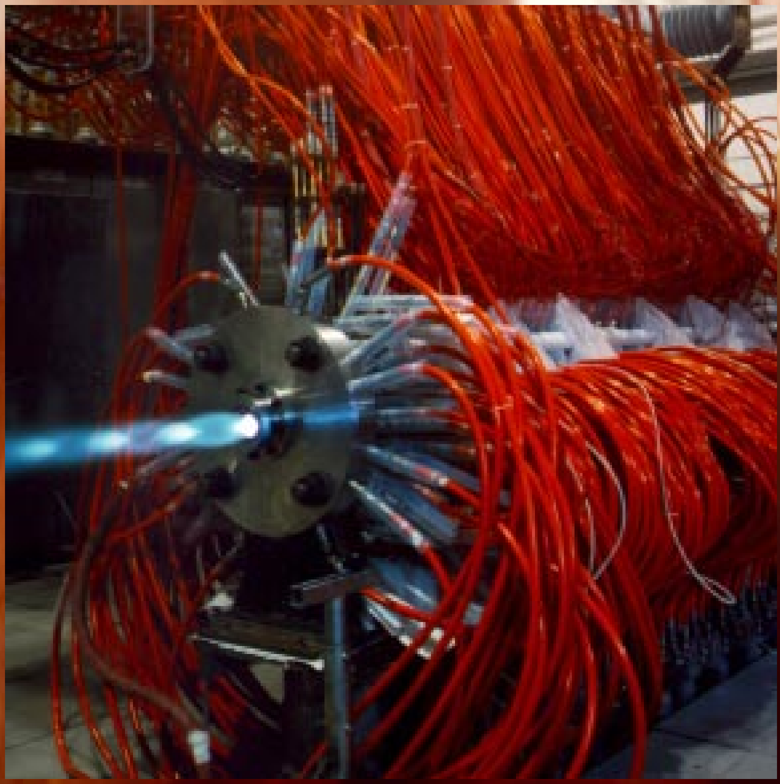
AEDC

The world's premier flight simulation center

Hypersonics Highlights



ARNOLD ENGINEERING DEVELOPMENT CENTER
An Air Force Materiel Command Test Center

ON THE COVER:

Top: Steam billows out of AEDC's Aerodynamic and Propulsion Test Unit.

Left, bottom: AEDC's H3 Test Unit.

Right, bottom: AEDC technician prepares a Navy Standard Missile model for testing.

Background: Nosetip material screening and evaluation in HEAT-H1 Arc facility.

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CATEGORY **EXPERTISE**
Point of Contact - Office Symbol; Phone; Fax

Aircraft Systems
AEDC/DOF; -7721; -3399 Aircraft/missile performance, stability, and control; propulsion/inlet integration and compatibility; store/stage/separation; weapons carriage; aero-optics; signatures

Aeropropulsion Systems
AEDC/DOP; -5305; -7205 Performance, operability, and observability of solid and liquid rocket systems at altitude; performance, operability, observability, and specialized testing of turbine systems; environmental testing (temperatures, precipitation, and icing)

Space & Missile Systems
AEDC/DOS; -5599; -3526 Sensors; nuclear weapons effects; contamination; thermal vacuum; infrared signa tures; space dynamics; aerothermal material; hypervelocity impact ablation and erosion; wake physics; bird impact

Technology
AEDC/DOT; -6523; -3559 Develop new facility concepts and instrumentation; develop new test and analysis techniques

Mission Support
AEDC/SDC; -5856 Small and large machining; fabrication; welding; chemical and metallurgical laboratory services

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Contents

"We are now transitioning from an air force into an air and space force on an evolutionary path to a space and air force."

Global Engagement:
A Vision for the 21st Century Air Force

Foreword

When the end of the Cold War became evident, the military forces of the United States of America recognized that the ability to plan for specific types and locations of conflicts had been severely curtailed.

Instead, the armed forces will now be expected to respond to conflicts that are large distances from the continental United States without much warning. This will require the services to be prepared to fight or to conduct mobility or special operations anywhere in the world on short notice. As part of this preparation, it has been recognized that airbreathing, high-speed propulsion systems will play an integral part in the war fighting effort. The "New World Vistas" study conducted by the Air Force sums up this need for high-speed propulsion systems by stating:

Even with the tremendous increase in space operations in the future there will continue to be a major place for air breathing platforms/vehicles. Time is now, always has been, and even more so in the information age future, will be of the essence in military operations especially those of the Air Force. All distances on the earth are fixed. If the Air Force is to execute faster than an enemy in the 21st century, then to reduce time, the only alternative is to go faster. Hypersonic air breathing flight is as natural as supersonic flight. Advanced cycles, dual-mode ramjet/scramjet engines and high temperature, lighter weight materials which allow for long range, long endurance high altitude supercruise are the enabling technologies.

As we approach the 21st century the United States' future global economic situation requires a strong and productive aerospace industry. Our current status as a leader in the global economy is due to the robust aerospace technology and development capability that provides products desired by other countries. A leadership role will be essential to support the research and development required to invest in hypersonic technology is essential.

Future military transports, reconnaissance, and weapons delivery systems, space transportation, offensive and defensive missiles, ordinance, and commercial air transportation systems will undoubtedly make full use of hypersonic flight technologies. For this country to maintain leadership in the aerospace industry, investment in hypersonic technology will be essential.

The initiatives of the United Kingdom, France, Germany, Japan, China, and Russia in commercial satellite launch systems and hypersonic flight vehicles indicate a widespread appreciation of the potential

Arnold Engineering Development Center, Arnold Air Force Base, Tenn.

commercial and military applications of hypersonic flight technologies.

Future high-speed commercial and military aerospace vehicles will be more complex and exceed the technology of past aircraft. Future vehicles will require higher levels of sophistication in ground-based testing to provide better accuracy in all aspects of performance as well as verification of supporting computer simulations.

Ensuring that the U.S. will have the capability to conceive, develop, and produce the state-of-the-art aerospace vehicles and systems in the 21st century will require that our national hypersonics ground-test facilities be maintained. An immediate long-term national commitment to the research and development of advanced test facilities capable of duplicating hypersonic flight conditions is needed.

AEDC's Role

Created shortly after World War II during peace time, AEDC resulted from the vision that the U.S. needed the basic developmental tools that would allow it to reach out to the horizons of technology in developing its modern military air systems. Over the years, significant test-facility additions have been made that have kept AEDC one of the premier aerospace ground-testing facilities in the world.

Today, despite the easing of international tensions and the inevitable pressure on the defense budget AEDC's responsibility to the nation remains unchanged. It is our mission to provide the United States with the multiservice national ground-test capability which will be required to develop the kind of aerospace systems that can protect against the wide range of threats (both military and economical) that could materialize over the next 20 to 30 years.

AEDC hypersonic facilities have many unique capabilities. As the hypersonics market changes, other facilities are closing. If we hold to the visions of Gen. H.H. "Hap" Arnold and Dr. Theodore von Karman, and our own Strategic Vision 2031, AEDC will become the center of choice for hypersonics testing, not only nationally, but internationally.

What is Hypersonic Ground Test & Evaluation?

The AEDC ground test facilities are used in the development of ballistic theatre and cruise missile defense interceptors, tactical missiles, high-speed aircraft, and launch vehicles. A variety of AEDC hypersonic facilities provide the customer the opportunity to test and evaluate a total weapon system from propulsion system development, individual components development, and then as an integrated weapon system package.

AEDC is comprised of three major facility complexes: the Engine Test Facility (ETF), the Propulsion Wind Tunnel Facility (PWT), and the von Karman Gas Dynamics Facility (VKF).

The principal ground test Facilities for the development of supersonic and hypersonic interceptors are located within the VKF complex. Large-scale models of defensive systems such as ballistic and tactical missile interceptors, high speed aircraft, and can be tested over simulated flight conditions from a Mach number range from 1.5 to 20.

The test facilities include conventional continuous-flow wind tunnels, intermittent blow down tunnel, impulse tunnel, continuous-flow arc-heated facilities and ballistic ranges. AEDC is more than just a collection of test facilities; it is a National Aerospace Ground-Test and Evaluation (T&E) complex which can provide a full range of T&E services tailored to our customers needs.

AEDC is an important national asset. Since its dedication 45 years ago, the center has been instrumental in every major U.S. aerospace program. AEDC has unique, national hypersonics assets and we must continue operation and investment in hypersonics facilities and capabilities to make todays dream tomorrows reality.

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Aerodynamic and Propulsion Test Unit

Steam billows out of AEDC's Aerodynamic and Propulsion Test Unit.

The Aerodynamic and Propulsion Test Unit (APTU) is a blowdown facility designed for true temperature aerodynamic, propulsion, and material/structures testing. A combustion heater (VAH) provides the required temperature. Liquid oxygen is added so the appropriate oxygen content exists in the test medium. The facility is completely computer-controlled during a run, and can make rapid pressure and temperature changes. The remote location of the facility plus the straight line ejector exhaust configuration allows for unique test capabilities such as test article hardware separation. Certain types of ammunition/explosive live fire testing can be done. The facility is sited for Class 1.1-1.3 explosives and hydrogen propellants.

A 22,000-cu ft high pressure air reservoir, which can be pressurized to 4,000 psia allows run duration from approximately 3 minutes to 12 minutes, depending on the Mach number selected and the altitude simulation required for the run. This air storage system is also the source for an annular air ejector, located in the exhaust duct, which is used to lower the test cell pressure to simulate altitude conditions.

Altitude Simulation and Run Duration

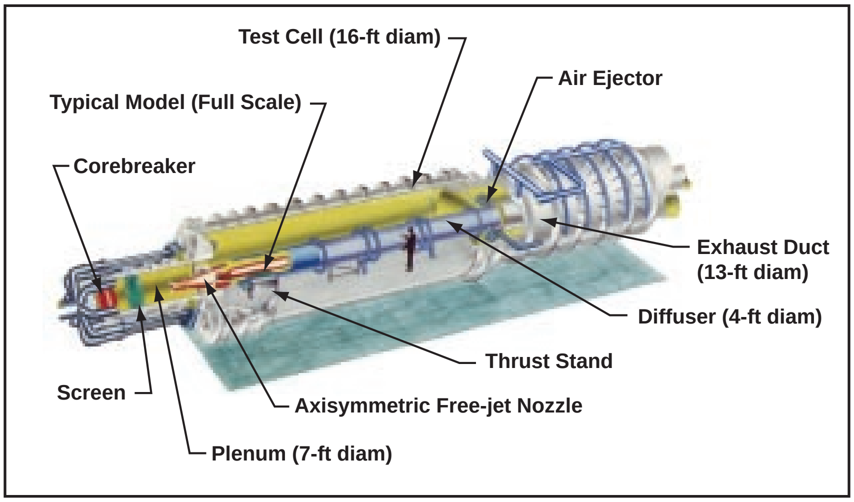
Auxiliary air ejectors have been installed to augment the pumping capacity of the original air ejector. The chart shows the estimated cell pressure as a function of the facility Mach number simulation.

APTU Gaseous Oxidizer System

The gaseous oxidizer system has 2,100 cubic feet of storage capacity at 3,800 psia and ambient temperature. A pressure control valve allows the delivery pressure to be held constant while a flow control valve allows the flow rate to be varied during a run.

APTU Fuel Systems

An ambient temperature gaseous hydrogen system has been added to



Artist drawing of Aerodynamic and Propulsion Test Unit test cell.

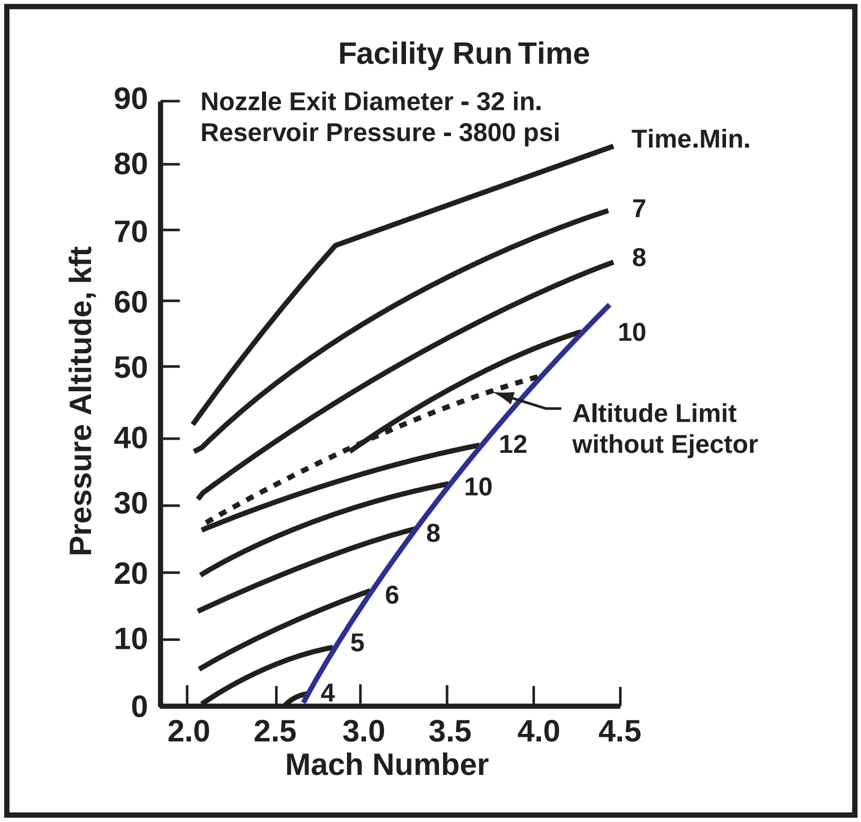
the APTU complex to provide test article fuel. Six hydrogen trailers can be connected to a manifold from which two lines enter the test cell. Valves in the manifold allow different combinations of trailers to feed the two supply lines. This allows two different delivery points on a test article that can be supplied at different pressures. The run time at each point will depend on the number of trailers serving the point, and the required delivery pressure.

Cooling Water Availability

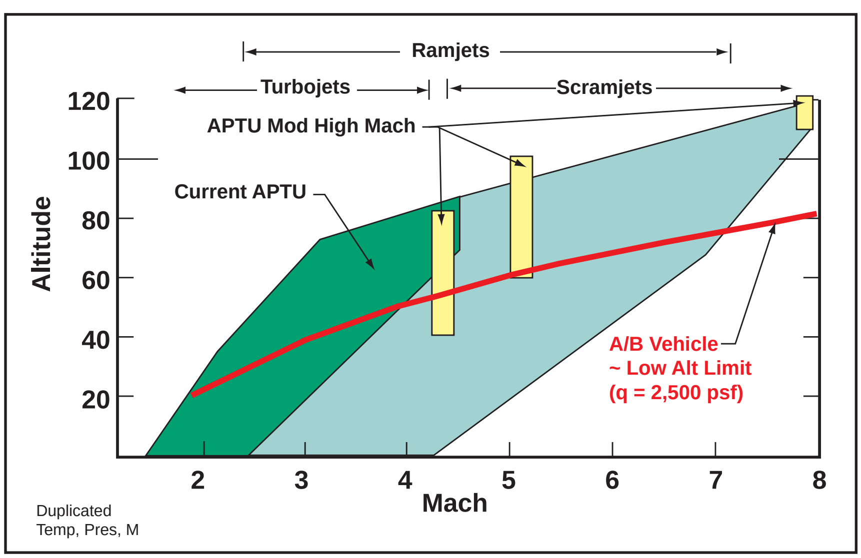
Cooling water is supplied to the APTU complex from the AEDC pumping station through a 36-in. diam. main at 90 psia. This water can be used directly for low-pressure test article cooling requirements. If high-pressure cooling water is needed, a series of high pressure pumps will be used individually or in combination as necessary.

Future Upgrade Program

The Air Force Hypersonic Technology (HyTech) Demonstrator Program initiated the APTU upgrade. APTU currently provides supersonic free jet test capability up to Mach 4.5. APTU upgrade will provide free jet and direct connect testing. In order to reduce the cost of the upgrade, APTU will use the National Aerospace Plane Air Heater from Marquart Engine Test Facility. An existing supersonic nozzle provides Mach 8 flight simulation environment. A nominal Mach 6 nozzle will be built as part of the upgrade. Additional air storage will be provided to increase run times. This upgrade will maintain existing lower speed test free jet capability.



Navy Standard Missile IR Dome window cooling test in APTU.



Materials & Structures

Facility Description

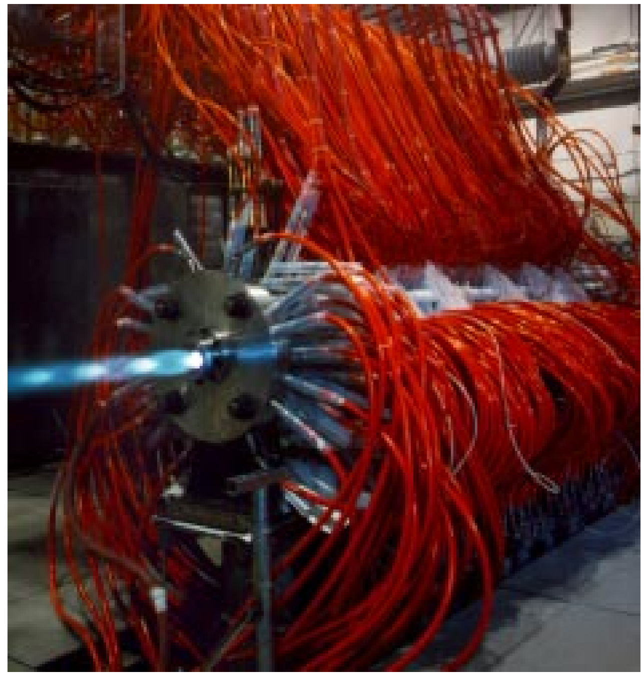
The AEDC arc-heated test facilities include the H1 and H3 high-pressure segmented arc heaters, and the H2 and HR Huels arc heaters. Both types utilize a high-voltage, DC electric arc discharge to heat air to total temperatures up to 13,000 degrees Rankine. High-pressure test capabilities are achieved by confining the electrical arc discharge to a water-cooled plenum section capable of withstanding chamber pressures above 100 atm. The combination of high-enthalpy test gas and high plenum pressure makes possible heat flux simulations representative of flight at speeds in excess of Mach 20 at high dynamic pressures simulating low-altitude flight (atmospheric re-entry).

HEAT-H1

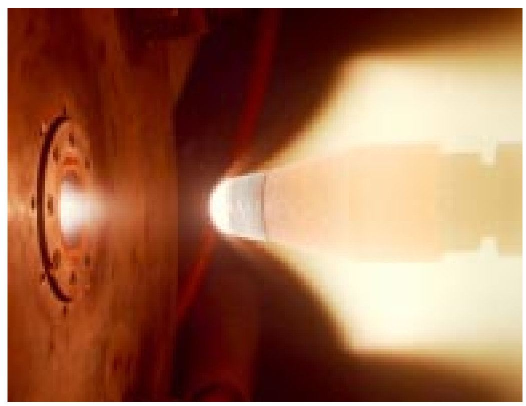
The HEAT-H1 Test Unit is an advanced performance arc-heated facility providing high-pressure, high-enthalpy test conditions for qualification of thermal protection materials, nosetips, and electromagnetic apertures and structures for hypersonic missiles, space access systems, and reentry vehicles. HEAT-H1 utilizes a segmented arc heater with multiple electrically isolated segments which form the heater plenum. The unique segmented construction allows the arc to be held at a fixed length to optimize heater efficiency and total enthalpy at high pressure and flow uniformity. A stilling/mixing chamber can be installed to mix cold air with the arc-heated air, thereby decreasing the total enthalpy, increasing the flow Reynolds number, and improving the uniformity of the flow enthalpy across the test jet.

HEAT-H2.

The HEAT-H2 Test Unit is an arc-heated aerothermal tunnel providing high-enthalpy flow at high Mach numbers and dynamic pressures simulating hypersonic flight at pressure altitudes from 70 to 160 kft. H2 utilizes an Huels-type arc heater to generate high-temperature, high-pressure air for expansion through a hypersonic nozzle into the evacuated test cell. The combination of the arc heater driver, various nozzle/throat combinations, the evacuated test cell, and exhauster makes possible high-enthalpy flows at Mach numbers from 5 to 9. Direction and distribution of the injected air can be selected to optimize the enthalpy distribution across the flow to match specific test requirements. Run times of 30 minutes or longer are available in HEAT-H2 for selected operating conditions.



H3 arc heater



Nosetip material screening and evaluation in H1.

Externally cooled dual mode window survivability and performance test in arc heated test unit H-1.

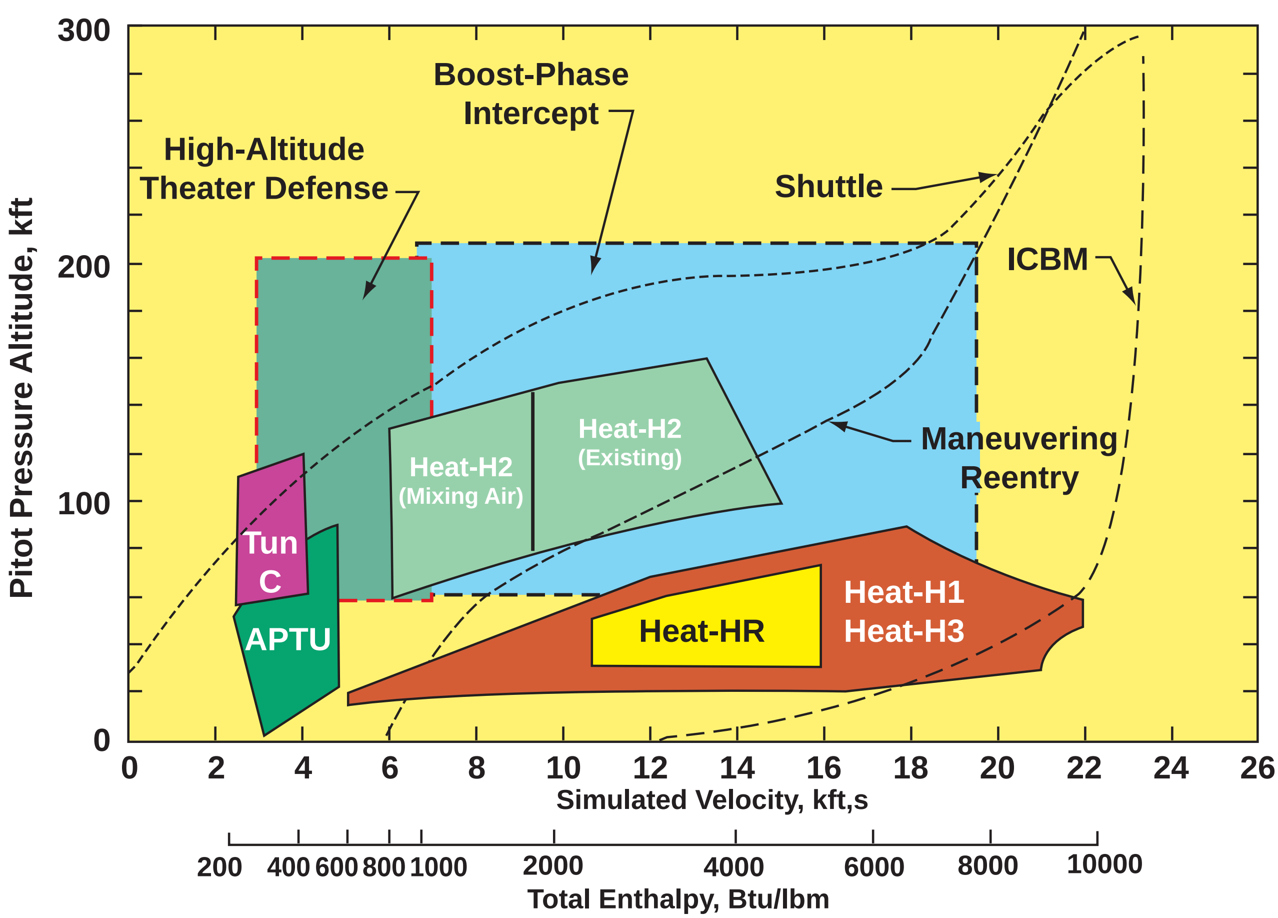
HEAT-H3 and the Arc Heater Development Program

A multi-year technology program at AEDC has resulted in development of the next generation high-pressure, high-enthalpy segmented arc heater. The primary objective of the program was design, development, and evaluation of a 3-inch bore segmented arc heater with operational performance up to 150 atm. The larger heater, designated H3, is currently active as a technology test bed heater, and is designed to eventually provide proportionately larger high-enthalpy flows for testing of materials, aerothermal structures, and hypersonic propulsion components.

Aerothermal Test Techniques

A variety of test techniques are used to evaluate material performance under realistic conditions. Typical test techniques include steady-state ablation testing of nosetip materials; nosetip boundary-layer transition tests during which the nosetip is subjected to a Reynolds number variation of a factor of five during the run; wedge tests where two-dimensional material samples are exposed to various pressure/heat-transfer rate combinations; combined ablation/erosion tests using graphite dust particles accelerated in the arc heater to high velocity; cooling-effectiveness tests on actively-cooled electromagnetic apertures or transpiration-cooled nosetips; and hot transmission testing of antenna window materials. The facility is under continuous development, and other special testing techniques, such as variation of nosetip/wedge angle-of-attack, rolling moment measurements, scramjet combustor testing, and other nonstandard test techniques can be implemented.

Recent testing in the AEDC arcs has included heat shield and nosetip materials tests in support of Air Force ICBM and Navy SLBM ballistic missile systems, combustor materials tests in support of Air Force hypersonic missile development, and materials and electromagnetic aperture tests in support of Army and BMDO hypersonic interceptor missile systems development. In addition, technology work has been ongoing in support of the H3 advanced segmented heater development program.



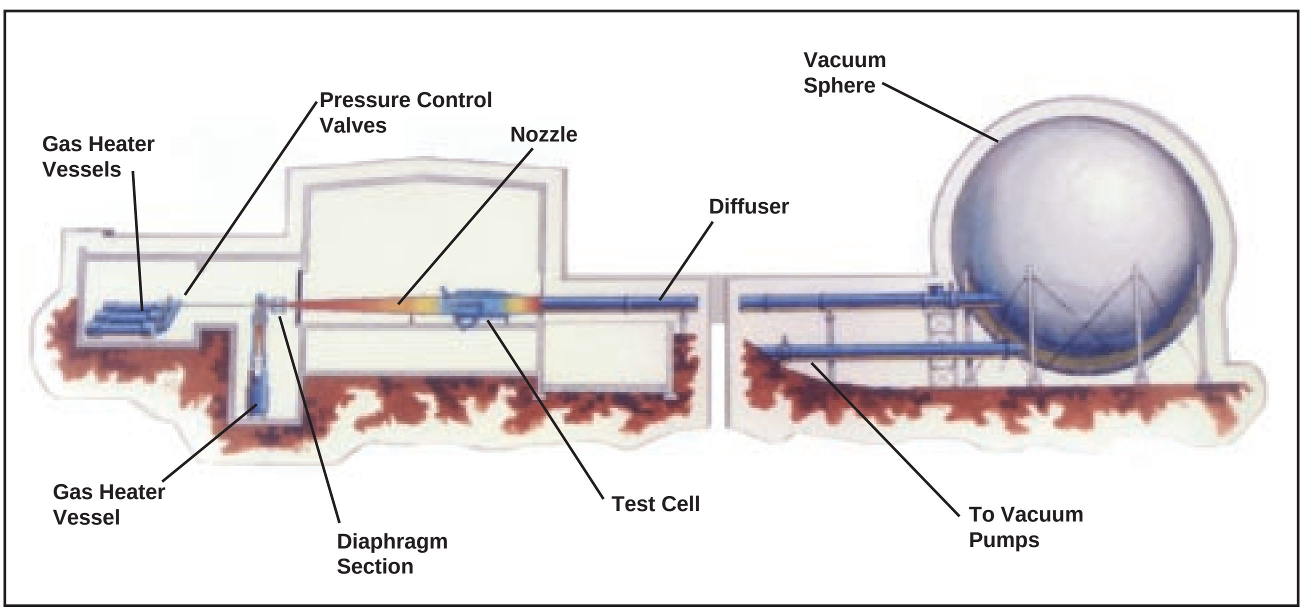
Hypervelocity Wind Tunnel 9 Facility

The Hypervelocity Wind Tunnel 9 Facility is the primary high Mach number, high Reynolds number facility for aerodynamic testing in the United States. This unique facility is located at the White Oak, Maryland site of AEDC.

The Hypervelocity Wind Tunnel 9 Facility provides aerodynamic simulation in critical altitude regimes associated with strategic offensive missile systems, advanced defensive interceptor systems, reentry vehicles, and hypersonic vehicle technologies.

Tunnel 9 is a blow down type facility with operational Mach numbers of 7, 8, 10, 14, and 16.5. This facility utilizes a unique storage heater which provides supply pressures up to 1430 atmospheres and supply temperatures up to 3460 degrees Rankine and sustains long-duration, constant-condition runs. Tunnel 9 contains two test legs to accommodate the multiple testing capabilities available at the facility. Each leg contains a test cell which is five feet in diameter and over twelve feet in length. These test cells can accommodate full-scale reentry bodies, full-scale endo-interceptors, and large-scale aerospace vehicles and hypersonic inlet models. With nominal test times up to 15 seconds, Tunnel 9 provides high test productivity by allowing parametric variations (such as angle-of-attack sweeps, control jet operations, window cooling operations, and/or flow surveys) on heavily instrumented models during a single run. The combination of constant test conditions, long test times, and large test cells at Tunnel 9 provides a meaningful, productive, and cost-effective test environment for aerodynamic, aerothermal, aerostructural, aero-optic, shroud removal, and hypersonic inlet experiments unavailable anywhere else.

Hypervelocity Wind Tunnel 9 is located at the White Oak, Maryland site of AEDC.



Tunnel 9 Testing Capabilities

Mach 7

Nominal Core Size: 8 inches
Reynolds Number Range: 1.8 to 16.7 million per foot
Run Time: 1 to 6 seconds

The Mach 7 Thermal/Structural Facility is located in one of the two test legs at Tunnel 9. This test leg provides a controlled ground test environment that duplicates actual Mach 7 flight conditions for altitudes as low as 34,000 feet for test times up to 6 seconds. Tunnel 9 is able to duplicate the thermal shock, peak heating, and thermal heat soak of actual flight for assessing the thermal and structural response of full-size seeker windows and radomes prior to flight testing. This capability is particularly important to endo-interceptor programs where sensor window survivability, cooling, mounting, and aero-optical performance are critical.

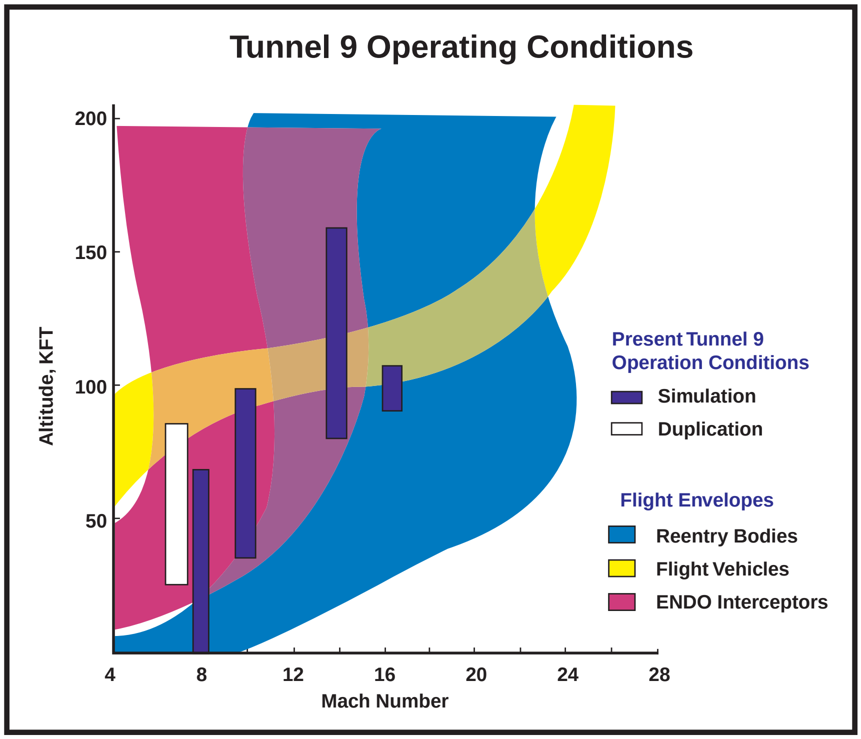
Mach 8

Nominal Core Size: 24 inches
Reynolds Number Range: 8.7 to 55.7 million per foot
Run Time: 0.2 to 0.75 seconds .

The Mach 8 test environment provides duplication of flight dynamic pressures up to 90 psia and maximum Reynolds Numbers of 56 million per foot. These test conditions are held constant for test times up to 0.75 seconds. The high dynamic pressures and long run times available at Mach 8 provide a critical testing capability in a controlled environment for interceptors and other programs utilizing shroud separation technologies.

Mach 10

Nominal Core Size: 40 inches
Reynolds Number Range: 0.86 to 21.9 million per foot
Run Time: 0.23 to 15 seconds

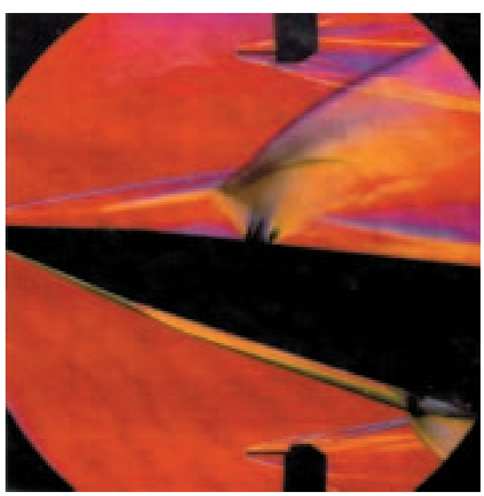


Mach 10 is a high Reynolds Number testing environment which provides naturally occurring turbulent boundary layers on the models. Computer-controlled pitching of the model and programmable blowing systems allow variations in test parameters during a single wind tunnel run.

Mach 14 & Mach 16.5

Nominal Core Size: 35 inches
Reynolds Number Range: 0.072 to 6.2 million per foot
Run Time: 0.7 to 15 seconds

The Mach 14 and Mach 16.5 test environments achieve both high Reynolds Numbers and high Mach Numbers coupled with long run times to provide critical altitude simulations needed by reentry and hypersonic technology programs. Parametric testing can be performed during a single wind tunnel run by utilizing the programmable blowing and computer-controlled pitching systems.



Above--Aero-optic Testing of interceptor forebody.
Left--Jet Interaction Control Testing of Hypersonic Vehicle.

Impact & Lethality Testing

Since 1963 AEDC has conducted more than 7000 hypervelocity ballistic range shots in its Hypervelocity Gun Range facilities. With completion of a major launcher upgrade in FY94, Range G became the largest routinely operated 2-stage, light-gas gun system in the nation.

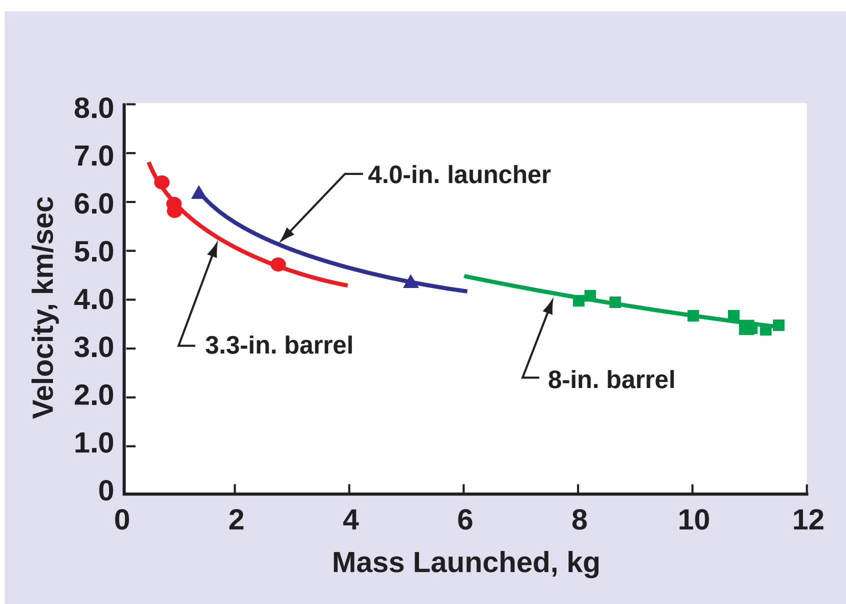
The system provides an unequalled "soft launch" (minimized acceleration loading) that permits the launching of extremely high-fidelity missile simulations at hypervelocity speeds.

Additional upgrades in FY95-FY97 added optional launch tubes of 4- and 8-in. diameter and extended the operational envelope to include projectiles that model near-full-scale missile designs.

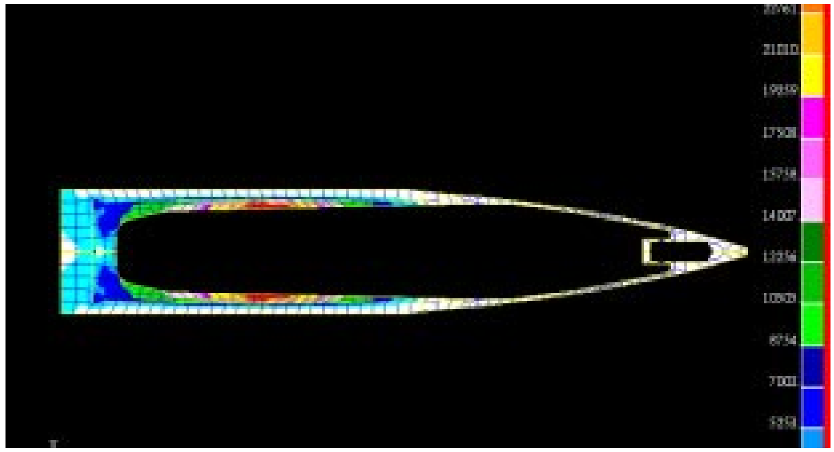
Range G Upgraded Launch System.

The primary challenge in designing projectiles for gun-range lethality testing is to develop a geometrically-scaled-projectile that matches, with sufficient fidelity, the axial and radial mass distribution of the actual missile, yet possesses adequate integrity to withstand the acceleration loads experienced during gun launch. Recent upgrades using 2-D and 3-D finite element analysis software (FEAMOD) coupled with AUTOCAD, the AEDC launcher code, and the graphical user interface tools of PATRAN provide a seamless design path that permits AEDC engineers to analyze proposed projectile designs in a simulation of the dynamic environment of launch. The analysis simulates stress wave propagation through the projectile body, characterizing by color schemes, stress concentrations which exceed material yield. With marginal areas identified, design changes are incorporated which minimize the probability of projectile failure during launch.

The increasing demand for lethality test capabilities that comply with "Live Fire" engagement scenarios continue to be met by innovative techniques designed to control projectile flight dynamics. During FY97, a cold-gas, jetting technique for pitch inducement was refined to a level of reliability that the technique has become a standard for lethality testing. Using up to 2000 psi of argon gas, stored within the projectile body, a predictable thrust vector is developed as the gas escapes through an orifice located in the side of the projectile nosetip. Release of the gas is initiated at launch by an

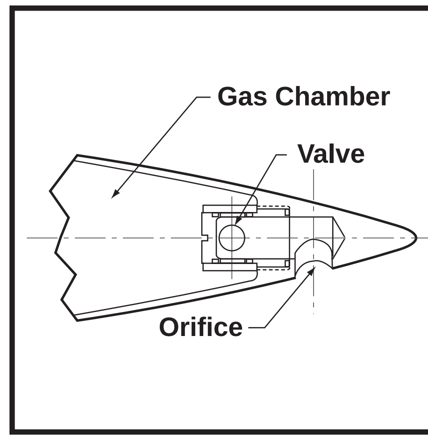


inertia activated valving system. Pitch amplitude at impact is controlled by variations in initial gas pressure and flight distance to target.



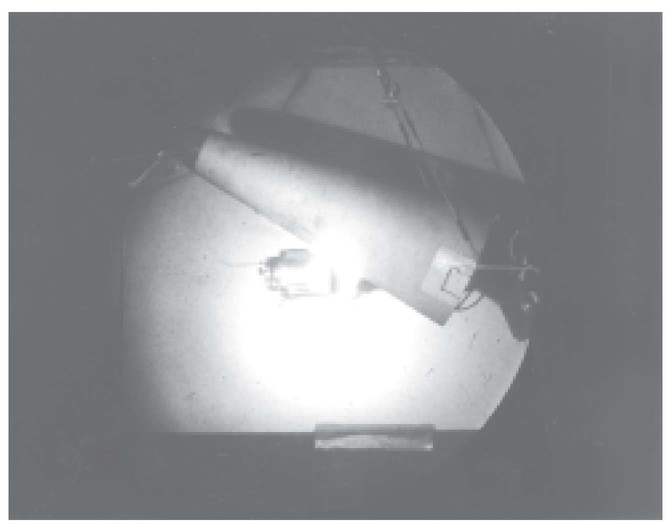
Computer Graphic Illustration of stress wave propagation through base of Range G Test Article.

An AEDC Machinist prepares to load a gasjet projectile into the breech of the new 4-in.-diameter launch tube.



Gasjet model nosetip design shows control valve and orifice.

Jetting action of gasjet projectile is shown as the projectile exits the launcher muzzle.



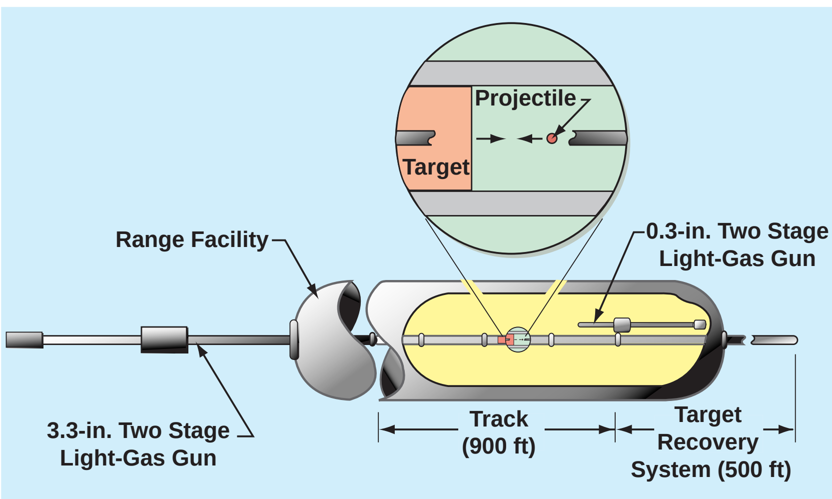
Attaining the required pitch amplitude, the gasjet projectile approaches the designated target.

Hypervelocity (7-15 km/sec) Impact Test Capability

High-speed impact testing has been limited to speeds less than 7 km/sec by performance limitations inherent in the two-stage light-gas guns which are generally used to accelerate impact models. Since space debris encounters and extoamoshperic kinetic-energy-weapons intercepts occur at much higher velocities (approaching 17 km/sec), considerable risk has been associated with extrapolating existing impact-test lower-speed results during design of various space systems. For several years, AEDC has been actively engaged in developing the counterfire technique to increase the velocity at which impact studies can be conducted. In the counterfire technique, a target model is launched at up to 7 km/sec from the 3.3 inch diameter range launcher. The target flies down the G-range track to an "impact zone" near the end of the Range test tank. At the appropriate time as determined by a fully automated, computer-based sequencing system, a second 0.33" dia. Launcher, located at the end of the range test tank and aimed in a direction opposing the G-Range launcher is fired such that its small projectile impacts the target model in the "impact zone." Since the small, counterfired projectile is traveling at speeds of up to 8.5 km/sec, the resultant impact occurs at relative velocities exceeding 15 km/sec. Following the impact event, the target model proceeds down the track into the recovery system at the end of the track, and the target model is recovered intact for post-test analysis and evaluation.

In fiscal year 1994, four counter fire impacts were generated with two of the target models being successfully recovered.

The counterfire technique is now operational and is available on a routine basis.



G-Range counterfire configuration

Pretest "semi-infinite" aluminum target and post test recovered target following counter-fire-impact at 12.2 km/sec.

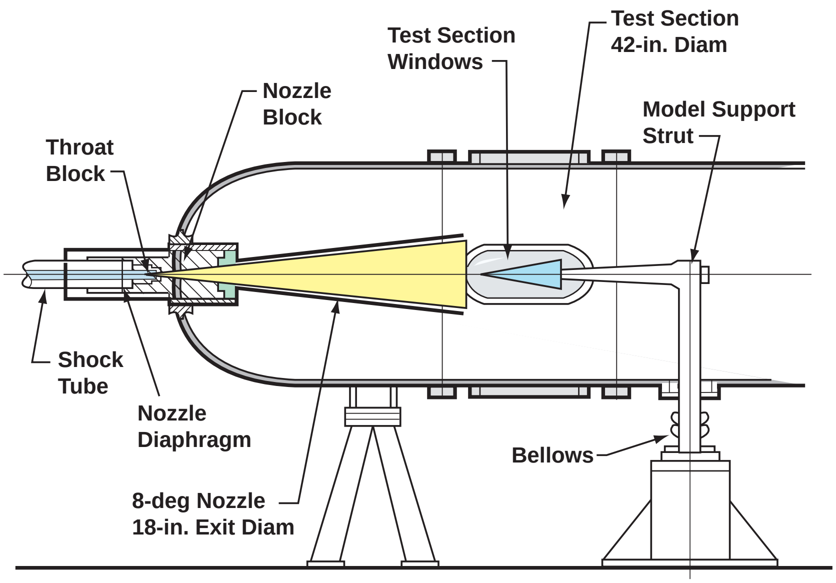
Multi-plate target and post test recovered target following counter-fire impact at 12.2 km/sec.

Hypersonic Gas Test Capability Development Facility

As part of the recent upgrade to AEDC Range complex, an existing two-stage light gas launcher was modified to become a free piston shock tunnel. Designated the AEDC Impulse tunnel, the new facility uses an explosively-driven free piston to drive a shock tube in a manner similar to the technique pioneered by Stalker in Australia. When developed to full capability, the Impulse tunnel will provide unequaled capabilities for studying hypersonic real-gas aerodynamic and combustion/propulsion effects at very high Mach number conditions. The on-going facility development program has six objectives:

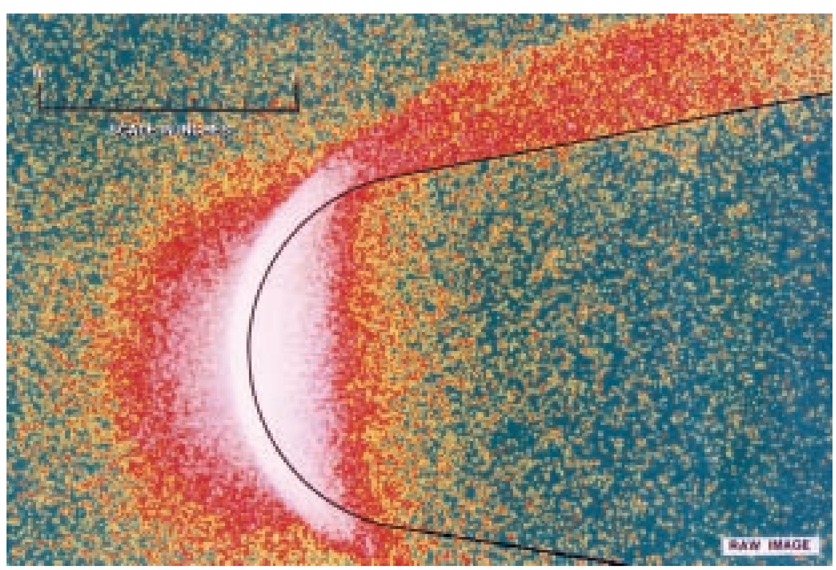
1. Design and verify performance of diaphragms to over 100 kpsi.
2. Perform initial shakedown and calibration of the facility to pressures in excess of 20 kpsi.
3. Develop a math model for predicting facility performance.
4. Continue development to higher pressures with an ultimate goal of 100 kpsi or higher.
5. Develop tools and techniques to analyze, design, and fabricate nozzle throats capable of surviving the severe aerothermal environment this facility is capable of producing.
6. Characterize free-stream flow quality in the test section using intrusive and nonintrusive measurement systems and techniques.

Test Section and Model Support for Impulse Tunnel



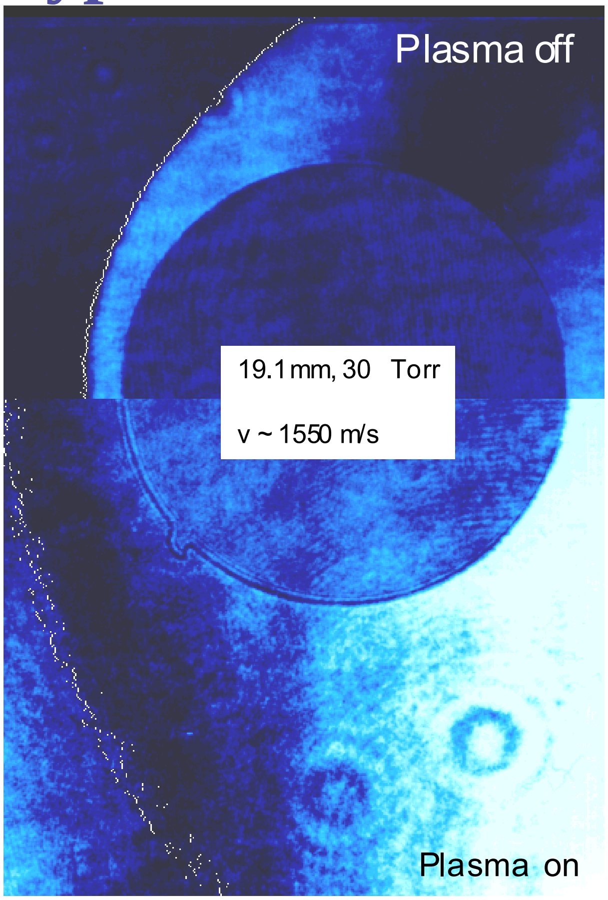
Hypersonic diagnostics

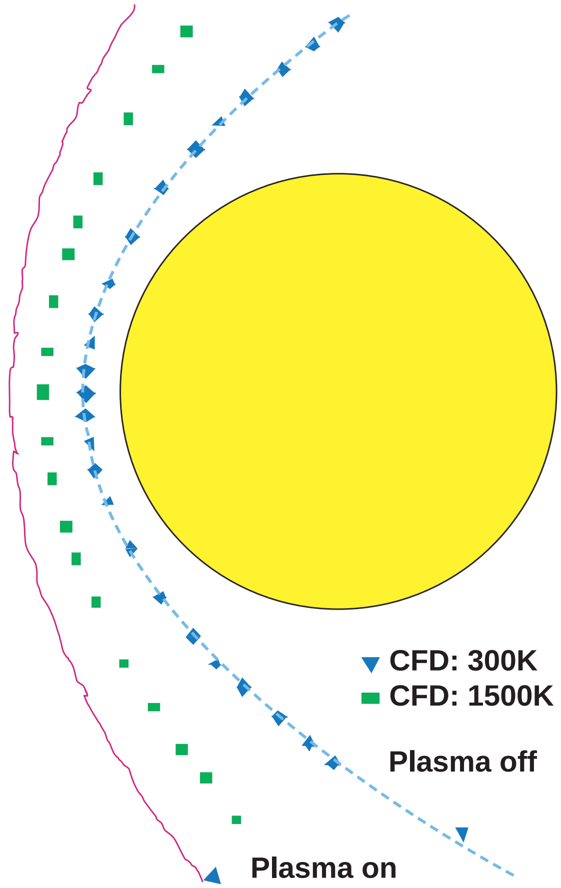
In concert with development of the AEDC Impulse tunnel, a very aggressive, multi-year program has been implemented to develop techniques to fully characterize the flow produced by the impulse tunnel as well as our other aerodynamic test facilities. Advances in applied laser technology have resulted in the recent development of a number of electro-optical systems that permit nonintrusive measurements in the hostile aerothermal environment of supersonic and hypersonic facilities. A notable feature of these new systems in addition to being mechanically nonintrusive, is that they often provide measurements that cannot be provided by intrusive devices. Operational systems available for use include: pulse holography, Fourier transform holographic interferometry, planar laser induced fluorescence (PLIF), and electron beam fluorescence. By applying these instruments and techniques, the quality of the facility flow (static conditions, species concentrations, run time, etc.) can be fully characterized as well as the flow surrounding the model in the test section.



Preliminary image of a calibration cone model.

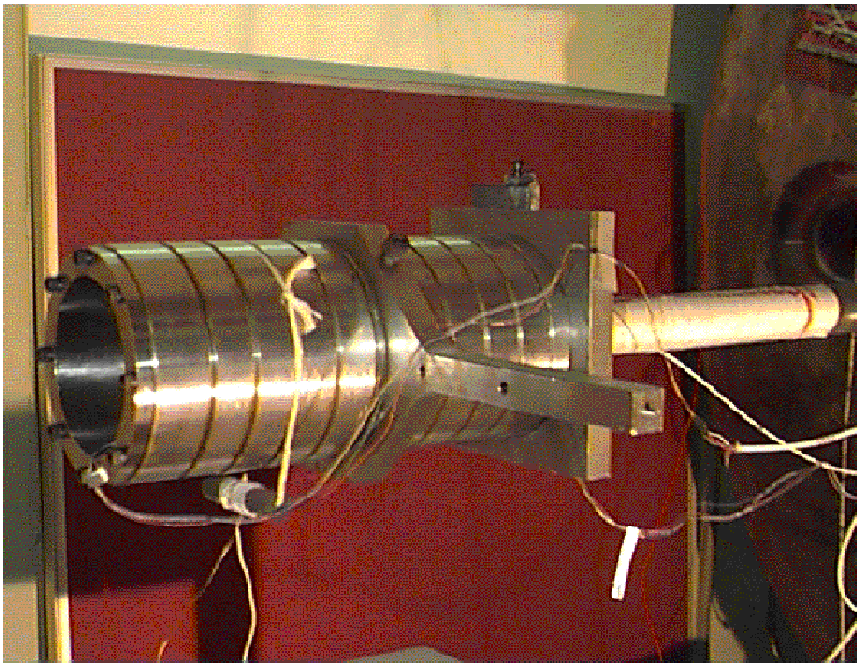
Hypersonic Technology Advancements





Ballistic Tests Performed in a Plasma Environment

A test program was undertaken at AEDC to investigate previously reported measurements of anomalous shock standoffs in weakly ionized gases. A Confirmation of the anomalous shock standoffs was obtained, and efforts were subsequently directed towards separating the effects of ionization from the effects of gas temperature on the shock profile. The AEDC tests, sponsored by Air Force Office of Scientific Research (AFOSR), will help explain the physics physical interaction of the plasma in an aerodynamic environment.



Laboratory Hardware

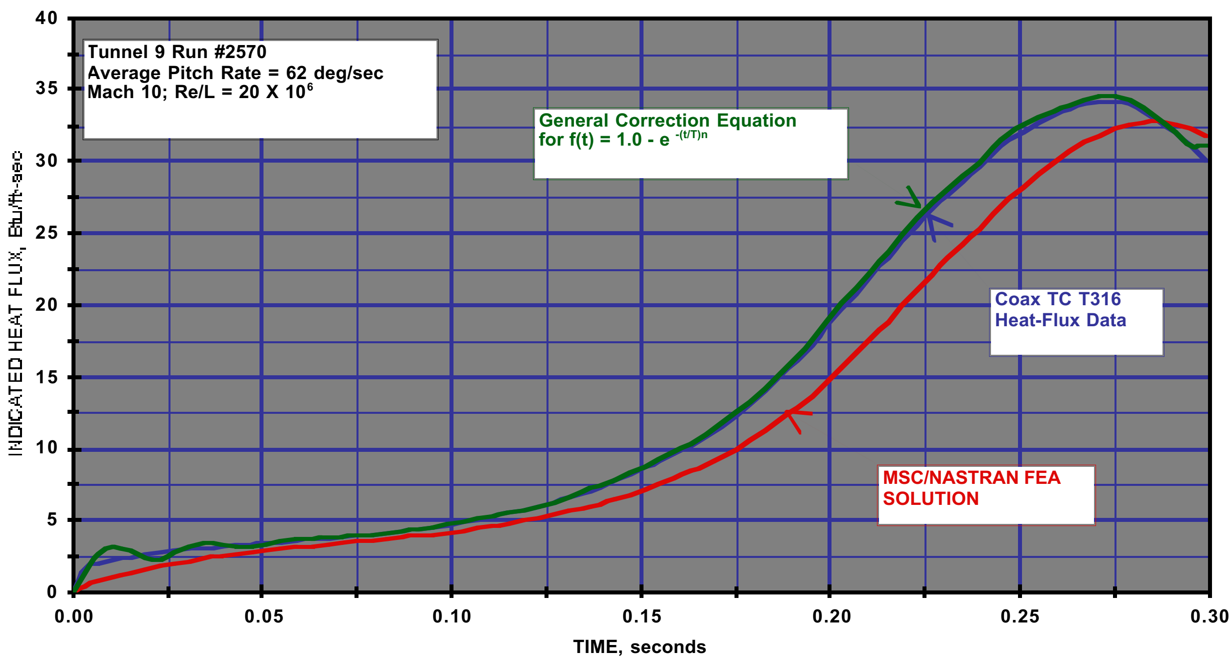
Hypersonic Diagnostics

Additional effects are being focused in advance test methologies for obtaiing wind tunnel experimental data on time dependdant aerodnamic phenomina. Highly maneverable systems using trust vector control /divert and attitude control systems jet controls will require high fideltiy time dependant measurements to devevlop robust flight control systems.

New Heat Transfer Testing Technique:

AEDC has completed a series of tests baslineing heat transfer gages at both VKF Tunnel B and the Tunnel 9 measurement systems. The successful completion of this effort will allow AEDC to offer testing of heavily instrumented models in Tunnels B/C and then run at Tunnel 9 without changing any instrumentation. The primary challenge was to develop miniature heat flux gages with time responses fast enough to run in Tunnel 9. The other challenge was to ensure sufficient sensitivity in the gauges to measure low heating levels in Tunnel B. All of these things combined will give the customer more quality. This new system will provide higher productivity and data quality for heat transfer testing.

Figure 13 Tunnel 9 Corrected Heat Flux Data Using S-B Gage FEA Model



AEDC Test Facilities
(Nominal Values)

ENGINE TEST FACILITY	Test Section Size: Cross Section, ft	Test Section Size: Length, ft	Total Temperature, °R	Speed Range	Pressure Altitude (Nominal), ft	Capacity of Installed Thrust Stand, lb	Primary Use*
Propulsion Development Test Cell T-1	12.3 diam	39 to 57	380 to 1,110	Mach 0 to 3.0	Sea Level to 80,000	30,000	(2) (6) (9)
Propulsion Development Test Cell T-2	12.3 diam	42 to 50.5	380 to 1,110	Mach 0 to 3.0	Sea Level to 80,000	30,000	(2) (6) (9)
Propulsion Development Test Cell T-3	12 diam	15	450 to 1,660	Mach 0 to 4.0	Sea Level to 100,000	20,000	(2) (3) (6) (9) (11)
Propulsion Development Test Cell T-4	12.3 diam	39 to 47.8	380 to 1,110	Mach 0 to 3.0	Sea Level to 80,000	50,000	(2) (6) (9)
Propulsion Development Test Cell T-5 ***	7 diam	17	395 to 660	Mach 0 to 2.0	Sea Level to 80,000	2,000	(2) (6) (9)
Propulsion Development Test Cell T-6 ****	3 diam	18	430 to 760	Mach 0 to 3.0	Sea Level to 90,000	None	(1) (3) (4) (6) (7) (11)
Propulsion Development Test Cell T-7 ***	7 diam	9	395 to 1,110	Mach 0 to 3.0	Sea Level to 80,000	1,000	(2) (6) (9)
Propulsion Development Test Cell T-11	10 x 10	17	395 to 860	Mach 0 to 2.0	Sea Level to 80,000	2,000	(2) (6) (9)
Propulsion Development Test Cell T-12	10 diam	20	396 to 860	Mach 0 to 2.0	Sea Level to 80,000	None (7,000 hp)	(2) (6) (9)
Propulsion Development Test Cell J-1	16 diam	65	395 to 1,210	Mach 0 to 3.2	Sea Level to 80,000	50,000	(2) (3) (6) (9)
Propulsion Development Test Cell J-2	20 diam	67.3	395 to 1,110	Mach 0 to 3.0	Sea Level to 80,000	50,000	(2) (3) (6) (9)
Propulsion Development Test Cell J-2A****	18.3 diam	32	(Wall, 144)	Static	450,000	20,000	(1) (5) (11)
Rocket Development Test Cell J-3	12 diam 17 diam	26 High 20, 30, 40 High	– – –	Static	125,000	200,000	(1) (5)
Rocket Development Test Cell J-4	48 diam	82 High	– – –	Static	100,000	500,000	(1) (5) (11)
Rocket Development Test Cell J-5 ***	16 diam	50	– – –	Static	100,000	300,000	(1) (5) (11)
Rocket Development Test Cell J-6	26 diam	62	– – –	Static	100,000	500,000	(1) (5) (11)
Sea Level Test Cell SL-1	24 x 24	50	Ambient	Static	Sea Level	52,500	(2)
Sea Level Test Cell SL-2	24 x 24	57	395 to 720	Mach 0 to 1.1	Sea Level	25,000	(2) (6) (9)
Sea Level Test Cell SL-3	24 x 24	57	395 to 720	Mach 0 to 1.1	Sea Level	25,000	(2) (6) (9)
Propulsion Development Test Cell C-1	28 diam	50 to 85	360 to 1,480	Mach 0 to 3.8	Sea Level to 100,000	100,000	(2) (3) (6) (9)
Propulsion Development Test Cell C-2	28 diam	50 to 85	360 to 1,110	Mach 0 to 3.0	Sea Level to 100,000	100,000	(2) (6) (9)

von KARMAN GAS DYNAMICS FACILITY	Test Section Size, in.	Total Pressure, psia	Total Temperature, °R	Speed Range	Pressure Altitude, ft	Dynamic Pressure, psf	Reynolds No./ft (x10^6)	Primary Use*
Supersonic Wind Tunnel A	40 x 40	1.5 to 200	530 to 750	Mach 1.5 to 5.5	16,000 to 151,000	53 to 1,780	0.3 to 9.2	(6) (7) (14)
Hypersonic Wind Tunnel B	50 diam	20 to 900	700 to 1,350	Mach 6 to 8	98,000 to 180,000	43 to 590	0.3 to 4.7	(6) (7) (14)
Hypersonic Wind Tunnel C	50 diam	200 to 1,900	1,650 to 1,950	Mach 10	132,000 to 188,000	43 to 430	0.3 to 2.4	(6) (7) (14)
Aerothermal Wind Tunnel C	25 diam Free Jet 25 diam Free Jet	200 to 2,000 20 to 180	1,220 to 1,900 720 to 1,660	Mach 8 Mach 4	95,000 to 149,000 56,000 to 105,000	132 to 1,322 231 to 1,928	0.7 to 7.8 0.2 to 8.1	(6) (7) (13) (6) (7) (13)
Aerodynamic and Propulsion Test Unit (APTU)	32 diam 36 diam 42 diam Free Jet 	20 to 160 20 to 300 40 to 300 20 to 240 50 to 300	700 to 1,000 700 to 1,200 700 to 1,300 700 to 1,150 700 to 1,600	Mach 2.20 Mach 2.72 Mach 3.50 Mach 2.55 Mach 4.10	Sea Level to 40,000 10,000 to 70,000 35,000 to 75,000 Sea Level to 65,000 55,000 to 80,000	900 to 7,300 600 to 9,300 650 to 4,800 700 to 8,500 500 to 2,900	3.15 3.16 1.10 2.17 1.6	(1) (3) (4) (6) (7) (9) (11) (12) (13)
Hypervelocity Range/Track G	120 diam	– – –	– – –	To 24,000 fps	Sea Level to 244,000	– – –	– – –	(8) (10)
Hypervelocity Impact Range S1	Target Tank 30 diam	– – –	– – –	To 32,000 fps	Sea Level to 10^5 torr	– – –	– – –	(10)
Bird Impact Range S3	240 x 144	– – –	– – –	200 to 1,400 fps	Sea Level	– – –	– – –	(10)

	Contoured Nozzle	Reynolds No./ft (x10^6)	Supply Pressure Range, atm	Nominal Supply Temp, °R	Usable Run Time, sec
TUNNEL 9	7	3.7 to 15.8	180 to 815	3,460	1 to 5
	8	8.7 to 55.7	135 to 815	1,660	0.2 to 0.75
	10	0.86 to 21.9	35 to 955	1,810	0.2 to 15
	14	0.072 to 6.2	7 to 1,295	3,160	0.7 to 15
	16.5	2.65 to 3.2	1,295 to 1,430	3,260	3.0 to 3.5

	Nozzle Exit Diameter, in.	Model Enthalpy, Btu/lb	Model Pilot Pressure, atm	Mach Number	Erosion Simulation: Dust Particle Diameter, μm	Erosion Simulation: Dust Velocity, fps	Primary Use*
High Enthalpy Ablation Test Unit (HEAT) H1	1.8 to 3.5	2,000 to 9,000	17 to 95	0.75 to 3.00	70 to 200 Graphite	5,800 to 7,300	(13)
High Enthalpy Ablation Test Unit (HEAT) HR **	1.8 to 3.2	2,000 to 5,200	19 to 77	1.1 - 4.0	– – –	– – –	(13)
High Enthalpy Ablation Test Unit (HEAT) H2	4 - 9.8	0.896 to 2,278	0.14 to 3.4	4.0 to 8.0	– – –	– – –	(7) (13)

	System	Type	Size	Max. Specimen Weight, lb	Max. g	Remarks	Primary Use*
Impact, Vibration, and Acceleration Test Unit ****	Vibration	Electrodynamic Ling A249	30-in. diam	2,800 at 10 g rms	75	30K-lb Max. Sine Force 32K-lb Max. Random Force 5.2 kHz, 1.0 in. Double Amp	(1)
	Shock	Electrodynamic Ling A249	30-in. diam	2,000	– – –	Pulse Shapes: Sawtooth, Half-Sine, etc.	
		Parallel-Pendulum	– – –	1,000	– – –	Travel, 2 ft	
	Acceleration	Centrifuge	17-ft rad	2,000	30	– – –	

USE LEGEND: * Testing of (1) Rockets, (2) Turbojets (3) Ramjets (4) Missile Base Heating Models, (5) Space Environmental Tests, (6) Aerodynamic Models, (7) Aerothermodynamic Models, (8) Aeroballistic Models, (9) Combined Aerodynamic Inlet and Propulsion System Tests, (10) Impact Studies, (11) Free-Jet Expansion of Rocket Exhaust Plumes, (12) Ablative Materials, (13) Ablative and Erosive Materials, (14) Store/Stage Separation

** Currently Mothballed
*** Standby Status
**** Currently Non-Operational

10/98

AEDC Test Facilities
(Nominal Values)

AEROSPACE CHAMBERS	Test Section Size: Cross Section, ft	Test Section Size: Length, ft	Wall Temp., K	Chamber Empty Pressure, torr	Pressure Altitude, miles (1962 U.S. Std Atm)	Thermal Radiation Simulation	Primary Use*
Mark I	42	(Vert.) 82	77	10^{-7}	210	Collimated Solar and Programmed Heat Flux	(5)
10V	10	(Vert.) 30	77	10^{-7}	200	Tungsten Lamps	
12V	12	(Vert.) 35	77	10^{-7}	200	8-ft-diam Xenon Solar and Programmed Tungsten Lamps	
7V	7	24	<20	10^{-7}	200	N/A	
FPCC	5	5	<20	10^{-7}	200	N/A	
DWSG	Varies	Varies	<20	N/A	200	N/A	
BRDF	3	5	AMB	10^{-5}	AMB	N/A	
COP	2	3	77	10^{-5}	200	N/A	
SAM	2	15	77	10^{-7}	200	Xenon Lamp	
SMOG	2	1	AMB	10^{-5}	AMB	N/A	
7A	3	5	<20	10^{-7}	200	– – –	
UHV	2	3	<20	10^{-7}	200	N/A	
4 X 10	4	10	<20	10^{-7}	200	– – –	
CROVAC	Varies	1	<20	10^{-7}	200	N/A	
DECADE	10-13k Rad(Si), 10,000 cm^2 target area, 1.5 by 2 m test articles in chamber						

PROPULSION WIND TUNNEL FACILITY	Test Section Size: Cross Section, ft	Test Section Size: Length, ft	Total Temperature, °R	Speed Range	Pressure Altitude (Nominal), ft	Dynamic Pressure, psf	Reynolds No./ft ($x10^{-6}$)	Primary Use*
Propulsion Wind Tunnel 16T	16 x 16	40	540 to 600	Mach 0.06 to 1.6	Sea Level to 90,000	2 to 1,100	0.2 to 6.0	(6) (9) (14)
Propulsion Wind Tunnel 16S ***	16 x 16	40	580 to 1,080	Mach 1.5 to 4.75	45,000 to 155,000	25 to 550	0.1 to 2.4	(6) (7) (9) (14)
Aerodynamic Wind Tunnel 4T	4 x 4	12.5	540 to 600	Mach 0.2 to 2.0	Sea Level to 65,000	20 to 1,400	2.0 to 7.0	(6) (14)

USE LEGEND: * Testing of (1) Rockets, (2) Turbojets (3) Ramjets (4) Missile Base Heating Models, (5) Space Environmental Tests, (6) Aerodynamic Models, (7) Aerothermodynamic Models, (8) Aeroballistic Models, (9) Combined Aerodynamic Inlet and Propulsion System Tests, (10) Impact Studies, (11) Free-Jet Expansion of Rocket Exhaust Plumes, (12) Ablative Materials, (13) Ablative and Erosive Materials, (14) Store/Stage Separation

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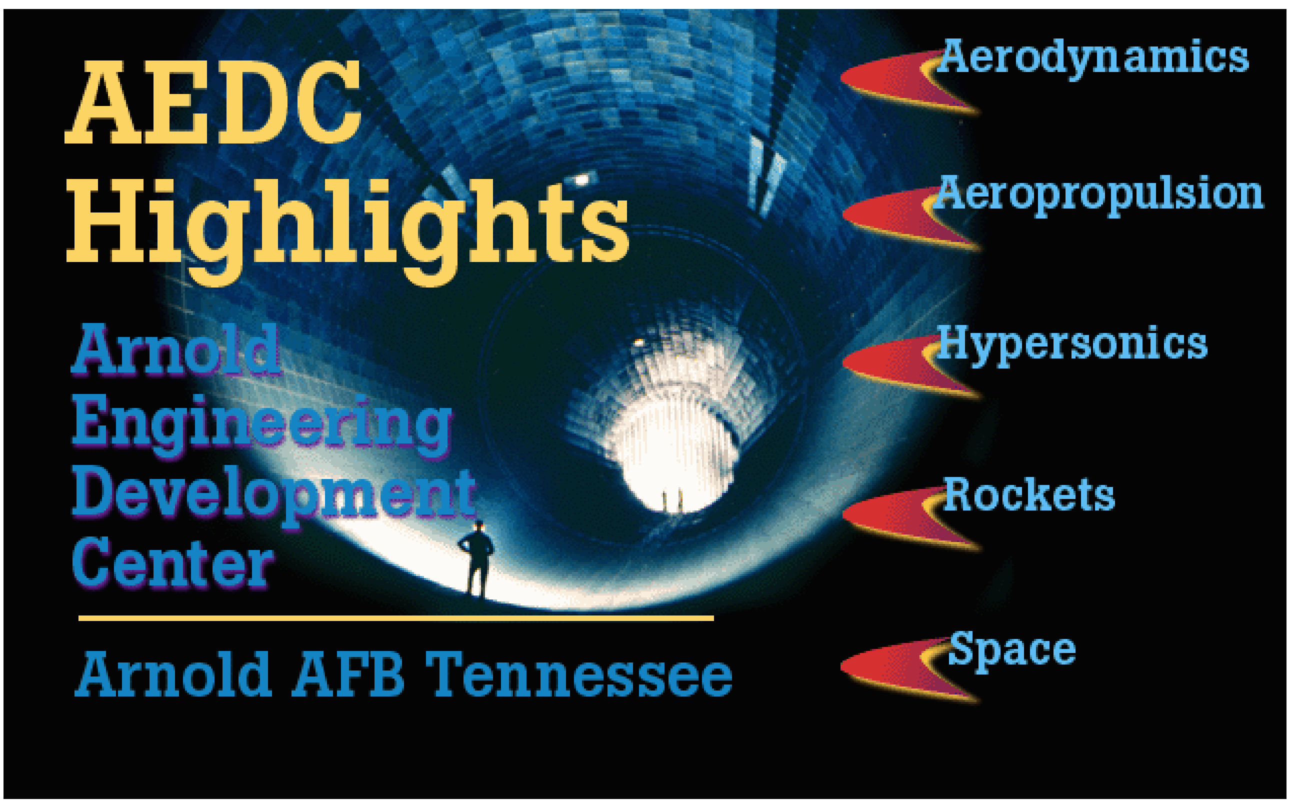

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