fiber optic delivery)
(0.91 microns, 910 nm)
-TFTG studies
-Slug calorimeter development

DISTRIBUTION STATEMENT A.

GAP SHARING

Who: Stakeholders/Customers/Ecosystem: DoD (Army, AF, Navy, DARPA,…), Major Aerospace companies (Boeing, LMCO, Raytheon, CUBRC, Northrop-Grumman, RTRC…), SBIR/STTR sized companies (AHMIC, Mesoscribe,etc), joint projects with NASA, SNL, LANL, LLNL, and other university researchers to be viewed as a "**force multiplier**" instead of "**competitor**".

What: Purpose:

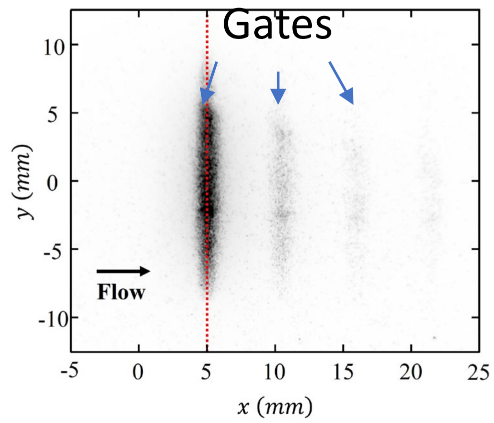
- Produce engineering advances, verification/validation, and testing/evaluation studies for Hypersonics.
- Produce flight tests when possible (using experiences of PSL)
- Produce a deep physical understanding of hypersonics for air-breathing & boost-glide vehicles, and re-entry systems.
- Produce and demonstrate new instrumentation approaches.
- Produce a rapid educational protocol for work force enhancement
- Produce, though support, a nationally competitive wind-tunnel complex that fills in gaps

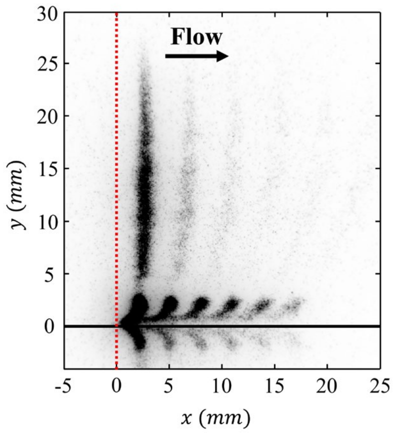
* Produce high-quality screening, and small to large sized test facilities for materials and manufacturing efforts.

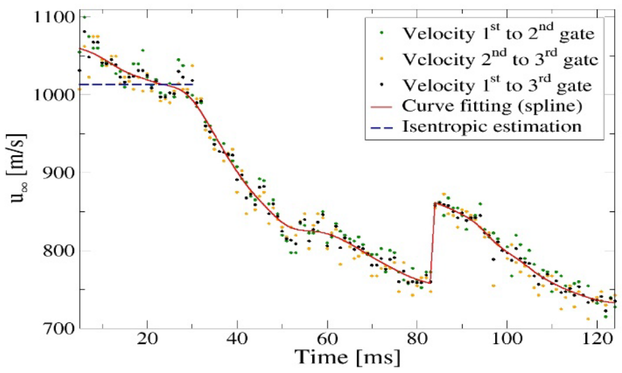
- Produce a transformative advancement in heat flux measurements (stagnation point, second-mode instability,…).
- Produce an environment for increasing economic growth and commerce (start ups, relocations, conferences,…)

Example of Federal Dollars at Work

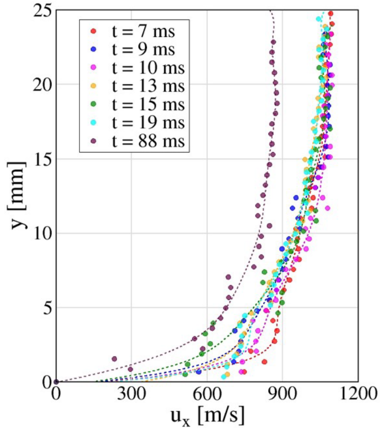
Femtosecond laser electronic excitation tagging velocimetry (FLEET): A $500K Instrumentation system supported by DoD (2023-24) and already developing state-of-the-art results.
The measurement of flow velocity is indicated and calculated in millisecond time scale.



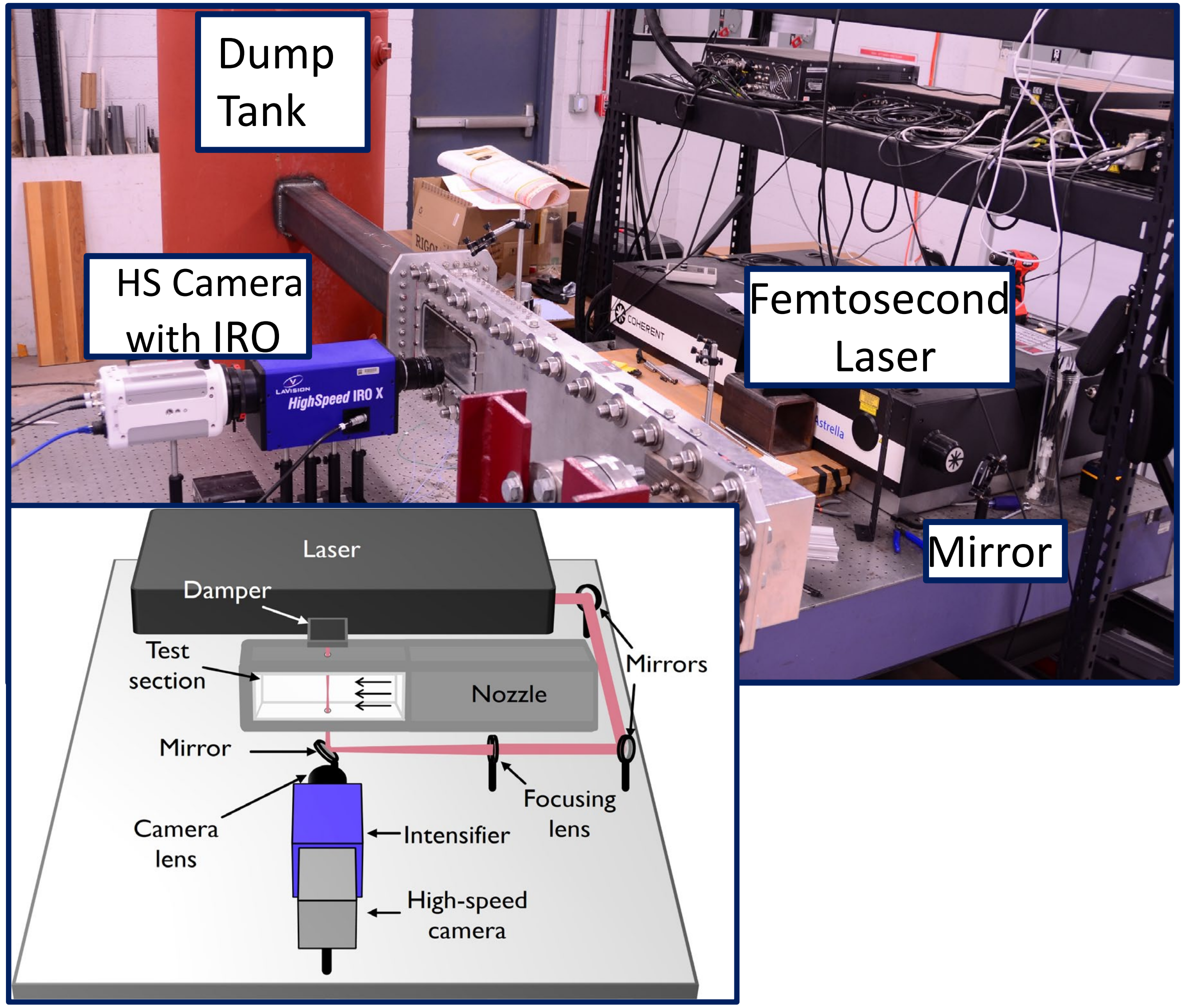




Velocity in free Stream



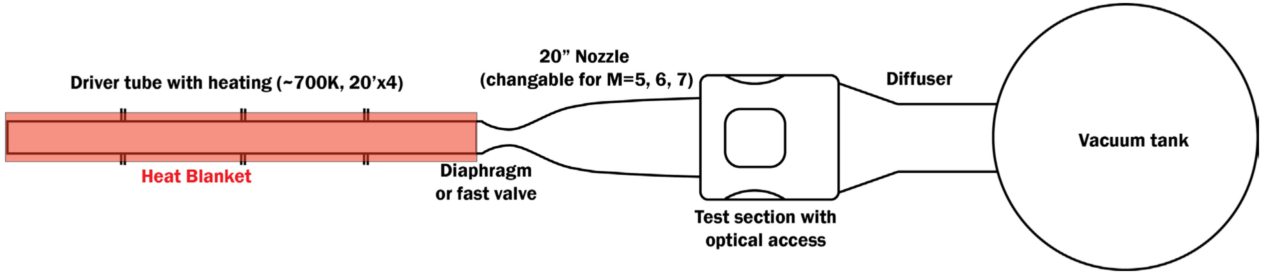
Velocity profile measured in the boundary layer



Recent Excitement- **Graduate** classes (co-listed for seniors with permission of instructor, tech elective) with a focus on hypersonics

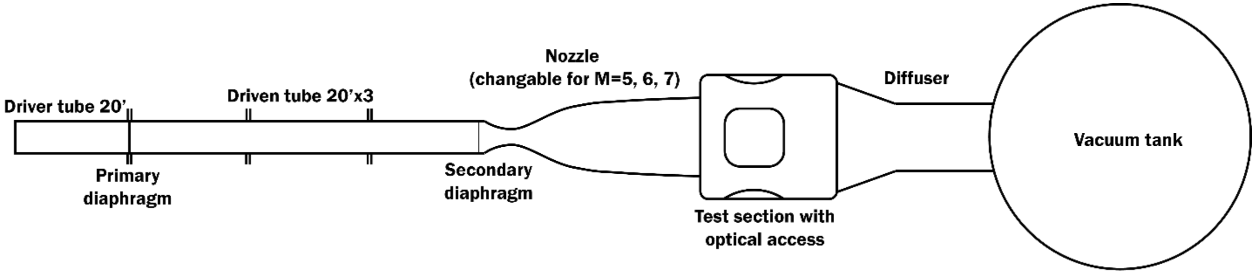
Special Topics-Title/ term	Content	Instructor
Hypersonic Aerothermodynamics (S2022, S2024)	Hypersonic and high-temperature gas dynamics with focus on thermal and chemical non-equilibrium effects.	Dr. A. Gross
Sensors and Inverse Analysis for Hypersonics	Study the development of data reduction equations based on first principles and resolving for unknown heat flux. Slug calorimeters, thermocouples, thin-film gauges are used in examples.	Dr. J.I. Frankel
Experimental Hypersonics	This course focuses on measurement techniques in hypersonic flow including Schlieren, FLDI, and FLEET. Students will gain practical experience through hands-on experiments conducted in the NMSU Mach 5 shock tunnel	Dr. F. Shu
Machine Learning in Fluid Flow	The course focuses on introducing data-driven approaches and machine learning techniques to address various engineering problems. Students will have the opportunity to learn by doing with various machine learning codes provided in the course.	Dr. Q. Liu

Proposed: Heated Multiple Mach Number Hypersonic Wind Tunnel



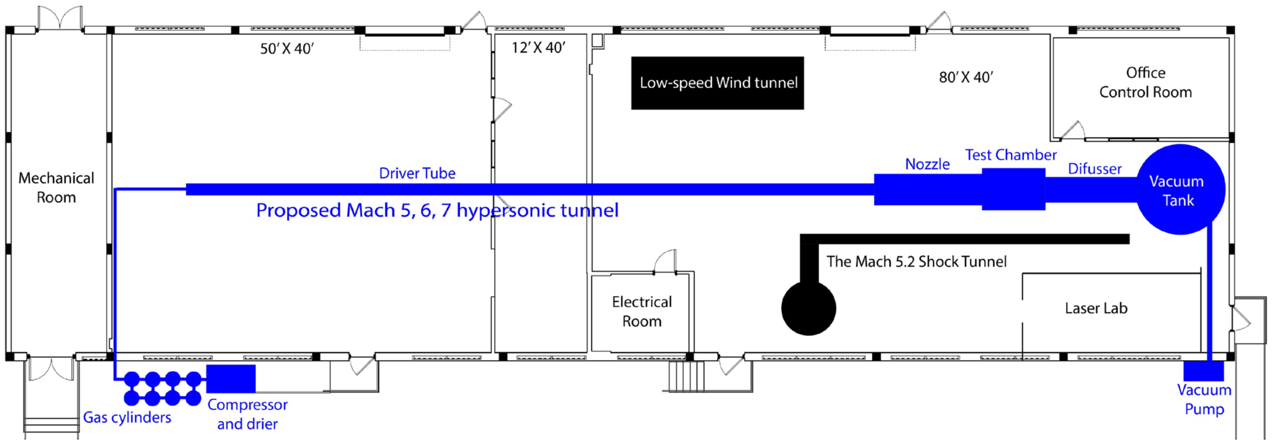
Schematic of the proposed hypersonic tunnel when configured as a **Ludwieg tube**.

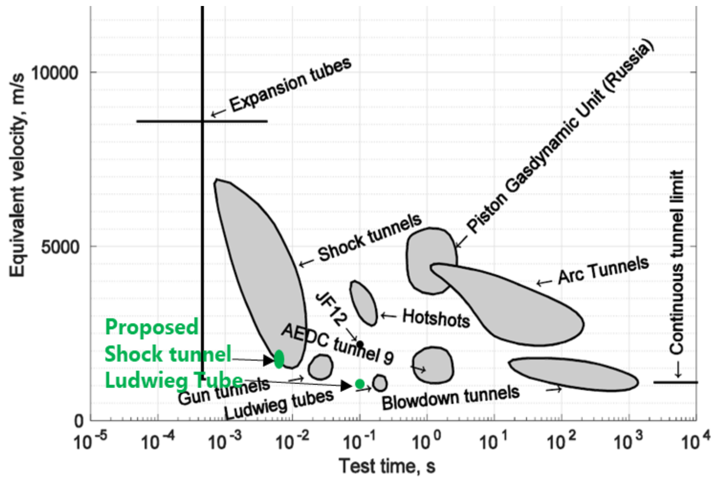
Mach	p_0 (MPa)	T_0 (K)	V_∞ (m/s)	p_∞ (Pa)	T_∞ (K)	ρ_∞ (kg/m^3)	Re (1/m)
5	4	700	1083	7560	117	0.226	30E+06
6	4	700	1111	2533	85	0.103	20E+06
7	4	700	1130	966	65	0.052	14E+06



Schematic of the proposed hypersonic tunnel when configured as a **shock tunnel.**

	Mach	p_4 (Mpa)	p_1 (kPa)	p_0 (MPa)	T_0 (K)	p_∞ (Pa)	T_∞ (K)	ρ_∞ (kg/m^3)	V_∞ (m/s)	Re (1/m)
Heated (500K)	5	4	88	3.3	1980	6237	330	0.066	1821	6.0E+06
	6	4	88	3.3	1980	2090	241	0.030	1869	3.6E+06
	7	4	88	3.3	1980	797	183	0.015	1900	2.3E+06
Not heated (293K)	5	4	88	4.5	1390	8505	232	0.128	1525	1.3E+07
	6	4	88	4.5	1390	2850	170	0.059	1566	8.0E+06
	7	4	88	4.5	1390	1087	129	0.029	1592	5.3E+06





0.5 m test section diameter
~100 ms test time (Ludwieg tube)
~7 ms test time (Shock tunnel)