Arnold Engineering Development Complex
TEST CAPABILITIES GUIDE

An Air Force Test Center
Test Complex

AEDC THROUGH THE YEARS

The 1940s

November 1944
- Gen. Henry "Hap" Arnold directs formation of the Scientific Advisory Group.

June 1945
- *Trans-Atlantic Memo* proposes the Air Engineering Development Center.

December 1945
- Dr. Theodore von Kármán's report *Toward New Horizons* lays the foundation for an Air Force research and development program.

September 1947
- The US Air Force becomes a separate military service.

April 1948
- The former Army training area Camp Forrest is named as the site for the Air Engineering Development Center.

1949
- Congress authorizes $100 million for the construction of the Air Engineering Development Center.

The 1950s

March 1950
- The Secretary of Defense approves construction of the new facility.

June 1950
- The Army Corps of Engineers begins construction on a perimeter fence and access road.
- Work begins on a dam on the Elk River to create a reservoir to provide cooling water for testing facilities.

June 1951
- President Harry S. Truman dedicates the facility in honor of five-star General of the Air Force Henry "Hap" Arnold, naming it the Arnold Engineering Development Center.

October 1952
- PeeWee, a 1-foot wind tunnel built to identify problems in the 16-foot tunnels, goes into operation at AEDC.

1953
- Construction on the Engine Test Facility is completed.

September 1953
- The Falcon guided missile is placed in the test section of tunnel E-1 and is tested at nearly five times the speed of sound.

1954
- The first engine, a J47 turbojet for the B-47 bomber, is tested at a simulated altitude of 30,000 feet.

April 1954
- The first issue of *High Mach*, the center's employee newspaper, is published.

March 1957
- Escape velocity, the speed needed to leave Earth's gravity, is reached in the Gas Dynamics Facility's Hotshot 2 tunnel.

November 1957
- A jet engine is tested in the new Propulsion Wind Tunnel, validating the larger transonic wind tunnel design.

July 1959
- The supersonic circuit of the PWT facility is completed.

October 1959
- A facility designed for testing aerospace designs at high speeds is dedicated to Dr. Theodore von Kármán as the von Kármán Gas Dynamics Facility.

The 1960s

January 1961
- The supersonic circuit of PWT is accepted by the Air Force.

June 1961
- Air Force Secretary Eugene Zuckert comes to AEDC to break ground for J-4, the world's largest rocket altitude cell.

December 1963
- The Air Force accepts both the J-4 and J-5 rocket test cells.
- The first rocket engine – a Skybolt – is fired in J-5.

1964
- The J-4 Large Rocket Engine Test Facility is dedicated.

1968
- A 4-foot transonic wind tunnel is added to the PWT facility.

May 1969
- The McDonnell Douglas F-15 begins testing in the 16-foot supersonic wind tunnel.

The 1970s

1972
- A design contract is awarded for construction of the new Aeropropulsion Systems Test Facility.
- A launcher to determine the effect of impacts of birds on high-speed aircraft is developed.

1976
- The U.S. Department of the Interior registers AEDC as a unique, natural area.

CONTINUED ON INSIDE OF BACK COVER.

ARNOLD ENGINEERING DEVELOPMENT COMPLEX

The Arnold Engineering Development Complex, part of the Air Force Test Center (AFTC), proves the superiority of systems required to meet the demands of the National Defense Strategy.

Headquartered at Arnold Air Force Base in Tennessee, the Complex also includes geographically separated units in California, Colorado, Florida, Maryland, New Mexico, Ohio and Utah.

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TEST DIVISION

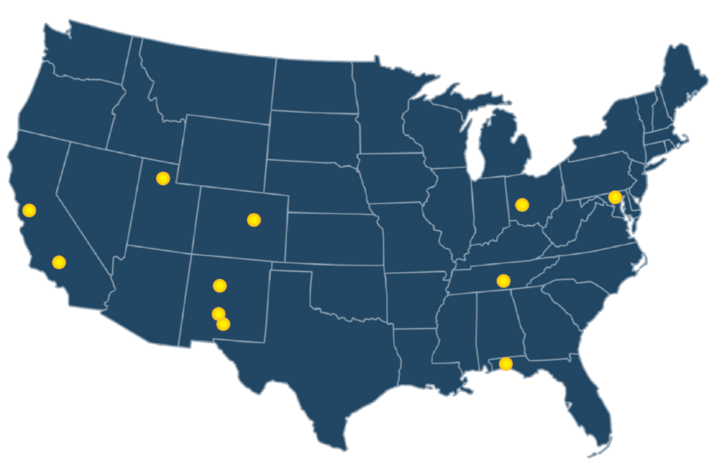
704TH TEST GROUP

AEDC MISSION

To prove the superiority of systems required to meet the demands of the National Defense Strategy

AEDC VISION

Second to none!



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TEST DIVISION

DOING BUSINESS WITH THE TEST DIVISION

AEDC offers extensive test and evaluation capabilities, and our team is focused on providing the best possible data and a positive test experience for our customers. The AEDC test capabilities can be used by government, private industry and academia.

The following steps summarize how typical test programs are planned and conducted by Team AEDC:

1. The customer contacts an AEDC representative to inquire about our test and evaluation services. Lead time for using AEDC capabilities is primarily based on test complexity and can range from two weeks for less complex tests to 24 months for very complex ones.
2. AEDC provides an initial rough order of magnitude (ROM) cost estimate and schedule availability for customer inquiries.
3. If the estimated cost and schedule are acceptable to the customer, AEDC requires that a test request be submitted.
4. AEDC contacts the customer to determine schedule dates and set up the initial pretest meeting. The customer is required to provide AEDC advanced funding for initial project planning and estimating.
5. After the initial pre-test meeting, the customer provides a detailed test plan containing the test objectives, scope, schedule, desired test program matrix, test article descriptions, instrumentation, data reduction and analysis requirements. AEDC prepares a statement of capability (SOC) or contract using this information, which will be the formal agreement between AEDC and the customer for test requirements scope, schedule, risks and costs.
6. Once the SOC or contract has been signed, the balance of test funding is required by AEDC to proceed.
7. AEDC test branch representatives will work closely with the test customer throughout the test planning phase to review and finalize the test plan, test matrix, and data reduction and analysis requirements, and prepare the necessary documents to schedule test periods and configure all systems to support testing.
8. The AEDC Customer Service Representative (CSR) assists the customer with getting on base using the visit authorization letter (VAL) process, accessing AEDC computers, long distance access when at an AEDC location and general AEDC and local area information. Customers are free to contact the CSR at any time with questions.
9. During the testing process, the customer is billed for actual charges and costs for facility operations.
10. Once the test has been completed, AEDC provides analyses and data products as detailed in the SOC or contract.

For assistance or additional information about AEDC, visit our website: www.arnold.af.mil or contact the AEDC Public Affairs Office at Arnold.AEDC.PA@us.af.mil or call (931) 454-4204.

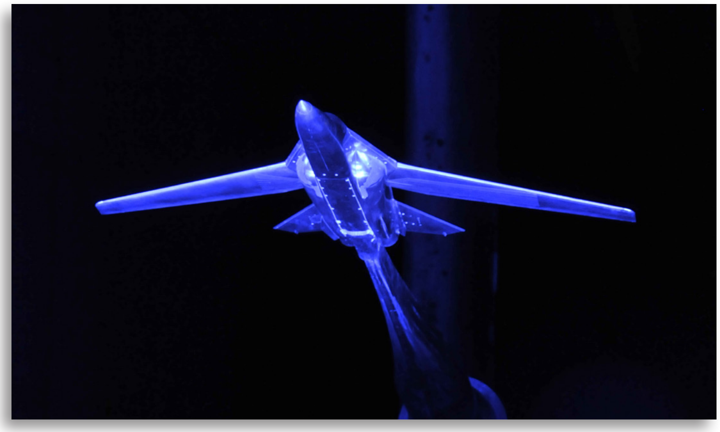
AERODYNAMICS TEST BRANCH

The Aerodynamics Test Branch of AEDC provides aerodynamic effects and captive trajectory ground-test capabilities through the operation of nine wind tunnels from subsonic to hypersonic speeds at simulated altitudes. AEDC utilizes these capabilities to deliver decision-quality data and analysis to U.S. government, U.S. industry and international partners.

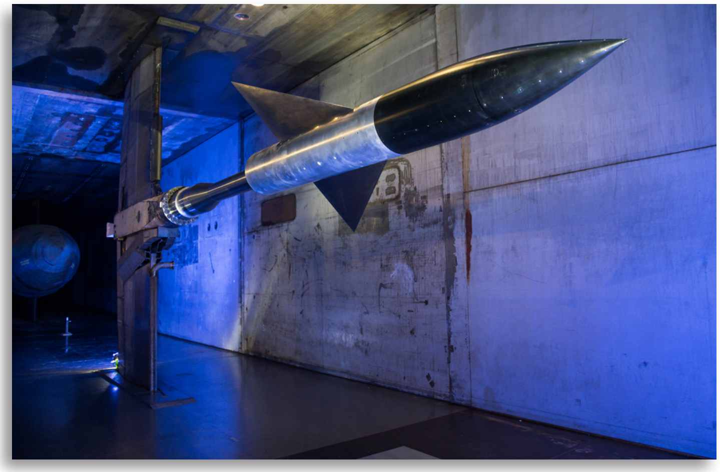
The wind tunnels in the Propulsion Wind Tunnel Facility (PWT), the von Kármán Gas Dynamics Facility (VKF), Hypervelocity Wind Tunnel 9 and National Full-Scale Aerodynamics Complex (NFAC) are used to support test and evaluation in many areas, including vehicle aerodynamic performance evaluation and validation, weapons integration, inlet/airframe integration, exhaust jet effects and reaction control systems, code validation, proof-of-concept, large- and full-scale component research and development, system integration, acoustics, thermal protection system evaluation, hypersonic flow physics, space launch vehicles, operational propulsion systems and captive flight.

An extensive inventory of instrumentation is available, including force and moment balances, heat flux gauges and electronically-scanned pressure modules. The Branch can provide design, fabrication and calibration services of select instrumentation. The Branch is also experienced with other wind tunnel test instrumentation, such as model attitude measurement devices and dynamic pressure transducers, and can utilize several flow visualization techniques, including pressure-sensitive paint (PSP). In addition, customers can choose to have AEDC design, fabricate and instrument their wind tunnel test models to best meet program requirements. Systems can be modified to accommodate customer's digital or analog systems.

The Aerodynamics Test Branch provides analysis support for all test programs performed within the Branch. Analysis support can cover the program's life cycle from analysis of alternatives throughout operation and sustainment. Customer test requirements and objectives are reviewed to ensure an adequate Test and Evaluation (T&E) campaign is planned to meet all objectives. Online technical support is provided which includes analysis and evaluation of the aerodynamic performance, data quality, repeatability characteristics of the system under test and real-time test data uncertainty using a Monte Carlo Simulation method. Additional analysis support utilizes modeling and simulation (M&S) tools such as hi-fidelity Computational Fluid Dynamics (CFD) to correct for installation effects, supplement aerodynamic databases and provide real-time diagnostic support. Aerodynamic databases and 6 degrees of freedom (6-DOF) store separation models are built for test customers. The end result is that test data is transformed into system-level knowledge, models and simulations through Integrated Test & Evaluation (IT&E).



STANDARD CHECK MODEL COATED IN PRESSURE-SENSITIVE PAINT

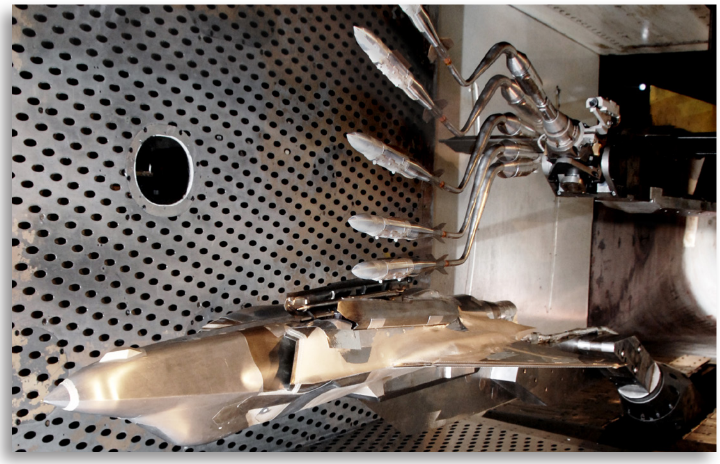


AGARD-B MODEL IN THE 16-FOOT SUPERSONIC WIND TUNNEL

PROPULSION WIND TUNNEL FACILITY

The Propulsion Wind Tunnel Facility (PWT) is comprised of two large wind tunnels, the 16-foot transonic (16T) and the 16-foot supersonic (16S), and one mid-size wind tunnel, the 4-foot transonic (4T). All three are operated as continuous-flow tunnels.

16T is the largest tunnel in the U.S. used for store separation testing. Air-breathing engines and rockets can be tested by using a scavenging system to remove exhaust from the flow stream. AEDC has recently expanded the test envelope of 16T, enabling testing at an additional range of Reynolds Numbers from Mach 0.3 to 0.6.



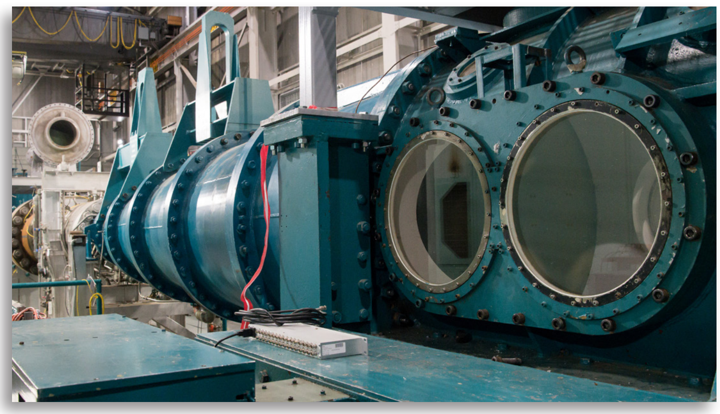
MULTIPLE EXPOSURE IMAGE OF AN F-35 LIGHTNING II MODEL AND GBU-31 JDAM MODEL STORE SEPARATION TESTING

After years of sitting dormant, 16S was brought back on line in 2021 to provide the ability to assess weapon system performance using large-scale models at parts of the flight envelope previously unattainable in ground tests.

In 2020, the Aerodynamics team added large-scale mass flow assembly calibration to the suite of capabilities available in 16T and 16S.

VON KÁRMÁN GAS DYNAMICS FACILITY

The von Kármán Gas Dynamics Facility (VKF) houses three mid-sized continuous-flow wind tunnels to provide high-quality flow. Tunnel A is a supersonic wind tunnel with a 2-D variable flex-wall nozzle. Tunnels B and C are continuous-flow hypersonic wind tunnels, utilizing fixed Mach number



TUNNEL C IN THE VON KÁRMÁN GAS DYNAMICS FACILITY

Aerodynamics Test Branch Test Facility Capabilities

Tunnel	Test Section Size: Cross Section (ft)	Test Section Size: Length* (ft)	Speed Range (Mach No.)	Reynolds No. Range (million per feet)	Dynamic Pressure (psf)	Total Pressure	Total Temperature (˚F)	Pressure Altitude (nominal, K ft)
Propulsion Wind Tunnel 16T	16 x 16	40	0.05 - 1.6	0.03 - 7.2	0.35 - 1161	200 - 3950 (psf)	80 - 140	Sea Level - 86
Propulsion Wind Tunnel 16S	16 x16	40	1.5 - 4.75	0.1 - 2.4	25 - 564	200 - 1900 (psf)	100 - 650	43 - 154
Aerodnynamic Wind Tunnel 4T	4 x 4	12.5	0.05 - 2.46	0.02 - 7.1	0.17 - 1465	100 - 3400 (psf)	80 - 140	Sea Level - 115
Supersonic Wind Tunnel A	3.3 x 3.3	9	1.5 - 5.5	0.3 - 8.5	50 - 1750	3 - 195 (psi)	90 - 280	17 - 152
Hypersonic Wind Tunnel B	4.17 diam	9	6 or 8	0.4 - 5.2	66 - 620	40 - 900 (psi)	290 - 890	100 - 162
Hypersonic Wind Tunnel C	4.17 diam	9	10	0.3 - 3.0	48 - 475	200 - 2000 (psi)	1220 - 1700	130 - 180
High Reynolds No. Wind Tunnel C	freejet	3	8	0.5 - 7.9	132 - 1256	200 - 1900 (psi)	760 - 1440	97 - 147
Aerothermal Wind Tunnel C	2.08 diam freejet	3	4	0.3 - 7.1	212 - 2018	20 - 190 (psi)	290 - 1440	56 - 106
Hypersonic Wind Tunnel 9	2.9 diam freejet	12	8	4 - 48	960 - 11300	1000 - 12500 (psi)	1100 - 1200	Sea Level - 65
	5 diam	12	10	0.25 - 20	50 - 4000	150 - 14000 (psi)	1200 - 1400	39 - 128
	5 diam	12	14	0.05 - 3.6	8 - 900	100 - 19000 (psi)	1750 - 2800	82 - 173
	5 diam	12	18	0.5 - 1.4	56 - 210	3600 - 15000 (psi)	2300 - 2800	105-130
Aerothermal Wind Tunnel 9	11.3 (in) diam freejet	9	6.7	2 - 7.6	1680 - 6850	1300 - 5500 (psi)	2100 - 2900	52 - 82
NFAC	40 x 80	80	0 - 270 knots	< 2.7	0 - 250			Sea Level
	80 x 120	190	0 - 90 knots	< 1	0 - 28			Sea Level

* Nominal test section length dimensions are shown. The actual model lengths that can be tested depend on Mach number and should be coordinated with the AEDC test engineering staff.

nozzles. Each tunnel is equipped with a model inject system allowing continuous pitch and roll sweeps of the test articles. The model inject systems also provide a means to remove test articles from the flow so that changes of test articles can be performed during air-on operation, resulting in high data productivity rates.

HYPERVELOCITY WIND TUNNEL 9

Hypervelocity Wind Tunnel 9, located at White Oak, Maryland, is a high-Reynolds number, large-scale ground-test facility capable of simultaneously collecting continuous pitch-polar static force and moment, pressure and heat-transfer data. The test team performs cost-effective research and development test and evaluation of hypersonic science and technology in support of hypersonic systems and vehicle technologies. Types of tests conducted at Tunnel 9 have included aerodynamic, aerothermal, seeker-window thermal-structural and aero-optic, shroud removal, hypersonic inlet, and fundamental flow physics.

In 2020, a Mach 18 nozzle was calibrated. Shortly after, the team began conducting customer tests using the new nozzle. The nozzle is used to provide the highest test speeds across AEDC wind tunnels. Tunnel 9 provides calibrated test conditions at Mach 7, 8, 10, 14 and 18.

HYPERSONIC TECHNOLOGY VEHICLE-1 MODEL AT HYPERVELOCITY WIND TUNNEL 9

NATIONAL FULL-SCALE AERODYNAMICS COMPLEX

The National Full-Scale Aerodynamics Complex (NFAC), located at Moffett Field in Mountain View, California, is home to a suite of low-speed wind tunnels. NFAC includes two sea-level tunnels, the 40- by 80-foot test section, which is capable of 0-270 knots, and the 80- by 120-foot test section, which can test between 0-90 knots.

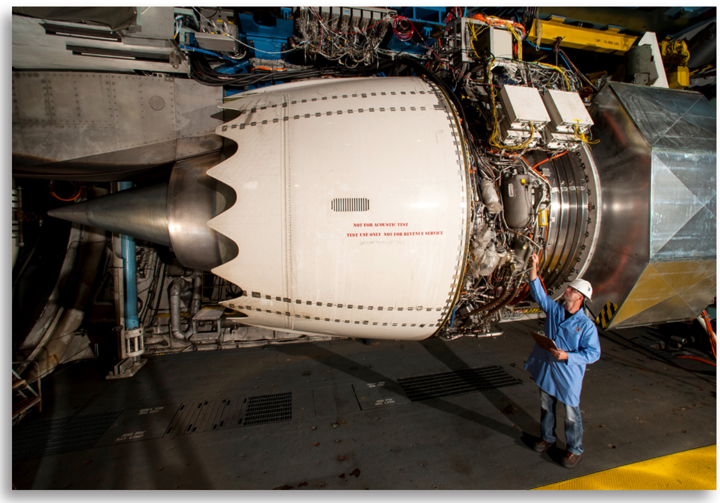
The NFAC team conducts aerodynamic research at large scale on rotor and tiltrotor aircraft, powered lift aircraft, turbine engines, ground vehicles and decelerator systems. The facility also provides a full-scale test capability supporting a variety of research areas including refueling systems, aero-acoustics and airframe-engine integration.

NASA/ARMY TILTROTOR TEST RIG IN THE 40- BY 80-FOOT TUNNEL AT NFAC

PROPULSION TEST BRANCH

The Propulsion Test Branch of AEDC tests the powerhouses of aircraft and missiles, delivering actionable data to decision makers with vital information to prepare for flight testing and increase the knowledge about currently-fielded engines.

Across a suite of test cells, the Branch can support test and evaluation of performance, operability, aeromechanical, icing, corrosion, inlet pressure distortion and temperature distortion, accelerated mission testing (AMT), engine-inlet dynamics, mission simulations and engine component testing.



ROLLS-ROYCE TRENT 1000 ENGINE IN C-2

Test cells are outfitted with instrumentation to measure a variety of variables including force, fuel flows, airflows, high-frequency response pressures, displacement, acceleration, and digitally-scanned temperatures and pressures. High-speed video is also available and is being researched for use in assessing engine vibrations. The amount of instrumentation varies by cell, ranging from 600 channels to more than 3,000, with the frequency of recording ranging from one to more than 1 million samples per second. The systems can accommodate customers' systems whether analog or digital.

TEST CELLS C-1 AND C-2

Test Cells C-1 and C-2 enable testing of large military and commercial engines in simulated

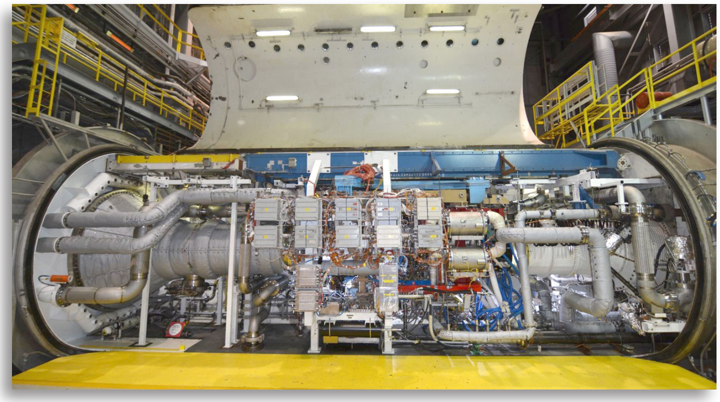
Propulsion Test Branch Test Facility Capabilities

Propulsion Development Test Cell	Test Section Size: Cross Section (ft)	Test Section Size: Length (ft)	Nominal Capability Range: Speed Range (Mach No.)	Nominal Capability Range: Total Temperature (˚F)	Nominal Capability Range: Pressure Altitude (nominal, K ft)	Nominal Capability Range: Axial Thrust Capacity (K lb)
Test Cell C-1	28 diam	45	0 - 3.0	-60 - 350	Sea Level - 75	100
Test Cell C-2	28 diam	47	0 - 2.3	-60 - 350	Sea Level - 75	100
Test Cell J-1	16 diam	44	0 - 3.2	-60 - 720	Sea Level - 75	70
Test Cell J-2	20 diam	46	0 - 2.6	-60 - 450	Sea Level - 75	50
Test Cell SL-2	24 x 24	60	0 - 1.4	-15 - 260	Sea Level	70
Test Cell SL-3	24 x 24	60	0 - 1.4	-15 - 260	Sea Level	70
Test Cell T-3	12 diam	15	0 - 3.6	-80 - 1000	Sea Level - 100	20
Test Cell T-11	10 x 10	17	0 - 2.0	-80 - 250	Sea Level - 65	10
MCL Test Chamber	**Cross Section (ft)**	**Height (ft)**	**Speed Range (Mach No.)**	**Total Temperature (˚F)**	**Pressure Altitude (nominal, K ft)**	**Axial Thrust Capacity (K lb)**
Main Chamber	250 x 260	70	Variable	-65 - 165		
Equipment Test Chamber	30 x 130	25	Variable	-65 - 165		
Sun, Wind, Rain and Dust Chamber	50 x 50	30	Variable	50 - 140		
Salt Fog Chamber	16 x 55	16		ambient - 120		
Altitude Chamber	9 x 13	8		ambient	Sea Level - 82	0

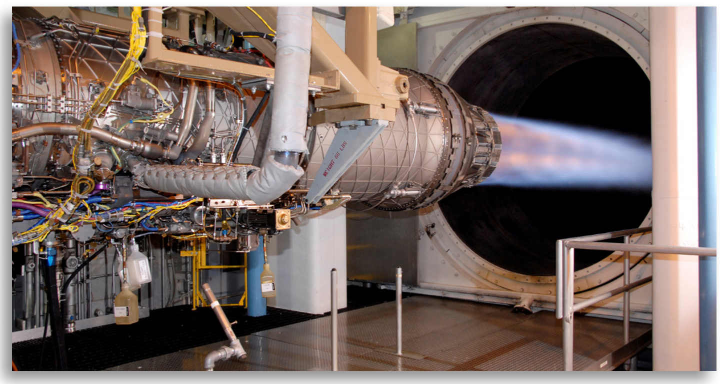
NOTE 1: Expanded capability is available with custom upgrades to test cells.
NOTE 2: Maximum performance values (temperature, speed altitude) do not occur simulataneously. Comparison of specific test points to cell capability will be required to ascertain feasibility.

altitude conditions. In addition to performance testing of augmented turbine engines and turbofan engines, aeromechanical testing, vectored-thrust testing, icing testing and inlet pressure distortion testing can be conducted in the C test cells.

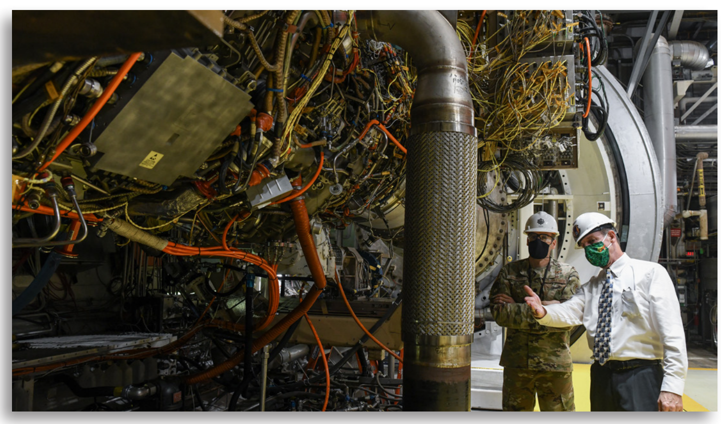
In recent years, C-1 has been primarily used to test F119 engines for the F-22 Raptor and F135 engines for the F-35 Lightning II. C-2 has been used extensively to test large high-bypass engines for modern commercial airliners, but is also capable of military engine testing.



PRATT & WHITNEY ADAPTIVE ENGINE TECHNOLOGY DEMONSTRATOR ENGINE CORE IN J-1



TESTING OF AN F100-PW-229 ENGINE IN SL-3



F135 ENGINE IN J-2

TEST CELLS J-1 AND J-2

Medium and large turbine engines are tested in simulated altitude conditions in J-1 and J-2. The capabilities are similar to those of the C test cells, but for smaller-scale engines.

In recent years, J-1 and J-2 have been primarily used to test component improvements for the F119 engines for the F-22 Raptor and to qualify the F135 engines for the F-35 Lightning II. Adaptive Engine Technology Development (AETD) tests have also been conducted in J-1 and J-2 in the past three years. These engines will provide a fuel efficiency improvement of more than 25 percent by utilizing next generation technologies.

TEST CELLS T-3 AND T-11

T-3 and T-11 are small-scale altitude test cells for testing combustion, turbine and cruise missile engines. T-11 has been modified to enable the rapid installation and removal of test modules that provide unique environments for technology testing in direct-connect, freejet and icing configurations. T-3 has received significant upgrades to increase the testing envelope and modernize the data acquisition system. T-3 has the unique capability to be used to test high-speed propulsion systems up through Mach 3.5 and beyond.

TEST CELLS SL-2 AND SL-3

SL-2 and SL-3 are sea level test cells used for cost-effective durability testing of large, augmented turbine engines at near-sea level conditions. Arnold AFB sits at approximately 1,000 feet above sea level.

Accelerated mission testing is primarily used to assess durability. AMT allows the simulation of a lifetime of missions in a matter of weeks. The facility can also support RAM AMT, in which air inlet pressures are higher than ambient. AMT and RAM AMT conditions can be alternated throughout a single test program to increase efficiency and reduce cost. In addition to AMT, SL-3 is equipped for specialized testing, such as corrosion testing.

In recent years, SL-2 and SL-3 have been primarily used to test F100 engines for the F-16 Falcon, F119 engines for the F-22 Raptor, and F135 engines for the F-35 Lightning II.

MCKINLEY CLIMATIC LABORATORY

The McKinley Climatic Laboratory (MCL) at Eglin AFB in Florida consists of five testing chambers, which are used to subject systems to the extremes of the various climates found around the world for the purpose of proving operational reliability.

The five test chambers are: the Main Chamber, a large environmental chamber; the Equipment Test Chamber, a smaller version of the Main Chamber; the Sun, Wind, Rain and Dust Chamber; the Salt Fog Chamber; and the Altitude Chamber.

One of the most recent aircraft tested was a HH-60W Jolly Green II, the Air Force's new combat search and rescue helicopter.

RAIN TESTING OF THE HH-60W JOLLY GREEN II

SPACE TEST BRANCH

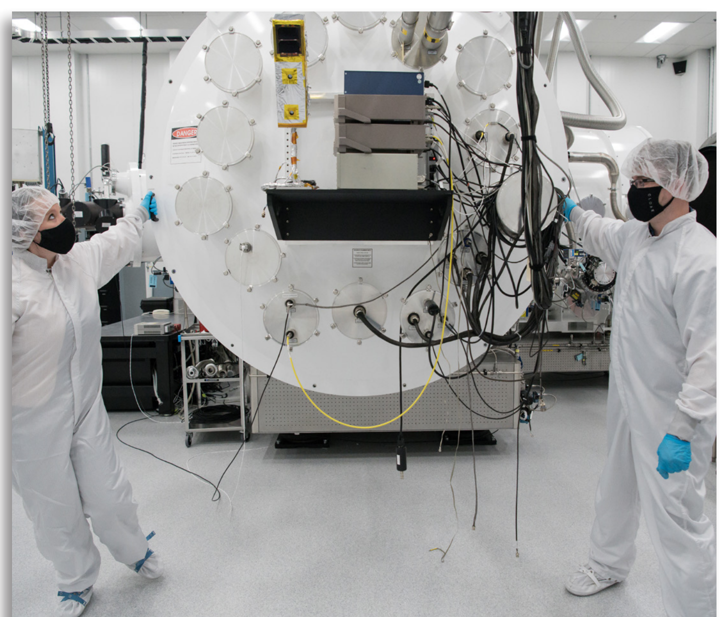
The Space Test Branch at AEDC conducts test and evaluation (T&E) of space and missile weapon systems using technical subject matter experts and a diverse array of ground test facilities to deliver timely, relevant and defensible knowledge to decision makers.

The Branch provides five distinct T&E capabilities in support of national programs – High-Altitude/Space Environmental Effects and Sensors Ground T&E; High Temperature Material Characterization and Evaluation; Hypervelocity Flyout, Impact and Lethality Ground T&E; Multi-Spectral Signature Measurement and Analysis; and Rocket Propulsion Ground T&E. Together, these T&E capabilities support and integrate the development of tactical missile interceptors, ballistic missiles, launch vehicles, re-entry materials, hypersonic air vehicles, space sensors and satellite systems.

HIGH-ALTITUDE/SPACE ENVIRONMENTAL EFFECTS AND SENSORS GROUND T&E

The AEDC Space Chambers enable high-altitude/space environmental effects and sensors testing. The thermal-vacuum space environment is simulated to study its effects on space materials, systems, subsystems, small satellites, components of larger satellites and entire satellites.

7V and 10V Chambers are designed to provide complete characterization and radiometric

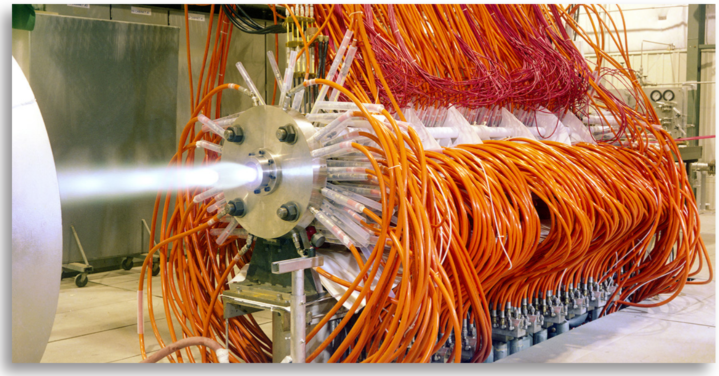


STAT THERMAL VACUUM CHAMBER

calibration of visible and infrared sensors in all categories of sensor characterization – flood, point, polarized source, spectral calibration and mission simulation, and off-axis rejection test capability.

The Space Threat Assessment Testbed (STAT) is used to subject test articles to the natural electrons, protons and atomic oxygen from the surrounding space “weather.” Subject test articles are exposed to environmental factors such as outgassing and ionization from satellite operations.

Designed as a solar simulation capability, 12V has been transformed into a space electric propulsion T&E capability. Mark I permits full-scale testing of space systems and provides 2 seconds of weightless, free-fall conditions.



H3 ATMOSPHERIC TEST CELL IN OPERATIONS

LASER DIAGNOSTICS IN RANGE G

HIGH-TEMPERATURE MATERIALS CHARACTERIZATION AND EVALUATION

Characterizing and evaluating the ablation/erosion of thermal protection materials/systems (TPM/TPS) is achieved in the AEDC segmented arc jet test cells (H1, H3, and H2). These arc heaters are used to simulate the aerodynamic heating and mid-to-high shear pressures of extreme environmental conditions experienced in re-entry and hypersonic flight. This T&E capability is crucial in developing hypersonic weapon systems and re-entry vehicles for the U.S.

HYPERVELOCITY FLYOUT, IMPACT AND LETHALITY GROUND T&E

Evaluating the aerodynamics and impact lethality of hypervelocity/hypersonic systems occurs in the AEDC ballistic ranges – G, I and S-1 – to collect and analyze flight characteristics of projectiles in re-entry, hypersonic and orbital flight environments, and the result of their impact.

Range G is the largest two-stage, light-gas gun in the U.S., providing an unequaled minimized-acceleration-loading capability for the launch of extremely high-fidelity models at hypervelocity speeds. The models are launched into an instrumented chamber that can be maintained at pressure to simulate various altitudes. A four-rail guidance system can be installed to guide projectiles along a specific path to a precise point on a target. The Branch is currently in the process of reactivating its weather encounter test capability, which generates rain, snow, ice and dust fields to simulate real-world flight conditions.

Ranges I and S-1 also have chambers that can be maintained at altitude pressures. These ranges are ideal for testing space debris impact and firing projectiles capable of withstanding high-acceleration loads. They can be quickly reset to allow multiple shots in a single day.

All ranges can be outfitted with precise event timing, extensive instrumentation, including high-speed digital cameras, digital X-rays, high-speed data recorders and laser triggering systems.

MULTI-SPECTRAL SIGNATURE MEASUREMENT AND ANALYSIS

Multi-spectral signature measurement and analysis is carried out by the AEDC Advanced Missile Signature Center (AMSC) to support the development and evaluation of missile defense systems, aircraft warning systems, surrogate threat simulators and countermeasures.

Space Test Branch Test & Evaluation Capabilities

High-Altitude/Space Environmental Effects and Sensors Ground T&E

Test Facility	Chamber Size	Temperature	Vacuum	Test Type	Source/Calibration/Capabilities
7V	7 ft diam x 21 ft long *(optional 7 ft diam x 8 ft long chamber)*	Background: 15 K Sensor: Ambient - 15 K	10^{-7} torr	Sensor Calibration and Characterization	2 Independently Moving Precision Blackbody Targets - 500 K Dynamic Complex Scenes - IR Arrays, 512 x 512, 45 Hz, 1° x 1° FOV
10V	10 ft diam x 30 ft long			Closed-Loop HWIL	2 Independently Moving Precision Blackbody Targets - 500 K 2 IR Arrays, 512 x 512, 45 Hz 1 Visible Array, 1024 x 1024, 45 Hz
STAT	2.5 ft x 2.5 ft x 2.5 ft	80 K	10^{-6} torr	Environmental Effects – Natural	Protons [30 - 150 KeV, 10^2 to 10^8 p+/cm2/sec]* Electrons [20 - 100 KeV, 5 x 10^2 to 5 x 10^8 e-/cm2/sec]* Atomic Oxygen [5 eV, 1 x 10^{10} to 2 x 10^{12} 0/cm2/sec]* Solar [120 - 2,500 nm photons at 1 sun (± 20%)]
				Environmental Effects – Induced	Thrust Ions, Material Outgassing, Spacecraft Charging
12V	12 ft diam x 35 ft high			Electric Propulsion	2M L/sec Xenon Pumping Capacity
Mark 1	40 ft diam x 82 ft high			Environmental Effects	2 sec Vacuum Free-Fall; Space Domain Awareness

High-Temperature Materials Characterization and Evaluation

Test Facility	Nozzle Exit (in. diam)	Mach No.	Enthalpy (BTU/lbm)	Pressure (atm)	Mass Flow (lbm/sec)	Run Time (min)
H1	0.75 - 3.0	1.8 - 3.5	600 - 8,500	up to 120	0.5 - 8	1 - 2
H3	1.2 - 4.5			up to 150	3 - 25	
H2	5.0 - 42.0	3.4 - 8.3	1,200 - 5,500	up to 120	2 - 10	3 - 30

Hypervelocity Flyout and Lethality Ground T&E

Test Facility	Launch Barrel (in. diam)	Projectile Mass (grams)	Velocity (ft/sec)	Altitude (ft)	Efficiency
Ballistic Range G	3.3	450 - 6,000	4,900 - 22,700	Sea Level - 225,000	1 test/week
	4.0	450 - 6,000	4,900 - 19,700		
	8.0	6,000 - 20,000	5,600 - 17,100		
Ballistic Range I	2.5	300 - 4,000	4,900 - 22,100	Sea Level - 225,000	1 test/day
Ballistic Range S-1	0.75	1.3 - 15.5	4,900 - 26,200	Sea Level - 300,000	2 tests/day
Ballistic Range S-3 **	7.0	1,500 - 25,500	131 - 2,300	Sea Level	2 tests/day

Multi-Spectral Signature Measurement Analysis

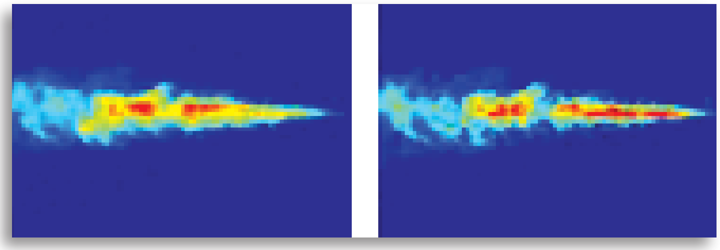
Test Team	Equipment	Calibration
Field Measurement	Radiometers, Imagers, Spectrometers, Trackers in 0.2 - 15 µm spectral bands	National Institute of Standards and Technology
Modeling and Simulation	Scientists, Engineers, Computer Programmers, Threat Data Repository, Modeling Tools (JANNAF, VIPER, SPURC, ModEx Computational Toolkit, FIST, COAST and more)	Independent Verification and Validation

Rocket Propulsion Ground T&E

Test Facility	Test Cell (ft)	Thrust (lbf)	Altitude (ft)	Temperature (°F)	Run Time (min)
J-6 Rocket Motor Test Cell	26 diam x 62 long	5,000 - 500,000	up to 100,000	15 - 100	1-6
J-4 Rocket Engine Test cell **	48 diam x 82 high			15 - 110	5

* High fluxes available with smaller test volumes
** Inactive

The AMSC Field Measurement Team, which can deploy anywhere in the world, collects optical, infrared and ultraviolet signatures from missile launches, impact engagements and threat systems, including air-to-air and surface-to-air missiles, anti-tank guided missiles, man-portable air defenses and rocket-propelled grenades, and small arms fire.

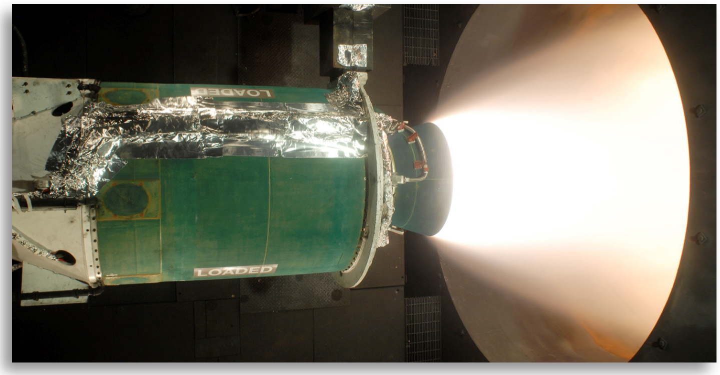


MEASURED, LEFT, AND SIMULATED TACTICAL MISSILE PLUMES

The AMSC Modeling and Simulation Team takes that data and creates modeling tools that replicate the threat system signatures for the development of detection, identification and self-protection systems.

ROCKET PROPULSION GROUND T&E

Rocket propulsion testing is conducted in the J-6 and J-4 test cells. Testing in J-6 is focused on solid rocket motors, such as those in the Minuteman III Intercontinental Ballistic Missile. Though J-4 is currently inactive, it focused on liquid rocket engines for space launch, but has also been used for solid rocket testing.



MINUTEMAN III STAGE 3 ROCKET MOTOR SIMULATED ALTITUDE TESTING IN J-6

Motors and engines are tested from ignition through steady-state thrust production to thrust termination at simulated altitude conditions. The data acquisition system can acquire up to 500,000 samples/sec. State-of-the-art techniques such as wideband infrared and ultraviolet radiometric coverage, emission/absorption detection, laser-induced fluorescence, plume surveys and real-time X-ray radiography are available for use.

HYPERSONIC SYSTEMS TEST BRANCH

The Hypersonic Systems Test Branch of AEDC provides a unique, vertically-integrated capabilities set to support the hypersonic testing needs of the DOD. The Branch is involved in every step of the developmental process for test and evaluation (T&E) of hypersonic systems.

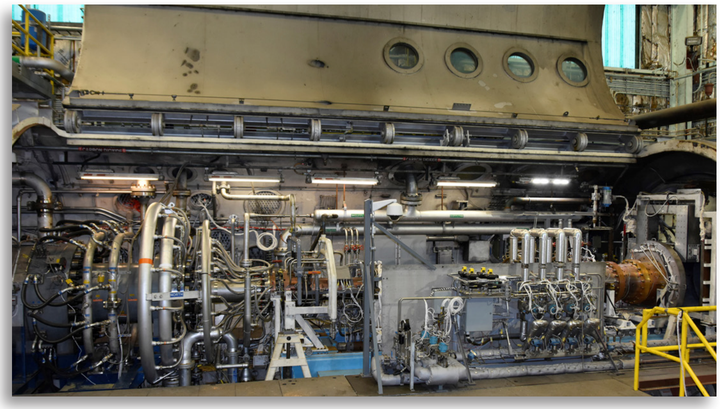
As the executing agent for the High Speed Systems Test Program (HSST) of the Test Resource Management Center, the Branch takes a leading role in the DOD's development and improvement of T&E technologies for hypersonics. As the portfolio manager of the Hypersonic Test and Evaluation Investment Portfolio (HyTIP), the Branch transitions matured technologies from the HSST into the nation's hypersonic ground and flight test capabilities. The Hypersonic Ground Test Team at Arnold AFB and the Hypersonic Flight Test Team at Edwards AFB, California, provide the test execution capability of the Branch.

HYPERSONIC GROUND TEST TEAM

The Hypersonic Ground Test Team operates the Aerodynamic and Propulsion Test Unit (APTU). The combustion-heated blow-down wind tunnel is used to evaluate the performance of hypersonic air-breathing propulsion systems. The test cell can be configured for direct connect and freejet testing systems in the facility and can collect pressure, temperature and voltage data signals from more than 600 channels.

The team recently used APTU to test a scramjet, setting two records in the process – the largest scramjet ever tested in the U.S. in direct-connect configuration and the highest thrust produced by an air-breathing, hypersonic engine in Air Force history.

Another facility under construction at Arnold AFB will expand the team's ability to test hypersonic systems. HyTIP, through Project Phoenix, is converting the former rocket motor test facility, J-5, into a clean-air, variable-Mach, hypersonic tunnel with longer run times than APTU.



AFRL MEDIUM SCALE CRITICAL COMPONENTS PROGRAM TESTING IN APTU

HYPERSONIC FLIGHT TEST TEAM

The Hypersonic Flight Test Team works in concert with fellow Air Force Test Center organizations, program offices, operational users, test ranges, Air Force Research Laboratory, Missile Defense Agency and industry partners to execute flight testing of hypersonic systems. The team provides test safety analysis and planning, technical consultation, trajectory analysis and optimization, simulation, test execution and program management.

The team was involved in testing the X-15, the Space Shuttle, the X-43 and the X-51 Waverider. Most recently, the team supported testing of the Air-Launched Rapid Response Weapon, a rapid-prototyping project with a goal of delivering a conventional hypersonic weapons capability to the warfighter.

CAPTIVE-CARRY FLIGHT TEST OF THE AGM-183A AIR-LAUNCHED RAPID RESPONSE WEAPON INSTRUMENTED MEASUREMENT VEHICLE 2 USING A B-52 STRATOFORTRESS

Hypersonic Systems Test Branch Ground Test Facility Capabilities

Hypersonics Development Test Cell	Cross Section (in)	Speed Range (Mach No.)	Total Temperature (°R)	Pressure Altitude (nominal, K ft)	On-Condition Run Time (sec)
APTU - Supersonic	42 diam	3.1	1460 max	21 - 54	120 max
	42 diam	4.3	2300 max	63.7 - 88.4	240 max
APTU - Hypersonic	42 diam	5.2	2650 max	54.5 - 96.4	120 max
	42 diam	6.3	3233 max	76 - 105	90 max
	42 diam	7.2	4700 max	88 - 110	60

NOTE 1: Expanded capability is available with custom upgrades to test cells.
NOTE 2: Maximum performance values (temperature, speed altitude) do not occur simulataneously. Comparison of specific test points to cell capability will be required to ascertain feasibility.

ICBM DEVELOPMENTAL TEST BRANCH

The Inter-Continental Ballistic Missile Developmental Test Branch (TDI) and Ground-Based Strategic Deterrent (GBSD) Combined Test Force (CTF), located at Hill Air Force Base, Utah, provide developmental test and evaluation (DT&E) support for the modernization and service life extension of the LGM-30 Minuteman III (MMIII), and development of next-generation GBSD ICBMs.

The Air Force Test Center (AFTC) is the MMIII and GBSD Lead Developmental Test and Evaluation Organization (LDTO) and AEDC is the Executing Test Organization (ETO). The Branch and CTF provide personnel with the various skills necessary to support ICBM DT&E.

UNARMED MINUTEMAN III ICBM LAUNCH

The Branch works alongside the Air Force Nuclear Weapons Center (AFNWC) MMIII and GBSD System Program Offices, the 576th Flight Test Squadron at Vandenberg AFB, California, and the Air Force Operational Test and Evaluation Center (AFOTEC) to support the MMIII and GBSD programs. An additional remote operating location at Vandenberg AFB will be stood up to support GBSD testing.

INTEGRATED ANALYSIS BRANCH

The Integrated Analysis Branch (TDA) of AEDC provides highly-skilled analysts to program offices, Modeling and Simulation (M&S) developers and facility analysts in support of acquisition program offices and others in the research, development, test and evaluation (RDT&E) process and uses M&S capabilities to design facilities, plan tests, understand test data, resolve anomalies and investigate future capabilities. M&S capabilities not otherwise available are developed in-house.

REAL-TIME TEST DISPLAY SYSTEM USED BY AEDC ANALYSTS

TDA provides additional capability to the Propulsion Test Branch, Aerodynamics Test Branch, Space Test Branch and Hypersonic Systems Test Branch analysis, as well as that of contractors and other government organizations by providing an integrated analysis approach using Model-Based Systems Engineering and Digital Engineering to provide a comprehensive understanding of Systems under Test/Development. The integrated analysts, M&S developers and facility analysts provide a value-added product to customers by working within the systems engineering frameworks and architectures to identify key models within the framework and how modeling and simulation, test and evaluation and analysis can support the work of using those models to make optimal programmatic decisions.

The Integrated Analysis Branch assists the program offices and technologists in answering questions such as: What is the purpose of performing the test? Is this the right type of test? Is the proper data and metadata being collected and utilized in the appropriate manner? Are the proper models being appropriately integrated into a framework that will allow test data and analysis to be used to validate and improve the understanding of the system? Was sufficient data collected to improve the system model sufficiently and perform uncertainty analysis with enough rigor to provide system-level uncertainty quantification that supports programmatic decisions?

By understanding the stakeholders' needs, the Integrated Analysis Branch will continue to provide relevant support that program offices and the warfighters have come to depend on in advancing national interests and in weapon systems development.

TEST SYSTEMS BRANCH

The Test Systems Branch of AEDC provides support to test branches and customers through a broad range of services. Engineers, craft workers and other personnel apply their expertise to enable accurate testing now and to ensure AEDC is ready to test the aerospace systems of tomorrow.

MODEL AND MACHINE SHOP

The Model and Machine Shop at Arnold Air Force Base is staffed by skilled craft workers such as welders and machinists. They are capable of making incredibly precise models of aircraft and stores and creating the unique pieces of hardware that can be required for tests or facilities. Capabilities available to execute this task include a computer-numerically-controlled five-axis machine and coordinate-measuring equipment for inspecting and documenting complex contours.

AN INSIDE MACHINIST WORKS ON A PART FOR A TEST MODEL

INSTRUMENTATION AND DIAGNOSTICS

Research and implementation of Instrumentation and Diagnostics (I&D) techniques provides AEDC and test engineers with state-of-the-art methods to gather high-quality measurements in

AN INSTRUMENT TECH MAKING A SCHMIDT-BOELTER HEAT FLUX GAUGE real time during complex tests while minimizing measurement uncertainties and hardware interference.

Personnel have developed intrusive and non-intrusive techniques to document quantitative, spatially resolved flow-field measurements and qualitative flow visualization for the full array of testing conducted by AEDC.

For intrusive techniques, the probes are tested to ensure they can withstand the harsh test environments while delivering highly accurate data. Probes have successfully been used to quantify Mach number, temperature, pressure and flow angularity in high-enthalpy flow streams. Efforts are continually made to improve the survivability of probes at ever more extreme temperatures, pressures and Mach numbers.

Proven non-intrusive optical diagnostics techniques are regularly used at AEDC to monitor test facility flow quality and to acquire field properties. These include laser sheet visualization, background-oriented schlieren, particle image velocimetry and planar doppler velocimetry. Additional optical measurement techniques are under development to further the ability of test engineers to assess test facility and test article performance without hardware interference.

AEROTHERMAL MEASUREMENT LABORATORY

The Aerothermal Measurement Laboratory (ATML) team supports applied research in aerothermal test measurement techniques through the use of analytical tools and characterization equipment. The experts of ATML specialize in the fabrication and installation of sensors for measuring heat flux experienced by models under test. Their work often supports hypersonic testing.

METALLURGICAL/NONDESTRUCTIVE EVALUATION LABORATORY

The Metallurgical/Nondestructive Evaluation Laboratory serves AEDC and provides direct support for customers at Arnold AFB, Hypervelocity Wind Tunnel 9 at White Oak, Maryland, and the National Full-Scale Aerodynamics Complex at Moffett Field, California. Services provided include stress, tensile strength, radiographic, ultrasonic, liquid penetration and magnetic particle testing.

CHEMICAL LABORATORY

The Chemical Laboratory team analyzes a variety of materials including metals, soils, rocket propellants, exhaust gases and water. The majority of testing is of oils and fuel used in the test facilities. The on-site lab provides Arnold AFB personnel and AEDC customers with timely, cost-efficient access to chemical analysis.

FACILITY AND TESTING TECHNOLOGY

The Facility and Testing Technology efforts of the Test Systems Branch ensure AEDC is ready to support the demands for the testing of future aerospace systems. This is accomplished through improving existing test facilities and developing new test facilities and methods. The Branch operates select test facilities as laboratories to support these goals. SL-1, a sea level test cell at Arnold AFB, houses an F404 turbofan engine that is being utilized as an engine sensors testbed. This provides engine sensor vendors the opportunity to test new hardware and techniques on a modern turbine engine.

F404 ENGINE FOR USE AS ENGINE SENSOR TESTBED

704TH TEST GROUP

DOING BUSINESS WITH THE 704TH TEST GROUP

The 704th Test Group offers extensive test and evaluation capabilities, and is focused on providing the best possible data and a positive test experience for customers. The 704th Test Group's squadrons provide world-class support to government, private industry and academia.

The following steps summarize how typical test programs are planned and conducted at 704 TG facilities:

1. The customer contacts a 704 TG representative to inquire about our testing and evaluation services. Lead time to using 704 TG facilities varies based on test requirements (Flight Test, GPS/Inertial, Radar Cross Section Measurement, Landing Gear Systems, Aircraft Survivability, Holloman High Speed Test Track, Directed Energy) and is primarily based on test complexity, and can range from two weeks for less complex tests to 24 months for very complex ones.
2. The customer provides (with Squadron point of contact (POC) support) a program introduction document (PID) to determine test scope, requested resources and schedule requests. The PID will contain the customer's requirements for testing, including test objectives and required data.
3. The 704 TG squadron POC provides an initial rough order of magnitude (ROM) cost estimate (including initial test planning funds) and schedule availability for customer inquiries.
4. If the estimated cost and schedule are acceptable to the customer, the 704 TG squadron representative drafts an initial Statement of Capabilities (SOC) for the customer to review. The SOC acts as the test support contract with the 704 TG.
5. The 704th Test Group POC schedules an initial planning meeting with the customer and other stakeholders to begin developing the test plan.
6. After the initial pre-test meeting, the 704th Test Group POC will develop a detailed test plan containing the test objectives, scope, schedule, test program matrix, and data reduction and analysis requirements.
7. The 704 TG squadron representatives will work closely with the test customer throughout the test planning phase to review and finalize the test plan, test matrix, and data reduction and analysis requirements, schedule required test periods and configure all systems to support testing.
8. The 704 TG squadron representatives will serve as the primary customer interface for testing, including all aspects of operations while deployed to 704 TG facilities.
9. During the testing process, the customer is billed for actual charges.
10. Once the test has been completed, the 704 TG provides analyses and data products as detailed in the SOC or contract.
11. When final test conduct and closeout billing are complete, any remaining funds will be returned to the customer.

For assistance or additional information about the 704th Test Group, visit our website: www.arnold.af.mil/Units/704th-Test-Group/ or contact the 704th Test Support Squadron Office at 704TG.HQ.Requests@us.af.mil or call (575) 572-1370.

704TH TEST GROUP, DETACHMENT 1

Detachment 1, 704th Test Group, also known as the National Radar Cross Section (RCS) Test Facility (NRTF), operates the Radar Target Scatter (RATSCAT) Advanced Measurement Systems (RAMS) site at White Sands Missile Range in New Mexico. Det. 1 securely provides our national defense partners with accurate, impartial and timely RCS measurements, antenna patterns and comprehensive data products.

NRTF conducts narrowband and wideband RCS signature characterization of scaled, full-scale and flyable articles, as well as characterization of antenna radiation patterns and antenna backscatter. Full-service test support includes range support, rapid-response test preparation, model design/construction and data collection/processing. The remote and secure location enables specialized tests of developmental and fielded systems.

NRTF continually improves its capabilities to keep pace with modern friendly and adversary capabilities. Completed and ongoing upgrades include an Advanced RCS Metrology Radar system with improved sensitivity and up to six times measurement throughput; a 40-foot turntable for testing up to 60,000 lbs. non-penetrable, full-scale targets; advanced signal processing capabilities, providing new insight to RCS phenomena and increased analysis throughput; low VHF measurements; and upgraded Ka-band measurements.

NRTF is fielding an in-flight, or dynamic, RCS measurement system to meet increasing national demand. The relative strengths and weaknesses of static and dynamic testing creates a complementary pair of capabilities.

JUCAS ON PYLON

CHECKOUT OF FULL-SCALE TURNTABLE CAPABILITY USING A T-38C

704th Test Group Detachment 1 Test Facility Capabilities			
RAMS Site	**Dimensions (ft)**	**Target Support Pylon Ht. (ft)**	**Target Weight Support (lbs)**
	8,900 ft x 300 ft paved, shadow-plane range	56 max.	60,000 max.
RAMS Coherent Measurement System	**Frequency Range (GHz)**		**Modes of Operation**
	.6 - 18, 32 - 38		Narrowband RCS, radar imaging, other diagnostic radar
RAMS VHF/UHF Measurement System	**Frequency Range (MHz)**	**Distance Range (ft)**	**Operations**
	30 - 600	1,500 - 2,500	Mobile radar system with adjustable height antennas

586TH FLIGHT TEST SQUADRON

The 586th Flight Test Squadron (586 FLTS), based at Holloman AFB, New Mexico, plans, coordinates, conducts and analyzes flight tests of advanced weapons and avionics systems. The Squadron flies four highly-modified Northrop T-38C Talons, one Beechcraft C-12F and one Beechcraft C-12J. The 586 FLTS services are provided for Department of Defense and commercial customers across the full spectrum of program size and complexity. Support includes – but isn't limited to – testing of target surrogates, guidance systems, laser systems, air-to-air and air-to-ground systems, long-range and standoff weapons, live warheads, and photo/safety chase.

The 586 FLTS works within a small test budget with low cost per flight hour that enables development programs to move beyond the laboratory environment without compromising support for larger and more complex programs and flight test solutions required for major acquisition programs.

Most of the flight testing is conducted at White Sands Missile Range (WSMR), where 586 FLTS, Detachment 1, serves as the Air Force liaison for all Air Force programs tested at the Range. As the liaison, Det. 1, maintains the relationships to coordinate range support (funding, targets, data) for test programs. Det. 1 assists customers by developing operational requirements, scheduling range and airspace, assessing safety risks, and coordinating environmental assessments. Additional assets, such as unmanned aerial targets, both full- and subscale, a variety of ground targets, and acoustic signature testing can be coordinated with WSMR are all coordinated through Det. 1.

Test missions by the Squadron are overseen from a control room with access to real-time aircraft and weapon telemetry, UHF, VHF and high-speed digital fiber-optic communication with WSMR and other test facilities for secure data collection, processing, reconstruction and transfer.

AIR FORCE T-38C TALON USED FOR FLIGHT TEST OPERATIONS

AIR FORCE C-12J CARRYING SNIPER ADVANCED TARGETING POD

586th Flight Test Squadron Test Capabilities

Aircraft	Airspeed/ Mach	Altitude (K ft)	Duration	Nz Load Factor (g)	Capabilities	Stores	Carriage/Employment
T-38C	160-600 KCAS / 1.3M	45	1.0 - 1.2 hrs	7	Time, Space, Position Information (TSPI); Real-Time Telemetry (TM); L/C/Ku/Ka/S Band; Rear Cockpit Modular Pallet; Mode 4/5; Ethernet; Captive Carriage; Chaff and Flare; Electronic Attack; Towed Carriage; Photographic Coverage	MAU-12 Centerline Pylon	1,000 lb capacity
C-12J	110-250 KCAS	25	4 - 6 hrs	3	TSPI, L/C/Ku/Ka/S Band, Targeting Pods, Link-16, ADS-B, Ethernet, Modular Customizable Racks, Captive Carriage	Dual MA-4 Pylon	2 Store Configuration: 500 lb capacity ea. 1 Store Configuration: 750 lb capacity

746TH TEST SQUADRON

The 746th Test Squadron (746 TS), which operates the Central Inertial and GPS Test Facility (CIGTF), is based at Holloman AFB and is a national test asset. The 746 TS conducts subsystem- and component-level developmental and operational testing of guidance and navigation systems. The 746 TS provides expert test and evaluation of GPS, inertial navigation systems (INS), and embedded GPS/INS (EGI) navigation and guidance systems. The 746 TS evaluation of GPS includes all aspects of GPS receiver performance to include testing of new GPS satellite/receiver compatibility prior to launch and on-orbit, analyzing signal-in-space characteristics affecting receiver performance and assessing operational performance of GPS in the global airspace and electronic combat environments. The Squadron also performs trade studies, technical consultation services and analyses regarding Position, Navigation and Time (PNT) platform integration.

The 746 TS is located in a seismically quiet location and has the most complete collection of large precision centrifuges, rate tables and environmental test beds in the nation. The location of the 746 TS on Holloman AFB, adjacent to White Sands Missile Range (WSMR), consolidates a full range of low-, medium- and high-dynamic testing in laboratory, ground, flight, high-speed test track and GPS threat environments, all in one location.

SMALL TEST VEHICLE

INERTIAL LABORATORY

Its seismically quiet location enables the 746 TS to conduct precision testing of high-accuracy guidance systems and space-based pointing and tracking systems. The inertial laboratory team operates a centrifuge test bed with a counter-rotating platform that subjects test items to sustained acceleration environments up to 50g. Other available test beds include: two- and three-axis test tables, magnetic field generators, linear vibrators, precision angle generators, combined environments chambers and a salt-fog chamber.

NAVIGATION TEST AND EVALUATION LABORATORY

The 746 TS operates a GPS simulation laboratory, GPS satellite reference stations (fixed and mobile) and data analysis stations, as well as a variety of state-of-the-art Portable Box Jammers and High-Power Jammers. These capabilities, combined with the Navigation Test and Evaluation Laboratory (NavTEL), support the test and integration of either standalone GPS receivers or integrated/embedded GPS/INS navigators.

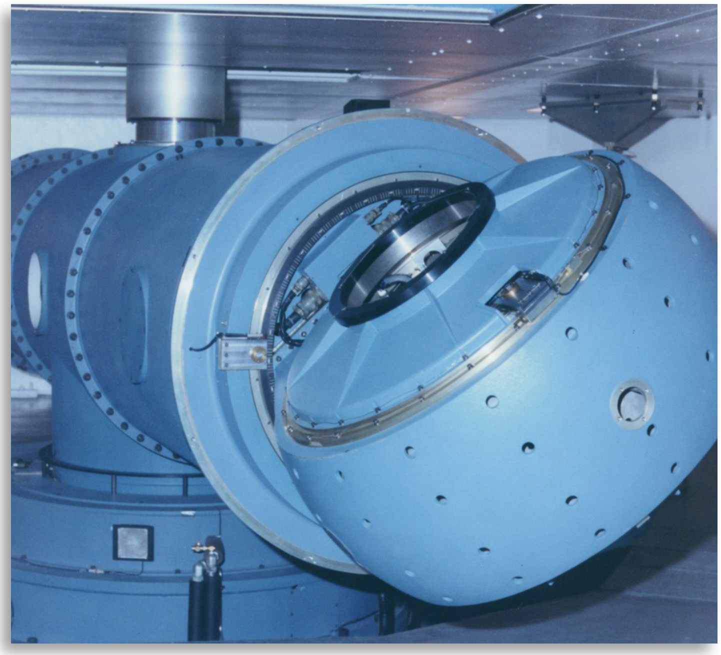
FLIGHT AND FIELD TESTING

Additionally, the 746 TS operates several self-contained ground vehicles in support of PNT field testing and has access to a variety of aircraft including the C-12J, C-12D, AT-38B and HH-60 Helicopter in cooperation with the 586th Flight Test Squadron and the local Army Aviation detachment.

NAVIGATION WARFARE TESTING

The 746 TS uses its GPS jamming systems to evaluate GPS performance in a navigation warfare environment and to support the development of receiver anti-jam technologies, GPS jammer location systems and counter-threat tactics, techniques and procedures. The 746 TS conducts these tests either statically on the Static Antenna Test Range (SATR), where open-air, precision, high jammer-to-signal ratio testing is available or dynamically on board test vehicles or aircraft test beds at WSMR and other locations. Flight and field PNT systems can be measured against the Ultra High Accuracy Reference System, which provides cm-level truth accuracy in benign or GPS-challenged environments.

With this wealth of technical guidance and navigation test expertise, analysis experience and a comprehensive suite of precision test capabilities to ensure navigational component and system testing well into the future, the 746 TS continues its long 60-plus year tradition of excellence in meeting the nation's inertial and PNT testing needs.



120-INCH CENTRIFUGE

846TH TEST SQUADRON

The 846th Test Squadron operates the Holloman High Speed Test Track (HHSTT), the world's premier rocket sled test track, at Holloman AFB. Sled testing provides a critical link between laboratory-type investigations and full-scale flight tests by simulating selected portions of the flight environment under accurately-programmed and highly-instrumented test conditions, often before flight-worthy hardware is available.

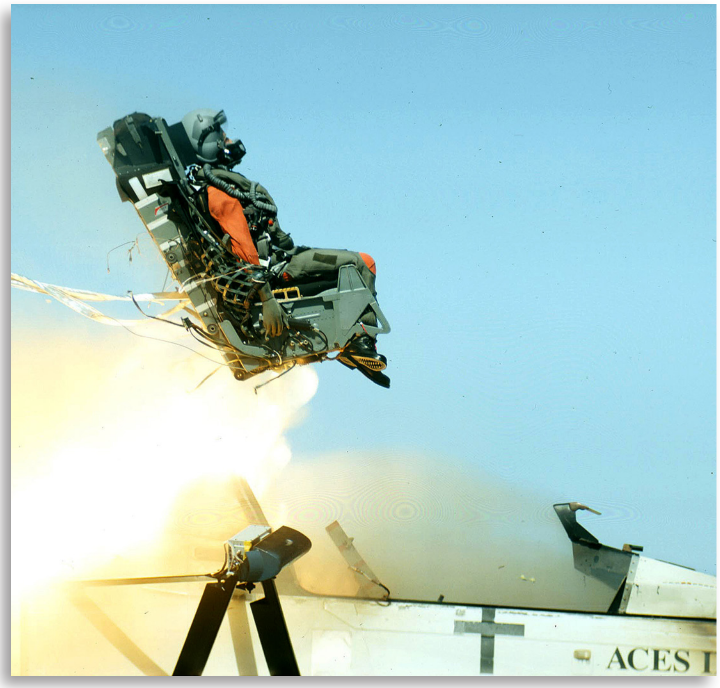
The Squadron is a one-stop shop providing test management, test design, structural design and instrumentation engineering/analysis, hardware fabrication, complex target construction, and other specialized support for testing at subsonic through hypersonic velocities. Dynamic testing is accomplished by accelerating sleds carrying subscale and full-scale test articles to velocities up to 9,400 ft/sec. Solid rocket motors are used to customize

HARD TARGET PENETRATION TESTING

test velocities with test events precisely staged along the continuously-welded, precisely-aligned 10-mile track.

The HHSTT complex includes an accurately-surveyed impact test area with customizable target suites for penetrating or explosive warhead tests, as well as an aircraft escape system test complex equipped with advanced instrumentation and photo-optics.

The Squadron is responding to a significant increase in demand for hypersonic weapons testing with a focus on improving high-speed braking methods to recover sleds for post-test analysis. Additionally, the Track's 6,000-foot simulated rainfield has recently been upgraded to provide a more precisely controlled and measurable weather effects test environment.



AIRCRAFT ESCAPE TESTING

Holloman High Speed Test Track Capabilities					
Track Length (ft)	Max. Speed (ft/sec)	Max. Acceleration (g)	Free-flight Test Range Length (nautical miles)	Test Types	Instrumentation
50,971	> 9,400	200	50	**• Munitions:** Warhead Lethality, Hard Target Penetrators, Missile Defense, Fuzing, Seekers **• Crew Escape:** Ejection Seats, Parachutes, Canopies, Rocket Catapults **• Guidance Systems:** Reference Measurement, Components and Full-Size Systems **• Directed Energy/Electronic Combat:** Infrared Countermeasures, Target Tracking/Illumination **• Environmental Effects:** Rain, Aerothermal, High G **• Aerodynamics:** Boundary Layer Transition, Dispensing Systems, Launch into Flight	Onboard and Track-side Photo-Optical, Hardened Data Acquisition Systems, Telemetry, Weibel RADAR

OPERATING LOCATION-AA

The 704th Test Group, Operating Location-AA at Kirtland AFB, New Mexico, is part of the Directed Energy (DE) Combined Test Force and serves as the Developmental Test and Evaluation (DT&E) liaison to both the Air Force Research Laboratory (AFRL) Directed Energy Directorate and the Air Force Operational Test and Evaluation Center (AFOTEC).

Instead of managing a test facility for this nascent technology, OL-AA currently utilizes test resources from across the Air Force, as well as other

DE SYSTEM MOUNTED ON A LIGHT TACTICAL VEHICLE military services, to recommend and execute test missions. Engineers are able to optimize resources throughout the enterprise to develop test concepts, methodology, procedures and techniques for DE systems to facilitate progress from research and development through test and evaluation to an acquisition-ready status. OL-AA supports testing of both High Power Microwave and High Energy Laser systems.

To date, OL-AA has provided significant support to the Air Force's Strategic Development Planning and Experimentation (SDPE) office Experiments 1 and 2 which tests and deploys DE systems to various Combatant Commands. The most recent efforts include Experiment 1 testing of several High Energy Laser and High Power Microwave Weapon systems designed for use as counter-unmanned aerial system (c-UAS) DE weapons. Later in fiscal year 2021 OL-AA will also conduct Risk Reduction testing for counter cruise missile (c-CM) DE systems which will culminate in Experiment 2 scheduled to execute mid-fiscal year 2022.

DE SYSTEM TESTED BY DE CTF IN 2018 AND 2021

In addition to ongoing support to the Air Force's Self-Protect High Energy Laser Demonstrator (SHiELD) programs, OL-AA has also recently been identified to lead testing efforts for three prototype c-UAS laser weapons systems expected to deliver at the end of fiscal year 2021.

AEROSPACE SURVIVABILITY & SAFETY OFFICE (OL-AC)

TEST SITE 3 TESTING GROUNDS FOR FULL-SCALE AIRCRAFT REPLICA

The 704th Test Group, Aerospace Survivability and Safety Office (704 TG/OL-AC) located at Wright-Patterson AFB, Ohio, conducts aerospace vehicle survivability, vulnerability and landing gear research, development, test and evaluation, and modeling and simulation to contribute to the development, advancement and safety of aerospace systems.

AEROSPACE VEHICLE SURVIVABILITY FACILITY

The Aerospace Vehicle Survivability Facility (AVSF) consists of multiple sites for subjecting aerospace combat vehicles to realistic operating conditions, including threats, to predict and assess the magnitude of combat damage and provide model input and improvements for system-level vulnerability assessments.

TEST SITE A

Test Site A is an indoor test site equipped with a RAMGUN used to generate high pressure waves in a fluid medium to simulate damage caused by ballistic threat impacts on surrounding aircraft structure. Joints and small components can be subjected to a highly-controlled pressure pulse to determine failure criteria for use in high-fidelity models and design studies in an efficient and cost-effective manner.

TEST SITE 1

Test Site 1 is an indoor ballistic test site used to support the development and refinement of new projectile launch techniques, develop threat simulation devices for the conducting of threat, armor and aircraft structure and component characterization studies. The site includes a gun range with an oak-lined chamber. The AVSF team is capable of custom loading threats for precise velocity impact studies of U.S. and foreign munitions at this test site.

TEST SITE 3

Test Site 3 is the most capable, highest-fidelity site within the AVSF for ballistic testing of full-sized aircraft and components in a simulated flight environment utilizing high-speed airflow, temperature conditioned fuel, and state-of-the-art data acquisition. Test Site 3 is also cleared for enclosed high-energy laser testing with variable energies up to 120kW.

LANDING GEAR TEST FACILITY

The Landing Gear Test Facility (LGTF) is a DOD-unique capability used to provide tri-service landing gear system ground testing of aerospace vehicle tires, wheels, brakes and landing gear assemblies under real-world operating conditions. Test support services include test engineering, custom instrumentation, test hardware design and fabrication, and data reduction and reporting. The highly-experienced LGTF team has the capability to measure runway conditions and then replicate the landing surface to accurately conduct tire performance and wear testing. Investments in digital engineering, additive manufacturing, high-speed infrared data collection and 3D scanning technologies have expanded these capabilities.

TIRE FORCE MACHINE

Aerospace Survivability & Safety Office Test Facility Capabilities

Landing Gear Test Facility

Landing Gear Systems	Capability	Test Machines
Wheels & Brakes	Wheel Qualification Wheel Roll Brake Wear Brake Qualification & RTO Variable Anti-Skid Systems	84 in. Variable Inertia Dynamometer 192 in. Variable Inertia Dynamometer 120 in. Fixed Inertia Dynamometer
Tires	Missionized Tire Wear Mechanical Properties Tire Qualification & RTO	120 in. Fixed Inertia Dynamometer 168 in. Fixed Inertia Dynamometer Large Baldwin Tire Force Machine
Landing Gear Assemblies	Impact Testing Durability/Lifecycle Fatigue Testing Landing Gear Shimmy Full-Spectrum Landing Gear Testing	4 Drop Towers Fatigue Test Machine 120 in. Fixed Inertia Dynamometer

AEDC: THE FULFILLMENT OF A VISION

On June 25, 1951, President Harry S. Truman dedicated the Air Engineering Development Center in memory of Gen. Henry 'Hap' Arnold, the first General of the Air Force.

"I am happy to dedicate this center to his memory and to name it the Arnold Engineering Development Center," Truman said. "The scientists who work here will explore what lies on the other side of the speed of sound. This is part of our effort to make our air power the best in the world and to keep it the best in the world."

Even before World War II had ended, Arnold set his sights on making sure the U.S. would enter the next fight with superior air power. In 1944, he called on scientist Dr. Theodore von Kármán to form the Scientific Advisory Group to provide recommendations to the Air Corps Chief on the direction aviation research should take. As part of their research the group surveyed German facilities, which had been found to be superior to those of Allied nations.

After this survey, one of the scientists, Dr. Frank Wattendorf, drafted the Trans-Atlantic Memo in 1945. This document became the baseline for establishing "a new Air Forces Development Center." Later that year, the group published Toward New Horizons, a blueprint for Air Force research and development. Toward New Horizons and another report, Proposed Air Engineering Development Center, both recommended using captured German test facilities and identified needs such as power for the center.

Site selection began and eventually Camp Forrest in Tennessee was chosen to be the future home of the Air Engineering Development Center. The Unitary Wind Tunnel and Air Engineering Development Act of 1949 allocated $100 million for construction of the facility.

Today, the Arnold Engineering Development Complex, headquartered at Arnold Air Force Base, Tenn., has organizations stretching across the nation.

Arnold Engineering Development Complex
Arnold AFB, TN 37389

www.arnold.af.mil

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The 1980s

1982
- Use of Computational Fluid Dynamics begins.

October 1984
- Construction is completed on the Aeropropulsion Systems Test Facility, the world's largest jet engine test facility.

November 1985
- An explosion during a test destroys the J-5 Rocket Test Facility. The facility is rebuilt a year later, ahead of schedule.

The 1990s

1992-1993
- AEDC formalizes alliances with a number of commercial aerospace organizations.
-

1993
- The first large commercial engine test takes place.

1994
- The J-6 Large Rocket Test Facility is completed.

1996
- The Decade facility is completed.

October 1997
- AEDC assumes management of the Hypervelocity Wind Tunnel 9 in White Oak, Maryland.

1998
- AEDC is named one the DOD's High-Performance Computing Centers.

The 2000s

2000
- Mark I is renovated.

2001
- Rededication of the center marks its 50th anniversary.

2006
- AEDC assumes control of the National Full-Scale Aerodynamics Complex, located at NASA's Ames Research Center, California.

June 2007
- AEDC commemorates its designation as an American Institute of Aeronautics and Astronautics historic site.

April 2008
- National Full-Scale Aerodynamics Complex tests new helicopter rotor system, marking first military test since facility reactivation.

October 2008
- Air Force awards $26.1 million contract to produce the Space Threat Assessment Testbed ground test capability at AEDC.

March 2009
- The 100th rocket motor is fired in J-6.

The 2010s

2016
- Control of The McKinley Climatic Laboratory at Eglin AFB, Florida, is realigned from the 96th Test Wing to AEDC.
- The 96th Test Group and 796th Test Support Squadron at Holloman AFB are inactivated and then activated under AEDC as the 704th Test Group and 704th Test Support Squadron.

2017
- The Hypersonic Combined Test Force at Edwards AFB, California is realigned from the 412th Test Wing and renamed the Hypersonic Flight Test Team (HFTT). The HFTT joins with the newly-formed Hypersonic Ground Test Team to create the Hypersonic Systems Test Branch.
- The ICBM Developmental Test Branch is stood up at Hill AFB, Utah.

2018
- Tiltrotor Test Rig is operated for the first time in the National Full-Scale Aerodynamics Complex.

2019
- AEDC joined Air Force Space Command Test and Evaluation, Air Combat Command's 53rd Wing, and Detachment 4 of the Air Force Operational Test and Evaluation Center in January 2019 as charter members of the first the Space Warfighting Combined Test Force (CTF). AEDC would go on to establish the Space Test Operating Location at Peterson AFB, Colorado, to support the CTF.
- Record for the highest thrust produced by an air-breathing hypersonic engine in Air Force history is set in the Aerodynamic and Propulsion Test Unit.

The 2020s

2020
- A HH-60W Jolly Green II, the Air Force's new combat search and rescue helicopter, undergoes environmental testing at McKinley Climatic Laboratory.
- First customer runs at Mach 18 in the Hypervelocity Wind Tunnel 9 are conducted.

2021
- After years sitting dormant, the 16-foot supersonic wind tunnel is restored to operational status with a successful air-on test run.

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Arnold Engineering Development Complex
Arnold AFB, TN 37389
www.arnold.af.mil

ARNOLD ENGINEERING DEVELOPMENT COMPLEX
1951-2021
YEARS
HAP ARNOLD DAY
OPEN HOUSE
June 26, 2021