ARNOLD ENGINEERING DEVELOPMENT COMPLEX

LINEAGE

Established as Air Engineering Development Division and organized on 1 Jan 1950
Redesignated as Arnold Engineering Development Center on 3 Aug 1951

STATIONS

Wright-Patterson AFB, OH, 1 Jan 1950
Arnold Engineering Development Center (later Arnold AFS; Arnold AFB; Arnold AS; Arnold AFB), TN, 14 Nov 1950

ASSIGNMENTS

HQ US Air Force, 1 Jan 1950
Air Research and Development (later Air Force Systems) Command, 1 May 1951
Air Force Materiel Command, 1 Jul 1992

COMMANDERS

MG W. L. Rogers, #1961
BG Gustav E. Lundquist, #1967

Col. W. Rutley July 1992-June 1993
Col. Lawrence P. Graviss July 1992-Sept. 1995
Col. Michael P. Wiedemer Oct. 1995-Jan. 1997
Col. Robert W. Chedister Jan. 1997-June 1998
Col. Michael L. Heil July 1998-July2001
Col. (later Brig. Gen.) David J. Eichhorn July 2001-Feb. 2004
Brig. Gen. David L. Stringer Feb. 2004-Dec. 2006
Col. Arthur F. Huber II Dec. 2006-July 2009
Col. Michael T. Panarisi July 2009-Aug. 2011

HONORS

Service Streamers

None

Campaign Streamers
None

Armed Forces Expeditionary Streamers
None

Decorations
Air Force Outstanding Unit Award
1 Jan 1983-31 Dec 1984

Air Force Organizational Excellence Awards
1 Jan 1973-31 Dec 1974
1 Jan 1976-31 Dec 1977
1 Jun 1989-31 May 1991
1 Jun 1993-31 May 1995
1 Jun 1995-31 May 1998
1 Jun 2006-31 May 2008

EMBLEM

Azure a bezant in dexter chief radiating three concentric arcs to sinister base Argent the second surmounted in sinister chief by a mullet Or and the third surmounted in dexter base by a mullet of the like; overall issuant from sinister base a pile reversed of the field fimbriated of the second charged with a flight symbol ascending bendwise Gules, all within a diminished bordure of the third. Attached below the shield, a White scroll edged with a narrow Yellow border and inscribed "ARNOLD ENGINEERING DEVELOPMENT COMPLEX" in Blue letters. Approved on 5 Jun 1957, modified on 5 Aug 1994

EMBLEM SIGNIFICANCE

Ultramarine blue and Air Force yellow are the Air Force colors. Blue alludes to the sky, the primary theater of Air Force operations. Yellow refers to the sun and the excellence required of Air Force personnel. The disc with concentric radiating rings suggests a wind tunnel and denotes the unit’s state-of-the-art wind tunnels. The wedge shape charged with a flight symbol represents an object and its “shock wave” when tested in the wind tunnel. It also symbolizes the Complex’s testing and evaluation of other extremely high speed flight characteristics. The two stars represent the Complex’s space functions.

MOTTO

NICKNAME

OPERATIONS

Arnold Engineering Development Center (AEDC) is the most advanced and largest complex of flight simulation test facilities in the world. The center's capabilities are comprised of more than 50 aerodynamic and propulsion wind tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other special-iced units. Facilities can simulate flight conditions from sea level to 300 miles in altitude and from sub-sonic velocities to Mach 20. AEDC is an important national resource and has contributed to the development of practically every one of the nation's top priority aerospace programs including space access, aircraft, missiles and satellites. Many of these pro-grams are highlighted in the following test facility descriptions.

The Arnold Engineering Development Center is an Air Force Materiel Command facility and is man-aged by the Air Force, but is operated by a contrac-tor workforce. AEDC's primary location is in Tennessee, but AEDC also operates two geographically separated facilities — the Hypervelocity Wind Tunnel 9 in Maryland and the National Full-Scale Aero-dynamics Complex in California. The responsibility for customer interface and test planning falls under the 704th Test Group, which has three main mission areas led by Air Force squadron commanders. The squadron and mission area designations are:

- 716th Test Squadron, Flight Systems
- 717th Test Squadron, Aeropropulsion Systems
- 718th Test Squadron, Space and Missile Systems

The balance of this guide describes the test capabilities that are currently maintained in an ac-tive status and have active or projected testing, as well as the specialized technical services that are available. A portion of the AEDC facilities are cur-rently in an inactive state and would require some additional lead time to support a test. The tables in each section include a summary of both active facilities as well as selected inactive facilities that might be of interest.

AEDC MISSION

Test and evaluate aircraft, missile and space sys-tems and subsystems at the flight conditions they will experience during a mission to help customers develop and qualify the systems for flight, improve system designs and establish performance before production, and help users troubleshoot problems with operational systems

Conduct a research and technology program to de-velop advanced testing techniques and instrumentation and to support the design of new test facilities. Continual improvement helps satisfy testing needs and keeps pace with rapidly advancing air-craft, missile and space system requirements

Maintain and modernize the center's existing test facilities

The 716th Test Squadron at Arnold Engineering Development Center (AEDC) and our two operating locations offer aerodynamic ground test capabilities from very low subsonic speeds through Mach 14 in various wind tunnels. These wind tunnels provide essential test and analysis services in support of DoD, national, U.S. industry and international aerospace programs. AEDC operates five active wind tunnels in two primary facilities, the Pro-pulsion Wind Tunnel Facility (PWT) and the von Karman Gas Dynamics Facility (VKF). AEDC also manages two wind tunnels at remote operating locations - the Hypervelocity Wind Tunnel 9 at Silver Spring, Md. and the National Full-Scale Aerodynamics Complex (NFAC) at Moffett Field, Calif.

AEDC wind tunnels are used for testing in 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, acous-tics, thermal protection system evaluation, hypersonic flow physics, space launch vehicles, operational propulsion systems and captive flight.

An extensive inventory of instrumentation is available for testing use, including force and moment balances, heat transfer gauges and electronically scanned pressure modules. AEDC can provide calibration services for force and moment balances. AEDC is experienced with other wind tunnel test instrumentation such as model attitude measurement devices, pressure sensitive paint (PSP), heat-transfer gauges, dynamic pressure trans-ducers and several flow visualization techniques. In addition, customers can choose to have AEDC design and fabricate their wind tunnel test models to best meet program requirements.

AEDC is a leader in wind tunnel data productivity, and its facilities are continually optimized through targeted investment and maintenance to provide customers with the highest quality aerodynamic data. With decades of experience testing and analyzing the nation's flying weapons systems, our team can provide program develop-ment experience to your system. Our engineers are highly trained and experienced in wind tunnel tests and associated analyses and use standardized, configuration-controlled test processes to ensure high quality, high fidelity, and accurate test results. Careful test planning and coordination with test customers ensures that test objectives are met and that testing is streamlined and efficient.

AEDC wind tunnel test sections are some of the largest in the world for the speed ranges they provide, being able to accommodate moderate- to large-scale models to limit scalability issues and increase the fidelity and quality of simulation.

Propulsion Wind Tunnel 16T provides flight vehicle developers with the aerodynamic, propulsion integration, and weapons integration test capabilities needed for accurate prediction of system performance. Large-scale models can be accommodated in the 16-ft square by 40-ft long test section and can be tested at Mach numbers from 0.05 to 1.60. Pressure in the test section can be varied to simulate unit Reynolds numbers from approximately 0.03 to 7.3 million per foot or altitude conditions from sea level to 76,000 ft. Air-breathing engine and rocket testing can also be performed in 16T using a scavenging system to remove exhaust from the flow stream.

Wind tunnel models can be supported in a variety of ways including a High Angle-of-Attack System (HAAS) for evaluating extreme flight attitudes and a Captive Trajectory Support (CTS) system for weapons integration testing. Other testing support services include utilities such as supplying high-pressure air to the test models for simulation of jet exhaust or control jets. A fuel system is also available for engine testing.

16T provides world-class test productivity by using automated and integrated test process controls. Modem steady-state and high-speed data systems with real-time displays and multichannel remote controls are available. High-rate continuous-sweep data acquisition is routinely acquired to provide a more complete assessment of model aerodynamics and related effects during test. Other data needs will be met as established through communication with the test customer.

One example of AEDC's continuous improvements in test technologies has been the development of the pressure sensitive paint (PSP) data acquisition system that provides full-time, 360-deg model coverage. This system allows engineers to acquire and evaluate global surface pressure data on wind tunnel models using a special paint whose luminescence is a function of the local test article surface pressures.

Major aircraft development programs, such as the recent Lockheed Martin F-35 Lightning II and Boeing's F/A-18E/F Super Hornet, have selected 16T as a primary aerodynamic test data supplier. Other high-performance military aircraft, such as the B-2A Spirit stealth bomber and the RQ-4 Global Hawk unmanned aerial vehicle, have undergone extensive testing in 16T, as have space vehicles such as the DoD's Evolved Expendable Launch Vehicle (EELV), the NASA Space Shuttle, and research vehicles such as the Blended Wing Body or the X-33 reusable launch vehicle.

16T has supported almost every major DoD and government flight vehicle program of the past 55 years, and our customers include both domestic and foreign private industry and academia.

AEDC's four-foot transonic wind tunnel (4T) is a versatile, continuous-flow, mid-size test facility that can be used for a variety of aerodynamic test needs. Used primarily in conducting small-scale aerodynamic and store separation testing, the tunnel has a 4.0- by 4.0- by 12.5-ft test section. The transonic designation indicates its primary use for testing at near-sonic airspeeds, however, its Mach number capability extends from about 0.05 to 2.46, and up to about 2.5 for some installations. Tunnel 4T can simulate altitudes from sea level to 98,000 ft and provide Reynolds numbers up to approximately 7.1 million/ft.

Although Tunnel 4T is primarily used in conducting small-scale aerodynamic and store separation testing, a variety of test types, many of which can be applied simultaneously during a single test entry, are available. Tunnel 4T has been used to conduct specialized testing such as material testing, and our engineers can develop special-iced test techniques to meet the unique test needs of our customers.

Supporting systems include modem, state-of-the-art, steady-state and high-speed data acquisition systems with automated test process controls for high test productivity similar to 16T. A limited pressure sensitive paint (PSP) system is available. Wind tunnel models are supported using a remotely actuated, high-angle, sting-support pitch and roll system for aerodynamic testing. Pressurized air can be routed to the test models for simulation of control jets. A sidewall mounting system with a manually actuated support is available for aerodynamic testing of large panels. A six-degree-of-freedom Captive Trajectory Support (CTS) system is available for store integration testing.

Tunnel 4T has supported almost every major national flight vehicle development program and has been used recently for weapons integration testing on several fighters such as the multi-service F-35 Lightning II, F-22A Raptor, F/A-18C Hornet, F-14 Tomcat, F-15 Eagle, and F-16 Fighting Falcon. The tunnel has also been used to test large vehicles such as the B-1 Lancer and has provided Space Shuttle material testing. Customers include DoD organizations, NASA, both domestic and foreign private industry and academia.

The Von Karman Gas Dynamics Facility (VKF) is comprised of a supersonic wind tunnel (Tunnel A) and two hypersonic wind tunnels (Tunnels B and C). These tunnels provide high-quality flow in the Mach number 1.5 to 10 flight regime and operate as variabte-density, continuous-flow units. Tunnels A, B, and C offer large test sections (40 in. to 50 in.) for aerodynamic testing and have unique operating capabilities.

The tunnels are used extensively to obtain large aerodynamic and aerothermodynamic databases to develop supersonic and hypersonic flight vehicles. Customers utilize these facilities to conduct testing for static stability, pressure loads, jet interaction, store separation and vehicle staging, heat transfer, inlet integration, material sampling, thermal mapping, and dynamic stability, including forced and free oscillation.

One unique feature of Tunnel A is its computer-controlled, continuous-curvature nozzle that can vary Mach number from 1.5 to 5.5. In addition. Tunnels B (Mach 6 and 8) and C (Mach 4,8, and 10) are the only operational hypersonic T&E facilities with continuous-flow capabilities. The Mach 4 Tunnel C configuration can match true flight conditions from 56,000 to 105,000 ft. Each tunnel is also equipped with a unique model injection system to allow reconfiguration of test articles during air-on operation, resulting in high data productivity for obtaining aerodynamic databases. Tunnel C offers an aerothermal environment for testing materials proposed for use on space vehicles and aircraft. The one-of-a-kind hypersonic wind tunnel can subject flight hardware to a combination of aerodynamic and thermo-dynamic effects up to 1440 F to study how materials respond to the combined effects of external heating, internal heat conduction, and pressure loading. Special photographic techniques are used in the tunnels to visualize shock waves and heating patterns.

Virtually every high-speed flight vehicle has required testing in Tunnels A, B and C, from reentry and tactical vehicles and space capsules to the X-planes and winged vehicles. Extensive testing in Tunnels A, B and C has also been performed on the NASA Space Transport System, National Aerospace Plane, X-37 orbital test vehicle, X-43 reusable launch vehicle, and Atlas space launch vehicle.

Hypervelocity Wind Tunnel 9, (Tunnel 9) an AEDC site located at White Oak near Silver Spring, Md., provides aerodynamic simulation critical to hypersonic sys-tem development and hypersonic vehicle technologies.

The facility supports testing for Air Force, Navy, Army, Missile Defense Agency, and NASA programs, as well as advanced hypersonic technologies such as wave-rider-type vehicles, scramjets and transatmospheric space planes.

Tunnel 9 is the primary high Mach number and high Reynolds number facility for hypersonic ground testing and the validation of computational simulations for the Air Force and DoD. Noteworthy advantages of Tunnel 9 over other facilities include a unique storage heater with pres-sures up to 1900 atm and temperatures up to 3650 R. Axisymmetric contoured nozzles for Mach 7, 8, 10 and 14 operation are also available.

When compared to other hypervelocity facilities, which have run times of a few milliseconds, the long test times (up to 15 sec.) available in Tunnel 9 provide higher productivity by allowing for parametric variation, e.g., an angle-of-attack sweep or flow survey, during a single run. The 5-ft-diam (1.5 m) test cell accommodates large-scale test articles.

The combination of operational range, long test times, and a large test cell results in the highest Reynolds number and makes Tunnel 9 the largest scale ground-test facility in the world, capable of simultaneously collecting continuous pitch-polar static force and moment, pressure and heat-transfer data during each run. Having the capability to test at flight-matched Reynolds numbers provides a significant risk reduction for the design and evaluation of hypersonic systems.

Tunnel 9 provides a useful and cost-effective environment for re-search and development test and evaluation (RDT&E) and for investi-gating the complex physics associated with hypersonic science and technology. Past testing includes aerodynamic, aerothermal, seeker window thermal-structural and aero-optic, shroud removal, hypersonic inlet, fundamental flow physics and computational fluid dynamics (CFD) validation experiments.

The National Full-Scale Aerodynamics Complex (NFAC) wind tunnel facility, located at NASA's Ames Re-search Center in Moffett Field, at Mountain View, Calif., is operated by Arnold Engineering Development Center. This facility is composed of two large test sections and a common, six-fan drive system. A wide range of available support systems combine with this unique facility to allow the successful completion of aerodynamic experiments that cannot be achieved anywhere else. Additionally, each of the test sections is acoustically lined for acoustic testing.

The 40- by 80-ft wind tunnel circuit originally constructed in the 1940s, is now capable of providing test velocities up to 300 knots and Reynolds numbers up to 3 million/ft. The 80- by 120-ft open circuit leg was added and a new fan drive system was installed in the 1980s. The 80- by 120-ft test section is the world's largest wind tunnel and is capable of testing a full-size Boeing 737 at velocities up to 100 knots at nominal unit Reynolds numbers of 1.1 million/ft.

A system of moveable vanes can be positioned so that air is either drawn through the 80- by 120-ft test section and exhausted into the atmosphere, or driven around the closed circuit through the 40- by 80-ft test section. A passive air exchange system is utilized in the 40 by 80 circuit to keep air temperatures below 125 F.

The new fan drive system is composed of six variable-pitch fans, each 40 ft in diameter, arranged in two rows of three. Each fan has 15 laminated wood blades and is powered by a 22,500 hp electric motor. The six fans rotate together at 180 rpm drawing 106 MW of electricity at full power while moving more than 60 tons of air per second.

Unique test-specific requirements are explored with each customer to guide the experiment design, and new systems are integrated into the facility as needed. Utility support systems that have been used for testing powered vehicles and components include variable-frequency electrical power, hydraulic power units, cooling water, 150-and 400-Hz electrical power and jet fuel systems. Rotor test beds incorporating electric motors and rotor balance systems are available for testing complete rotor and hub systems independent of the flight vehicle.

The 717th Test Squadron at Arnold Engineering Development Center (AEDC) is responsible for propulsion testing in the Engine Test Facility (ETF) test cells, which are used for development and evaluation testing of turbine-based propulsion systems for advanced aircraft. These test cells provide essential test and evaluation services in support of DoD, U.S. industry, and international programs. AEDC operates nine active test cells for atmospheric inlet and altitude testing.

AEDC test cells are used for testing in areas including performance, operability, aeromechanical, icing, corrosion, inlet pressure distortion, inlet temperature distortion, accelerated mission testing (AMT), engine-inlet dynamics, mission simulations, and engine component testing. Test cells are available in a range of sizes to meet customer needs. AEDC has the right test cell for virtually any requirement, whether the test article is a small cruise missile engine or a large turbofan engine for the airline industry.

The ETF contains instrumentation and controls infrastructure to acquire measurements from an extensive variety of instrumentation used in turbine-engine testing. The various sensors available can support the requirements of both production and development engines. Measurement capabilities include force, fuel flows, air flows, high-frequency-response pressures, displacement, acceleration, digitally-scanned temperatures, digitally-scanned pressures, and high-speed digital video. Measurement capabilities in the various test cells range from 600 channels to over 3000, with parameter recording options from 1 sample per second up to 10,000 samples per second. Control capabilities include up to 500 channels of control input/output using programmable logic controllers. Open- and closed-loop control functions can be monitored while testing and are merged in real time with instrumentation data. AEDC can provide exacting calibration services for force, fuel flow, and pressure measurements. Spectral structural analysis equipment provides real-time engine component health monitoring in conjunction with steady state and transient data. Our systems can be modified to accommodate the customer's digital or analog systems.

AEDC is a recognized leader in propulsion testing and our capabilities are constantly improved through targeted investment to provide customers with the highest-quality data. With five decades of experience, our specialists in ground testing can provide unrivaled assistance to your team, from pre-test planning through post-test analysis and evaluation. Our careful test planning and coordination with test customers ensures that test objectives are met and testing is streamlined and efficient.

Altitude Test Cells C-1 and C-2 comprise the Aeropropulsion Systems Test Facility (ASTF). This is a unique national asset designed to test large military and commercial engines in true mission environments. ASTF is part of the Engine Test Facility and has helped establish AEDC as the USAF center of expertise in turbine engine testing. C-1 and C-2 are each 28 ft in diameter and approximately 45 ft in length. Each cell is capable of testing up to Mach 2.3 and simulating altitudes of up to 75,000 ft. Either cell can provide engine inlet temperatures of up to 350 deg F and accommodate engines producing up to 100,000 Ib of thrust.

C-1 is normally used to conduct performance testing of large augmented turbine engines. C-2 can also be used to test large augmented turbine engines, but is has recently been used for performance testing of large turbofan engines. Aeromechanical testing, vectored-thrust testing, icing testing, and inlet pressure and temperature distortion testing may also be accomplished in ASTF.

Support systems in both cells include state-of-the-art digital steady-state and transient data acquisition systems capable of recording up to 3500 parameters. Multiple, remotely-operated Venturis and a multi-leg fuel system allow each test cell to make accurate measurements of engine airflow and fuel flow over the full range of engine operation. C-1 provides multi-component thrust capability for the measurement of axial, side, and vertical forces. This allows the determination of axial thrust as well as pitch and roll moments. C-2 provides axial thrust measurement and also has the capability of conducting icing testing at altitude, including the capability of transiently varying liquid water content and droplet size during a single cloud simulation. C-2 also has the capability of performing inlet temperature distortion testing.

In recent years, C-1 has principally tested F119 engines for the F-22A aircraft and F135 engines for the F-35 aircraft. C-2 has tested various large turbofan engines such as the GP7200 for the Airbus A380, the PW6000 for the Airbus A318, the Trent 1000 for the Boeing 787 and the XF7-10 for the Japanese P-X.

Test Cells J-1 and J-2 are altitude test cells sized for medium and large turbine engine testing. The cells are similar in capability to cells C-1 and C-2, but smaller in size. The cells are each approximately 44 ft in length, but J-1 is 16 ft in diameter while J-2 has a diameter of 20 ft. Both J-1 and J-2 are capable of simulating altitudes up to 75,000 ft and testing up to Mach 3.2 and Mach 2.6, respectively. J-1 can provide engine inlet temperatures of up to 720 F. The upper limit of J-2 is and 450 F. J-1 can accommodate engines that produce up to 70,000 Ib of thrust, while J-2 is sized for engines that produce up to 50,000 Ib of thrust.

J-1 is normally used to conduct performance, aeromechanical and operability testing of medium augmented turbine engines, while J-2 is typically used for similar testing of larger augmented turbine engines. Core testing may also be accomplished in J-1.

Support systems in both cells include state-of-the-art digital steady-state and transient data acquisition systems capable of recording up to 2600 parameters in J-1 and 3500 parameters in J-2. Multiple remotely-operated Venturis and a multileg fuel system allow each test cell to make accurate measurements of engine airflow and fuel flow over the full range of engine operation. Both cells are also equipped with axial thrust stands allowing for accurate thrust measurement.

In recent years, J-1 has tested the F100 for the F-15 and F-16; the F110 for the F-16; the F118 for the B-2 and U-2; the F101 for the B-1B; and performed core testing on the Advanced Turbine

Engine Gas Generator (ATEGG). J-2 has also tested the F110, F118 and F101 engines, as well as the F119 engine for the F-22A and the F135 and F136 engines for the F-35.

Sea-level Test Cells SL-2 and SL-3 provide the capability to economically conduct durability testing on large augmented turbine engines at near sea-level conditions (1000 ft altitude) by eliminating the cost of running inlet and exhaust plant machinery. The cells are each approximately 24 ft in height and width and 60 ft in length. In addition to running ambient pressure inlet conditions, they also provide the capability of using the ETF plant to run ram conditions (inlet pressures above ambient), allowing testing at up to Mach 1.2 when necessary to achieve test objectives. Inlet temperature capability extends from ambient to 120 deg F when running in the atmospheric inlet mode and from 20 to 270 F in ram mode. Both cells can accommodate engines that produce up to 70,000 Ib of thrust.

These sea-level cells are normally used for Accelerated Mission Testing (AMT). These tests evaluate engine durability and performance retention by repeatedly simulating the types of missions the engine will fly in service. The ram capability allows interspersed testing of atmospheric inlet and ram AMT during a single test program, and eliminates the expense of engine removal and installation into another facility. In addition to a more accurate representation of engine use, it saves the customer time and money by allowing the testing to be done with a single engine installation. Since atmospheric inlet testing in SL-2 or SL-3 does not require the plant machinery, test scheduling becomes very flexible, allowing rapid completion of test objectives. Either cell can accomplish up to 80 hrs of atmospheric inlet testing per week sustained capability, with higher surge capability.

Support systems in both cells include state-of-the-art digital steady-state and transient data acquisition systems capable of recording up to 1500 parameters in SL-2 and 2200 parameters in SL-3. Calibrated bellmouths and multileg fuel systems allow both test cells to make accurate measurements of engine airflow and fuel flow over the full range of engine operation. Both cells are equipped with axial thrust stands allowing for accurate thrust measurement. Additionally, SL-3 is equipped to perform specialized testing such as corrosion testing.

In recent years, SL-2 has tested the F100 engine for the F-15 and F-16 and the F119 engine for the F-22A. SL-3 has also tested the F100 engine, as well as the F135 engine for the F-35.

Altitude Test Cells T-3, T-4 and T-11 are a diverse mixture of cells with multiple test applications for testing small and medium turbine engines. Their sizes and capabilities are varied to accommodate a range of test articles. T-3 is 12 ft in diameter and 15 ft in length, T-11 is 10 ft in width and height and 17 ft in length and T-4 is 12 ft in diameter and 47 ft in length. T-4 is capable of testing at altitudes of 75,000 ft and Mach numbers of 2.5 while T-11 is capable of 55,000 ft and Mach numbers of 2.0. T-3 can simulate altitudes up to 100,000 ft and Mach numbers of up to 4.0. The maximum inlet temperature capabilities are 250 F for T-11, 400 F for T-4, and 1200 F for T-3. T-3, T-4, and T-11 can accommodate engines producing up to 20,000,50,000 and 30,000 Ib of thrust, respectively.

The F405 Engine for the T-45A Installed in T-4

These cells are used for a variety of types of testing. T-3 is used for high Mach number turbine engine testing, T-4 is normally used for performance and operability testing of medium turbine engines and T-11 is typically used for cruise missile engine testing. These three cells are not in continuous use at AEDC. Some activation time may be required prior to use.

Support systems include steady-state and transient data acquisition systems capable of recording up to 600 parameters in T-11,1100 parameters in T-3 and 1500 parameters in T-4. Venturis and/or calibrated bellmouths and multileg fuel systems allow each test cell to make accurate measurements of engine airflow and fuel flow over the full range of engine operation. T-3 is equipped with a multicom-ponent thrust stand, while T-4 and T-11 are equipped with axial thrust stands.

The F135 Combustor Rig for the F-35 Engine Installed in T-11

In recent years, T-3 has performed combustor core testing for Westinghouse and supersonic flight conditions for advanced engine designs; T-4 has tested the F100 engine for the F-15 and F-16, the F414 engine for the F/A-18E/F, the AE3007H engine for the Global Hawk and the F405 for the T-45A; and T-11 has tested the F107-WR402A engine for the JASSM-ER, the F415 engine for the Tactical Tomahawk cruise missile, the F107 engine for the BGM-109G cruise missile, the F112 engine for the ALCM, the JETEC engine demonstrator, and accomplished combustor segment testing for the F135 engine for the F-35.

The 718th Test Squadron, Space and Missile Systems, at Arnold Engineering Development Center (AEDC) is responsible for ground testing space and missile weapon systems from subsonic to hypersonic conditions reaching Mach 20. The 718th Test Squadron provides hypersonic, rocket propulsion and space environmental T&E services. This squadron coordinates testing in over 30 facilities that support the development of defensive ballistic and tactical missile interceptors as well as weapons systems such as theater, cruise missile, high-speed aircraft and launch vehicles.

Space test capabilities in this area include capabilities for evaluating infrared and visible sensor performance, mission simulation and other hardware-in-the-loop activities. This support includes testing and research for space systems in a thermal/vacuum environment from component level to full-scale, fight-qualified hardware. Additionally, for component scale hardware, testing to simulate full spectrum space environments is available and includes contamination, solar, atomic oxygen, outgassing, radiation and other effects.

The 718th Test Squadron is chartered with maintaining the nation's largest archive of missile and rocket hard-body and plume-infrared signature data in the Advanced Missile Signature Center (AMSC).

Hypervelocity Ballistic Range G is used to conduct kinetic energy lethality and impact phenomenology tests. The Range G launcher is the largest two-stage, light-gas gun system in the United States that provides unequalled "soft launch" (minimized acceleration loading) capability to launch extremely high-fidelity missile simulations at hypervelocity speeds. Quarter-scale testing is available at velocities from 4900 to 23,000 ft/sec (1.5- to 7-km/ sec). Recent improvements have extended the range of capabilities to near half scale.

The Range G launcher is capable of launching various types of projectiles at velocities up to 23,000 ft/sec (7.0 km/sec). Projectiles up to 8.0 in. (203 mm) in diameter are launched into a 10-ft (3-m)-diameter, 930-ft (283.5-m)-long instrumented tank that can be maintained at pressure altitude from sea level to 225,000 ft. Three sizes of interchangeable barrels; 3.3 in. (84 mm), 4 in. (102 mm), and 8 in. (203 mm), are available for use on the Range G launcher. A four-rail guidance system can be mated to the barrel in order to guide the projectile close to the target and provide increased hit-point accuracy.

The 3.3-in. (84-mm)-diam launch tube is typically used to support one-fourth scale testing (projectile and target one-fourth the size of the full-scale system), but in order to meet the lethality test requirements of missile defense programs, AEDC has developed the capability to launch larger scale projectiles up to 8 in. (203 mm) at higher velocities than those previously achievable at any ground-test facility. With this capability, AEDC is able to provide a greater level of projectile and target fidelity for tests conducted with two-stage light-gas guns.

The primary challenge in designing projectiles for gun range lethality testing is to develop a geometrically scaled projectile that matches the axial and radial mass distribution of the actual missile and is able to withstand the acceleration loads experienced during gun launch. The use of 3-D finite element analysis software (ABAQUS) coupled with the AEDC light-gas gun code provides a seamless projectile design capability.

The Range G facility has an extensive assortment of unique test instrumentation that can be located as required for a particular test. New instrumentation capabilities are currently under development to aid in kill assessment using multispectral/infrared signature measurements. A high-speed x-ray imaging system also being developed will provide a method for understanding post-impact debris dispersion.

The J-6 Facility provides ground-test simulations for solid-propellant rocket motors. J-6 has been used mainly for aging and surveillance and in testing of stages II and III for both Minuteman and Peacekeeper ICBMs. Additionally, J-6 has supported STAR37 motor qualification testing for the Air Force's Global Positioning Satellite (GPS) constellation. AEDC has unique test capabilities for testing rocket propulsion systems with high-perfor-mance/high-area-ratio nozzles and those requiring altitude start and restart, stage separation and spin testing. J-6 is the largest of its kind in the world and provides the only altitude test capability for large rocket propulsion systems in the United States. Ambient (sea-level) testing of rocket propulsion systems designed for high-altitude operations can compromise engine performance data and potentially jeopardize the structural integrity of the exhaust nozzle. Ground testing under simulated altitude conditions in J-6 includes carefully controlled test environments with extensive instrumentation and photographic coverage to determine the operability and performance of a test article.

The J-6 digital data acquisition system is designed to acquire up to 500,000 samples/sec. Testing can also include an extensive array of sophisticated rocket diagnostic instruments obtainable only in a ground test configuration. State-of-the-art techniques such as wide-band infrared and ultraviolet radiometric coverage, emission/ absorption detection, laser-induced fluorescence plume surveys and real-time radiography are applications sometimes used in J-6 testing.

J-6 is designed to test large detonable solid-propellant rocket motors with up to 80,000 Ibs. Measuring 26 ft in diameter by 62 ft long, the horizontally oriented test cell is capable of testing rocket motors at simulated altitudes up to 100,000 ft. The temperature conditioning system can maintain the test cell at an air temperature within the range of 15 to 110 F (5 F) from motor installation until pre-fire pump down at altitude conditions.

J-6 supports long-duration altitude tests of high-area-ratio nozzle performance including deployment operation with dynamic loads, thermal ignition tests, stage separation testing, heat transfer, post-heat soaking and failure analysis. This facility can be used to test many different types of motors with either large quantities or advanced mixes of propellants. The facility is equipped with three interchangeable diffusers that can accommodate thrust ranges from 5000 to 500,000 pounds force. The test cell is connected to a 250-ft-diam by 100-ft-high concrete dehumidification chamber that collects, cools and conditions the resulting rocket exhaust products.

The AEDC arc heater facility is used to provide high-enthalpy test environments to test materials and other means of thermal protection. The AEDC arc-heated test facilities include two high-pressure, segmented arc heaters (H1 and H3) and one Huels arc heater (H2). Both types utilize an arc discharge to heat air to temperatures up to 13,000 R. 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.

The 30-MW 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. The unique segmented construction allows the arc to be held at a fixed length to optimize heater efficiency, total enthalpy at high pressure, and flow uniformity. Normal operating conditions for the heater are about 20,000 V and 1200 amp, providing heater chamber pressures up to 120 atm at high stagnation enthalpies. The H1 test cell is equipped with a multiple-strut, programmable rotary model injection system capable of positioning one to seven test models sequentially into the test freejet for preset dwell times.

The 45-MW 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 up to 120 atm. H2 utilizes an N-4 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 the exhauster makes possible high-enthalpy flows at Mach numbers from 5 to 9.

The 70-MW H3 arc heater was developed to provide a large, high-pressure arc facility with sufficient size and performance for testing of full- and large-scale missile and reentry samples and structures. H3 is a 12-mod-ule, 50-percent geometric scale-up of the H1 segmented arc heater and is designed to operate at over twice the available power level and mass flow of H1, with operational pressure up to 150 atm.

The Aerodynamic and Propulsion Test Unit (APTU) is a blowdown test facility designed for testing true temperature performance of propulsion, material, structures and aerodynamics of supersonic and hypersonic systems and hardware.

For 25 years APTU used its vitiated air heater (VAN) to conduct many successful test programs. The VAH used isobutane as the fuel to generate test conditions. Maximum pressure and temperature were limited to 300 psia (20.4 atm) and 2000 R (1111 K), respectively. From 1992 to 2005, over 275 runs were made for a wide range of system development programs for propulsion, aerothermal and aerodynamic issues. Significant improvements in test productivity were made during that time frame with as many as four runs per day.

Under the High-Speed/Hypersonic Air-Breathing Propulsion Test and Evaluation Capability (HAPTEC) program, APTU began a series of major upgrades in 2002 to provide a ground-test capability for supersonic and hypersonic systems up to Mach 8. Upgrades are planned through 2011 that will be implemented without interference to customer test schedules. Phase one of the upgrade, completed in 2004, modified the APTU utility supply systems (high-pressure air, isobutane, liquid oxygen and water) and replaced the air ejector system to increase the facility's altitude simulation capability. Phase two centered on replacing the VAH with a much more capable high-pressure, high-temperature combustion air heater (CAM). APTU in its CAM configuration reached initial operational capability (IOC) of Mach 6.75 in September 2007. Phase three will add a varying Mach number test capability from as low as Mach 2 to above Mach 5, with fixed area ratio nozzles being used above Mach 6.

The CAH was designed to operate over a range of total pressure from 200 psia to 2800 psia (13.6 atm to 190.5 atm) and a range of total temperature from 1200 R to 4700 R (667 K to 2611 K). Though it has been cleared for operations up to Mach 6.75, it is capable of generating Mach 8 test conditions with the appropriate nozzle. Five fixed freejet nozzles are currently available to produce test conditions from Mach 3.1 to Mach 7.2.

When completed, the HAPTEC upgrades will provide customers with a much needed ground-test capability for the research, development and acquisition of high-speed and hypersonic propulsion systems.

The AEDC 7V (7-ft diam by 21 -ft long) and 10V (10-ft diam by 30-ft long) sensor chambers are part of a state-of-the-art space environment simulation test facility designed to test interceptors and surveillance sensors. These chambers are configured to provide complete characterization and radiometric calibration of a visible and infrared (IR) sensor. This includes all categories of sensor characterization (flood, point, polarized source, spectral calibration and mission simulation). An assortment of source systems allows evaluation of sensor performance over a wide range of target conditions. Current generation sensor arrays mounted in the chambers provide independent source and background evaluation and target position. Both chambers are cooled using gaseous helium shrouds with an optically clean vacuum system. 7V is in a Class 1000 Clean Room, while 10V is in a Class 10,000 Clean Room. A 300,000-lb seismic mass allows vibration isolation of the optical bench and all optical elements. A radiometric calibration system allows for accurate calibration of source systems that is traceable to the National Institute of Standards and Technology (NIST).

The 10V Chamber sensor test facility features a high-fidelity target system containing multiple independent point-source systems to simulate target acquisition and tracking operations. An IR scene projection system is used to simulate objects in the sensor's field-of-view and provides simulation of the terminal phase of the interceptor mission. A visible projection system is used to simulate star shots and objects that appear in the visible spectrum. The 10V Chamber is configured to provide end-to-end closed-loop mission simulation capability for interceptor and surveillance sensor systems, providing simulation of the sensor mission from launch to intercept.
Mark I (42-ft diam by 82-ft high) is DoD's largest vertical space chamber and has tested full-scale satellites and space platforms. This facility has the capability to stay on conditions months at a time under thermal vacuum conditions of 1 0~7 using cyro pumps and a liquid nitrogen liner at 77 K. With over 1,500 test data channels and the necessary support infrastructure, this facility can support a variety of test sceneries.

The 12V Chamber is a 12-ft-diam by 35-fl-high thermal vacuum test facility. The facility has its own nitrogen thermal shroud and an optional gaseous helium liner that can be cooled to 10 K. The chamber is currently configured for high-power electric propulsion (EP) thruster plume analysis and integration effects.

Nuclear effects testing is accomplished using a small X-ray simulator. The Modular Bremsstrahlung Source (MBS) provides nuclear effects testing on cables and small satellite components.

The Advanced Missile Signature Center (AMSC) is a national facility supporting the Missile Defense Agency (MDA), Defense Intelligence Agency Missile and Space Intelligence Center (DIA-MSIC) and other DoD programs with analysis, modeling, measurement, archival and distribution services. The AMSC archives include target, threat and battlespace environment signatures for missiles and other vehicles. Staff expertise and supporting infrastructure are primarily focused on tactical and ballistic missile ultraviolet, visible and infrared plume signatures. These capabilities are leveraged to also address signatures associated with missile post-burnout and reentry, celestial and terrestrial backgrounds, and other battlefield targets such as mortars, small arms fire and fixed and rotary wing aircraft.

AMSC experts use state-of-the-art instrumentation and infrastructure to collect temporal, spectral, and spatial signatures during static, launch, sled, and free flight tests on test ranges in and outside the USA. Sensors are calibrated to National Institute of Standards and Technology (NIST) pedigree and deployed for expert digital data collection, processing and quick-look products.

Complementing the measurement capabilities are expertise and computational tools for enhanced data processing, data analyses and physics-based modeling and simulation. AMSC maintains a suite of image processing/analysis tools and JANNAF-standard codes to exploit measured data and confidently extrapolate to signatures in the flight envelope that are not readily measured.

This extrapolation process anchors the modeled signatures to measured data. Thousands of modeled signatures are then coupled with an AMSC processing methodology to generate a hypercube of high-fidelity flight envelope signatures that are readily accessible for real-time, hardware-in-the-loop applications.

The AMSC efficiently manages digital data, documents and other non-digital media such as film and video at multiple classification levels. All documents are converted to softcopy text searchable form for information search and retrieval. For key digital data sets, primary data and metadata are merged into a common standard archive format that permits data recipients to quickly access and exploit data content. Film and video media in 16-, 35- and 70-mm film formats and all of the major video formats can be digitized, and image processing tools can be applied to further exploit collected data. Catalogs and certain program data sets are also available through access-controlled websites.

The Arnold Engineering Development Center supports a robust and versatile Applied Technology & Analysis Program focused on three primary disciplines: Mod-eling and Simulation (M&S), Instrumentation and Diagnostics (I&D) and Facility Enhancements and Test Techniques (FE&TT). A team of engineers, scientists and support personnel provide expertise to develop and adapt complex computational models, nonconventional diagnostic systems, advanced facility capabilities, test techniques and engineering-level facility models to ad-dress customer testing and AEDC facility infrastructure requirements.

The goal of the M&S focus area is to provide validated, computationally-efficient tools that can be transitioned to support test engineers in their efforts to optimize test matrices and test facility configurations, including placement of critical diagnostic instrumentation. Post-test CFD simulations provide insight for diagnosing and correcting data anomalies and extrapolating ground test data to flight scenarios.

Aerodynamic flow models predict environments surrounding complex aerodynamic vehicles. Interactions of the free stream flow with control surfaces and the separation of stores from aircraft bays and pylons are significant aerodynamic concerns addressed by computational fluid dynamic (CFD) methodologies. Physics-based CFD models are also applied to predict internal flow streams passing through turbine engine rotating components and to simulate highly energetic combustion phenomena occurring inside propulsion systems. Specialized facility models predict the thermo/fluid dynamic behavior of ground test facilities and provide insight for optimizing facility operations.

The goal of the I&D focus area is to provide AEDC test engineers and customers with state-of-the art diagnostic techniques which minimize measurement uncertainties, reduce diagnostic hardware interferences with interrogated flow environments, and provide high-reso-lution, real-time flow field characterization. The high-quality measurements are used to validate numerical models, guide model improvements and enhancements and provide test customers with unique insights into test article behavior.

Both intrusive and nonintrusive techniques are being developed and used to acquire quantitative, spatially resolved flow-field measurements and qualitative flow vi-sualization across the full spectrum of test environments. Significant ongoing efforts are focused on innovative designs, fabrication techniques and stringent calibration requirements of specialized probe systems for applications in harsh environments. Currently, diagnostic probes have been used successfully to quantify Mach number, temperature, pressure and flow angularity in high-enthalpy flow streams, including Mach numbers approaching 7. Probe sampling systems have been developed which chemically quench flow samples entering the probe in order to quantify both gaseous and particulate species. Innovative probe designs and state-of-the-art fabrication techniques have been developed for embedding miniaturized cameras and Micro Electro Mechanical Systems sensors within the probe tips, allowing visualization of combustion phenomena occurring inside turbine engine combustion chambers and augmentor components. Improvements in probe design for survivability at higher temperatures, pressures and Mach number conditions continue to be addressed.

Nonintrusive optical diagnostic systems are being developed and applied to quantify and visualize flow environments inside AEDC test cells. Specialized active optical techniques which stimulate and measure exhaust emission features have been successfully demonstrated. These measurements are used to derive spatially resolved flow-field properties including temperature, multiple velocity components and chemical specie concentrations within the flow. These techniques have been successfully demonstrated for monitoring test facility flow quality and for acquisition of quantitative flow-field properties on a noninterference basis.

The goal of the FE&TT focus area is to work enhancements closely with test engineers in developing and demonstrating specialized simulation hardware, facility systems and ground-test methodologies to address the challenges of providing realistic and efficient flight simulation conditions in ground-test environments.

The scope of technology efforts supporting FE&TT includes development and improvements of test facility systems and engineering-level facility models for the Propulsion, Aerodynamic and Space and Missile Systems areas. Specifically, this focus area supports identification of required technology development to support future test facility requirements and address T&E deficiencies, analysis of facility performance and durability issues and the development of advanced test methodology concepts.

In summary, the Applied Technology and Analysis Program combines technical expertise in M&S, I&D and FE&TT to support the Integrated Test and Evaluation (IT&E) process at AEDC. AEDC maintains dedicated technology investments to enhance these capabilities to support challenging requirements and address identified shortfalls in order to eliminate technical risks and uncertainties associated with ground testing and data integration and analysis.

In addition to extensive test and evaluation capabilities, AEDC can provide a full range of other services for its customers.

AEDC understands that confidentiality of customer test and evaluation information is paramount, so AEDC has an active security program. AEDC can perform DoD classified testing and provide test preparation areas, test facilities, control rooms and data systems that are secure.

AEDC's precision machine shop has a full complement of skilled machinists and a complete range of modem machines, from conventional to six-axis computer-numerically controlled (CMC), as well as electrical discharge machine tools. Heat treatment, chemical cleaning and welding facilities are also available. The machine shop maintains coordinate measuring equipment for precise measurement of complex contours to allow 100-percent inspection and recording of all dimensions.

The Metallurgical/Nondestructive Evaluation Laboratory provides metallurgical test and evaluation services including stress and tensile strength testing, welder certifications, radiographic inspections, and other nondestructive test services. The Chemical Laboratory provides chemical analysis of various components including fuels, oils, soils, liquid-rocket propellants, exhaust gases, water, and various other liquids and gases.

AEDC maintains the Precision Measurement Equipment Laboratory (PMEL), which is certified by the Air Force Metrology and Calibration (AFMETCAL). The PMEL provides calibration of test measurement instrumentation such as voltage measurement, pressure, temperature, and dewpoint standards at the appropriate intervals to ensure measurements that are traceable to the National Institute of Standards and Technology (NIST).

The Aerothermodynamic Measurement Laboratory (ATML) provides technical expertise, analytical tools, and calibration/characterization facilities for applied research in aerothermal test measurement techniques. ATML services include specialization in heat transfer and transient temperature measurement for application to space and atmospheric high-speed flight models. Specialized instrumentation is designed, fabricated, calibrated, and installed in supersonic and hypersonic test articles and facilities.

High-Performance Computing (HPC) computational resources are provided to support customers with time-critical mission support via rapid data analysis and the capability to computationally test high-fidelity physics models in a shorter time, thus saving resources. HPC computers are primarily used to provide computational fluid dynamics (CFD) solutions to customer requests and to develop numerical algorithm and physics modeling improvements.

As World War II was ending in Europe, General of the Army Henry H. "Hap" Arnold and Hungarian-born aerodynamicist Dr. Theodore von Karman met to discuss America's future requirements for air power. General Arnold, alarmed by the Germans' development of advanced jet aircraft and rockets, asked Dr. von Karman to convene a group of scientists to work out guidelines for air research for the next 20 years or more.

Dr. Frank Wattendorf, a member of this Scientific Advisory Group, proposed the creation of an Army Air Force center that would provide new directions and major new national capabilities for research and development programs. The primary purpose of the new center was to help the U.S.

lead technological developments, not merely keep up with them. In keeping with a larger blueprint for the future of the U.S. Air Force, the Scientific Advisory Group's study "Toward New Horizons" was published in December 1945.

In 1949, Congress passed Public Law 81-415: The Unitary Wind Tunnel Plan Act of 1949 and the Air Engineering Development Center Act of 1949. The laws were enacted to promote the national defense by authorizing a unitary plan for the construction of transonic and supersonic wind-tunnel facilities and the establishment of an Air Engineering Development Center.

Congress selected Middle Tennessee as the site for the new center because of its availability of land, water and power. Construction of the center began in 1950. President Harry S Truman dedicated the center on June 25, 1951, to the memory of General Arnold as the Arnold Engineering Development Center, on what would have been General Arnold's 65th birthday.

Over the last 55 years, as new military systems have been developed, their components

- engines, airframes, stores, sensors and more
- have made their way to AEDC facilities.

In the center's jet engine and rocket motor test cells, transonic, supersonic and hypersonic wind tunnels and ballistic and impact ranges, AEDC engineers and scientists have pushed these systems to the edge of simulated flight.

Almost every high performance aircraft flown by the Air Force, Navy and Marines can trace part of its roots to AEDC. The technological advances achieved in the last 55 years at the center have helped put man on the moon, established America's air dominance, deterred aggression, saved American lives on the battlefield and helped prosecute the global w.ir on terror.

AEDC stands out from other bases because of its distinctive work force - 84 percent contractor employees and 13 percent government personnel.

Since the center's inception in 1951, contractors have been utilized to save money and grow and foster an experienced group of people who would make their careers at AEDC.

This philosophy has worked. The average age of the contractor and government civilian work force is 47.8, with an average of 14.3 years of experience at the center. The average age of the active-duty military portion of the work force is 37, with an average of two years at the center.

AEDC employed 2,785 people in fiscal year 2008. This number includes active-duty military personnel from the Air Force and Navy, DoD civilians and contractor personnel. Active-duty military members made up less than 3 percent of the work force.

AEDC's government staff is composed of military personnel and civilian employees who provide management direction, resource allocation, oversight and contractor administration.

TVA Model Estimates for AEDC As of Sept. 30, 2008

Direct Employment at AEDC

Military	68
DoD Civilian	258
Non-appropriated Fund	48
ATA	2,325
Other	86
Base Exchange, Commissary, Ascend Federal Credit Union, tenant organizations, other contractors	
Total	2,785
Secondary Jobs Created	1,892
Total Employment Impact	4,677

The contractor for fiscal year 2008 was ATA, a joint venture of Jacobs, Computer Sciences Corp., and General Physics.

Technical excellence has always been a hallmark of AEDC; however, cost reductions and acquisition policies have driven the center to a greater focus on efficiency of operations. While efficiency is vital to the center's operations, it had softened the focus on technical rigor.

For that reason, leadership designed an initiative for AEDC to get back to the basics.

This initiative focused on developing and implementing methods to re-establish technical excellence amongst military, civilian and contractor personnel. By doing this, AEDC would instill a technical excellence culture.

Thus, the center established the AEDC Technical Excellence Board (TEB). The TEB, chaired by Dr. Ed Kraft, AEDC's chief technologist, is responsible for developing policies and practices to enhance technical excellence at AEDC and alleviating any barriers keeping the center from achieving technical excellence.

The TEB took a multi-faceted look at education, job experience, mentoring, recruiting and other areas to — come up with ways to ensure our customers that AEDC has a robust, technically sharp, respected work force now and in the future.

In December 2007, AEDC held its first technical forum. During the forum, the AEDC community gathered and discussed technical ideas and issues affecting the center and their work environment.

In 2008, after determining the best course of action, AEDC began executing the various aspects of the technical excellence initiative. This includes, but is not limited to, employee development, education, career broadening initiatives, technical achievement awards, recruitment activities, technical review forums, validation of research topics, participation in Technical Review Boards, technical publications, reviews of AEDC's technology program and much more.

AEDC has seen some benefits from its competitive contract award, including more definitive Air Force control of the operation, more effective cost control and improved responsiveness of the contractor to Air Force and AEDC customer needs.

In October 2003, Aerospace Testing Alliance (ATA) became the new contractor to provide the personnel and services for operating and supporting the center's test facilities and infrastructure. ATA is a joint venture of Jacobs, Computer Sciences Corp. (CSC) and General Physics. The contract has a possible length of 12 years in one-year increments and is worth up to $2.7 billion. ATA supports the center with a wide range of services including: operational maintenance of a wide variety of unique aerospace test facilities; information technology; desktop operation and maintenance; center communications; test utility operations; environmental, safety, industrial health and quality assurance; calibration, chemical and photo laboratories; civil engineering; transportation; materials management; fire protection; security services; emergency management; food services; custodial; and public affairs.

Six subcontractors help to make up ATA's organization.

ATA provides AEDC strong technical enhancement with its approach to management and operations.

One distinct feature setting AEDC apart from other military installations is its contractor work force. At AEDC, contractors represent almost 85 percent of the work force and perform almost 90 percent of the work.

A military work force is by design transient. Roughly every two to three years, new personnel transfer in or out, making it difficult to build corporate knowledge.

The original rationale for operating AEDC with private sector personnel was based on the limited availability of qualified technical personnel in the Air Force, either as military or civilians. Also recognized was the flexibility afforded by the use of private companies who could hire and terminate employees more easily than the federal government. In addition, a private company has a greater ability to tailor its pay scales or even individual salaries to market rates, thereby allowing them to recruit personnel with special skills who the government may not be able to attract.

The decision to use a for-profit corporation has proved beneficial. Although the original contracts were cost-plus-fixed fee, the contracts over the last 28 years have been cost-plus-award-fee. The award fee feature has enabled the Air Force to use the profit motive to incentivize contractors to continually improve productivity and quality while controlling costs.

White Oak

Due to the unique nature of the Hypervelocity Tunnel 9 test capability, utilization has been at record levels in recent years. Test income from fiscal year 2004 through fiscal year 2008 has continued at capacity level. Customers from each sector of the mission including missile defense, strategic systems and space access have performed testing events at Tunnel 9 located at Silver Spring, Md. All DoD agencies, Defense Advanced Research Projects Agency (DARPA) and

|Missile Defense Agency (MDA) were represented. In addition, the future looks solid for testing |from research labs, Small Business Innovation Research (SBIR) programs, private aerospace; companies and NASA. In fiscal year 2008, the Hypervelocity Wind Tunnel 9 completed 74 days of testing representing near-full capacity. Test programs were successfully completed for the U.S. Air Force, U.S. Navy, NASA and Lockheed Martin.

Mission Statement

Responsible for management and oversight of all aspects of the AEDC White Oak site. Manages the testing and evaluation of high-speed/hypersonic systems. Serves as the primary customer interface and center planning and execution agent for performing hypersonic system testing. Responsible for develop-ing and communicating the strategic roadmap for all aspects and support to the hypersonic product area. Responsible for all aspects of the test mission including budgeting, business development, test planning, test execution and data analysis and reporting. Directs high-speed/hypersonic analysis and evaluation program. Reports to the Commander of the 704th Test Group coordinating test planning, resourcing, execution and reporting activities.

Fiscal Year 2008 Highlights

The High-Alpha Reusable Launch Vehicle (RLV) test program investigated the aerodynamic and aerothermal performance characteristics of reentry vehicle configurations designed to enter the atmosphere at high angles-of-attack. Data acquired during these tests will form the basis for a new database that will enable design of higher performance trans-atmospheric vehicles and a design space for replacements of the current U.S. Space Shuttle. Testing concluded in October 2007 meeting all test objectives.

The U.S. Navy Reentry Systems Nose-tip test program provided characterization of several reentry body ablated nose-tip shapes. Aerothermal characterization was performed at Mach 8 on several nominal and ablated geometries. Data from this test entry will provide accurate design verification on candidate nose-tip materials for use in future reentry systems. All primary and secondary objectives were met.

The NASA Orion Crew Exploratory Vehicle (CEV) Aerothermal test program focused on investigating surface roughness-augmented heating at simulated hypersonic atmospheric reentry test conditions. Data acquired during these tests will be used by NASA to understand the heating environment which the vehicle will need to survive during atmospheric reentry. Testing concluded in the summer of 2008, with successful completion of 32 runs which met all primary and secondary test objectives.

The goal of the Reentry Nose tip Aero Trim test effort was to acquire empirical data to validate computational fluid dynamic (CFDJ codes that characterize the effects of asymmetric nose tip shapes on tri-conic reentry bodies at low angle of attack and low altitude conditions. Force, moment, surface pressure and surface temperature/heat transfer data were acquired from -3 to +3 degrees angle of attack at a Mach 8 free stream and high Reynolds number condition. Flowfield Schlieren/ shadowgraph imagery was also obtained. By the end of the fiscal year, a total test matrix of six runs was successfully accomplished. Data reduction and analysis began in fiscal year 2009.

Scheduled maintenance activities were successfully completed during the summer of fiscal year 2008 to maintain the facility in a mission ready status. The actual readiness and performance metrics for this capability were exceeded with a 100 percent availability and more than 97 percent success rate for test execution. The design of a new control room for the facility was completed and scheduled for installation during the first half of fiscal year 2009.

Fiscal Year 2009 Forecast

Tunnel 9 will begin a scheduled outage during the first two quarters of fiscal year 2009. Major construction of the federal property is to begin in October 2008 which will require suspending operations until complete. During that time, backlogged maintenance will commence and the new control room will be installed and verified. Once complete, testing is NFAC The National Full-Scale Aerodynamics Complex (NFAC), located at NASA Ames Research Center in Moffett Field, Calif., was reactivated in 2006 as an AEDC-operated facility. This wind tunnel testing facility - which closed in 2003 due to budget pressures - underwent two years of refurbishment before attaining full operational capability (FOC) in early 2008.

Fiscal Year 2008 Highlights

During the fiscal year, the U.S. Army, Defense Advanced Research Project Agency (DARPA), NASA and Sikorsky Aircraft Corporation tested at NFAC.

In December 2007, NFAC supported space exploration with the successful dynamic loads and development testing of NASA's Mars Science Laboratory parachute. The parachute - which is used to slow down spacecraft during entry, descent and landing - holds more air than a 3,000-square-foot house and is designed to survive loads in excess of 81,000 pounds. During testing, the parachute was attached to a launch arm, mounted on a swivel base inside the 80-by-120-foot wind tunnel, so it could be tested under conditions simulating entry into the Martian atmosphere.

After undergoing two rounds of testing, data concluded that the parachute could successfully survive while descending into the Martian atmosphere.

In early 2008, NFAC achieved FOC for rotorcraft testing which allowed the wind tunnel complex to conduct its first military test entry since its reactivation.

The first test article, Boeing Corporation's, Smart Material Actuated Rotor Technology (SMART) helicopter rotor, was tested in the 40-by-80-Foot Wind Tunnel to study the system’s forward flight characteristics and collect baseline data to validate cutting-edge aero-acoustic analysis codes. Furthermore, the information obtained from the rotorcraft testing helped advance DARPA's Helicopter Quieting Program. DARPA is utilizing the data to advance design tools for the next generation of the Department of Defense's service platforms.

In fiscal year 2008, the NFAC team was awarded the San Francisco Chapter of the American Helicopter Society 2008 award for Outstanding Contribution to the Powered-Lift Field Vertical Take-Off and Landing (VTOL). The award recognized the multi-service and industry team who completed a five-month detailed check-out of the UH-60 rotor system mounted on NASA's Large Rotor Test Apparatus (LRTA) in NFAC's 80-by-120-foot wind tunnel. This test enabled the first forward flight rotor test in the facility since 2003.

Revenues for fiscal year 2008 were approximately $1.5 million. Fiscal Year 2009 Forecast
During fiscal year 2009, NFAC will continue its focus on rotorcraft testing using the LRTA to evaluate the benefits of the Individual Blade Control (IBC) Technology for performance and acoustic enhancements.

Additionally, NASA's Mars Science Laboratory will return for a final series of testing before launching the satellite system in 2011.

Arnold Engineering Development Center (AEDC) is the most advanced and largest complex of flight simulation test facilities in the world. The center's capabilities are comprised of more than 50 aerodynamic and propulsion wind tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other special-iced units. Facilities can simulate flight conditions from sea level to 300 miles in altitude and from sub-sonic velocities to Mach 20. AEDC is an important national resource and has contributed to the development of practically every one of the nation's top priority aerospace programs including space access, aircraft, missiles and satellites. Many of these pro-grams are highlighted in the following test facility descriptions.

The Arnold Engineering Development Center is an Air Force Materiel Command facility and is man-aged by the Air Force, but is operated by a contrac-tor workforce. AEDC's primary location is in Tennessee, but AEDC also operates two geographically separated facilities — the Hypervelocity Wind Tunnel 9 in Maryland and the National Full-Scale Aero-dynamics Complex in California. The responsibility for customer interface and test planning falls under the 704th Test Group, which has three main mission areas led by Air Force squadron commanders. The squadron and mission area designations are:

- 716th Test Squadron, Flight Systems
- 717th Test Squadron, Aeropropulsion Systems
- 718th Test Squadron, Space and Missile Systems

The balance of this guide describes the test capabilities that are currently maintained in an ac-tive status and have active or projected testing, as well as the specialized technical services that are available. A portion of the AEDC facilities are cur-rently in an inactive state and would require some additional lead time to support a test. The tables in each section include a summary of both active facilities as well as selected inactive facilities that might be of interest.

AEDC MISSION
Test and evaluate aircraft, missile and space sys-tems and subsystems at the flight conditions they will experience during a mission to help customers develop and qualify the systems for

flight, improve system designs and establish performance before production, and help users troubleshoot problems with operational systems

Conduct a research and technology program to de-velop advanced testing techniques and instrumentation and to support the design of new test facilities. Continual improvement helps satisfy testing needs and keeps pace with rapidly advancing air-craft, missile and space system requirements

Maintain and modernize the center's existing test facilities

The 716th Test Squadron at Arnold Engineering Development Center (AEDC) and our two operating locations offer aerodynamic ground test capabilities from very low subsonic speeds through Mach 14 in various wind tunnels. These wind tunnels provide essential test and analysis services in support of DoD, national, U.S. industry and international aerospace programs. AEDC operates five active wind tunnels in two primary facilities, the Pro-pulsion Wind Tunnel Facility (PWT) and the von Karman Gas Dynamics Facility (VKF). AEDC also manages two wind tunnels at remote operating locations - the Hypervelocity Wind Tunnel 9 at Silver Spring, Md. and the National Full-Scale Aerodynamics Complex (NFAC) at Moffett Field, Calif.

AEDC wind tunnels are used for testing in 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, acous-tics, thermal protection system evaluation, hypersonic flow physics, space launch vehicles, operational propulsion systems and captive flight.

An extensive inventory of instrumentation is available for testing use, including force and moment balances, heat transfer gauges and electronically scanned pressure modules. AEDC can provide calibration services for force and moment balances. AEDC is experienced with other wind tunnel test instrumentation such as model attitude measurement devices, pressure sensitive paint (PSP), heat-transfer gauges, dynamic pressure trans-ducers and several flow visualization techniques. In addition, customers can choose to have AEDC design and fabricate their wind tunnel test models to best meet program requirements.

AEDC is a leader in wind tunnel data productivity, and its facilities are continually optimized through targeted investment and maintenance to provide customers with the highest quality aerodynamic data. With decades of experience testing and analyzing the nation's flying weapons systems, our team can provide program develop-ment experience to your system. Our engineers are highly trained and experienced in wind tunnel tests and associated analyses and use standardized, configuration-controlled test processes to ensure high quality, high fidelity, and accurate test results. Careful test planning and coordination with test customers ensures that test objectives are met and that testing is streamlined and efficient.

AEDC wind tunnel test sections are some of the largest in the world for the speed ranges they provide, being able to accommodate moderate- to large-scale models to limit scalability issues and increase the fidelity and quality of simulation.

Propulsion Wind Tunnel 16T provides flight vehicle developers with the aerodynamic, propulsion integration, and weapons integration test capabilities needed for accurate prediction of system performance. Large-scale models can be accommodated in the 16-ft square by 40-ft long test section and can be tested at Mach numbers from 0.05 to 1.60. Pressure in the test section can be varied to simulate unit Reynolds numbers from approximately 0.03 to 7.3 million per foot or altitude conditions from sea level to 76,000 ft. Air-breathing engine and rocket testing can also be performed in 16T using a scavenging system to remove exhaust from the flow stream.

Wind tunnel models can be supported in a variety of ways including a High Angle-of-Attack System (HAAS) for evaluating extreme flight attitudes and a Captive Trajectory Support (CTS) system for weapons integration testing. Other testing support services include utilities such as supplying high-pressure air to the test models for simulation of jet exhaust or control jets. A fuel system is also available for engine testing.
16T provides world-class test productivity by using automated and integrated test process controls. Modem steady-state and high-speed data systems with real-time displays and multichannel remote controls are available. High-rate continuous-sweep data acquisition is routinely acquired to provide a more complete assessment of model aerodynamics and related effects during test. Other data needs will be met as established through communication with the test customer.

One example of AEDC's continuous improvements in test technologies has been the development of the pressure sensitive paint (PSP) data acquisition system that provides full-time, 360-deg model coverage. This system allows engineers to acquire and evaluate global surface pressure data on wind tunnel models using a special paint whose luminescence is a function of the local test article surface pressures.

Major aircraft development programs, such as the recent Lockheed Martin F-35 Lightning II and Boeing's F/A-18E/F Super Hornet, have selected 16T as a primary aerodynamic test data supplier. Other high-performance military aircraft, such as the B-2A Spirit stealth bomber and the RQ-4 Global Hawk unmanned aerial vehicle, have undergone extensive testing in 16T, as have space vehicles such as the DoD's Evolved Expendable Launch Vehicle (EELV), the NASA Space Shuttle, and research vehicles such as the Blended Wing Body or the X-33 reusable launch vehicle.

16T has supported almost every major DoD and government flight vehicle program of the past 55 years, and our customers include both domestic and foreign private industry and academia.

AEDC's four-foot transonic wind tunnel (4T) is a versatile, continuous-flow, mid-size test facility that can be used for a variety of aerodynamic test needs. Used primarily in conducting small-scale aerodynamic and store separation testing, the tunnel has a 4.0- by 4.0- by 12.5-ft test section. The transonic designation indicates its primary use for testing at near-sonic airspeeds, however, its Mach number capability extends from about 0.05 to 2.46, and up to about 2.5 for some installations. Tunnel 4T can simulate altitudes from sea level to 98,000 ft and provide Reynolds numbers up to approximately 7.1 million/ft.

Although Tunnel 4T is primarily used in conducting small-scale aerodynamic and store separation testing, a variety of test types, many of which can be applied simultaneously during a single test entry, are available. Tunnel 4T has been used to conduct specialized testing such as material testing, and our engineers can develop special-iced test techniques to meet the unique test needs of our customers.

Supporting systems include modem, state-of-the-art, steady-state and high-speed data acquisition systems with automated test process controls for high test productivity similar to 16T. A limited pressure sensitive paint (PSP) system is available. Wind tunnel models are supported using a remotely actuated, high-angle, sting-support pitch and roll system for aerodynamic testing. Pressurized air can be routed to the test models for simulation of control jets. A sidewall mounting system with a manually actuated support is available for aerodynamic testing of large panels. A six-degree-of-freedom Captive Trajectory Support (CTS) system is available for store integration testing.

Tunnel 4T has supported almost every major national flight vehicle development program and has been used recently for weapons integration testing on several fighters such as the multi-service F-35 Lightning II, F-22A Raptor, F/A-18C Hornet, F-14 Tomcat, F-15 Eagle, and F-16 Fighting Falcon. The tunnel has also been used to test large vehicles such as the B-1 Lancer and has provided Space Shuttle material testing. Customers include DoD organizations, NASA, both domestic and foreign private industry and academia.

The Von Karman Gas Dynamics Facility (VKF) is comprised of a supersonic wind tunnel (Tunnel A) and two hypersonic wind tunnels (Tunnels B and C). These tunnels provide high-quality flow in the Mach number 1.5 to 10 flight regime and operate as variabte-density, continuous-flow units. Tunnels A, B, and C offer large test sections (40 in. to 50 in.) for aerodynamic testing and have unique operating capabilities.

The tunnels are used extensively to obtain large aerodynamic and aerothermodynamic databases to develop supersonic and hypersonic flight vehicles. Customers utilize these facilities to conduct testing for static stability, pressure loads, jet interaction, store separation and vehicle staging, heat transfer, inlet integration, material sampling, thermal mapping, and dynamic stability, including forced and free oscillation.

One unique feature of Tunnel A is its computer-controlled, continuous-curvature nozzle that can vary Mach number from 1.5 to 5.5. In addition. Tunnels B (Mach 6 and 8) and C (Mach 4,8, and 10) are the only operational hypersonic T&E facilities with continuous-flow capabilities. The Mach 4 Tunnel C configuration can match true flight conditions from 56,000 to 105,000 ft. Each tunnel is also equipped with a unique model injection system to allow reconfiguration of test articles during air-on operation, resulting in high data productivity for obtaining aerodynamic databases. Tunnel C offers an aerothermal environment for testing materials proposed for use on space vehicles and aircraft. The one-of-a-kind hypersonic wind tunnel can subject flight hardware to a combination of aerodynamic and thermo-dynamic effects up to 1440 F to study how materials respond to the combined effects of external heating, internal heat conduction, and pressure loading. Special photographic techniques are used in the tunnels to visualize shock waves and heating patterns.

Virtually every high-speed flight vehicle has required testing in Tunnels A, B and C, from reentry and tactical vehicles and space capsules to the X-planes and winged vehicles. Extensive testing in Tunnels A, B and C has also been performed on the NASA Space Transport System, National Aerospace Plane, X-37 orbital test vehicle, X-43 reusable launch vehicle, and Atlas space launch vehicle.

Hypervelocity Wind Tunnel 9, (Tunnel 9) an AEDC site located at White Oak near Silver Spring, Md., provides aerodynamic simulation critical to hypersonic sys-tem development and hypersonic vehicle technologies.

The facility supports testing for Air Force, Navy, Army, Missile Defense Agency, and NASA programs, as well as advanced hypersonic technologies such as wave-rider-type vehicles, scramjets and transatmospheric space planes.

Tunnel 9 is the primary high Mach number and high Reynolds number facility for hypersonic ground testing and the validation of computational simulations for the Air Force and DoD. Noteworthy advantages of Tunnel 9 over other facilities include a unique storage heater with pres-sures up to 1900 atm and temperatures up to 3650 R. Axisymmetric contoured nozzles for Mach 7, 8, 10 and 14 operation are also available.

When compared to other hypervelocity facilities, which have run times of a few milliseconds, the long test times (up to 15 sec.) available in Tunnel 9 provide higher productivity by allowing for parametric variation, e.g., an angle-of-attack sweep or flow survey, during a single run. The 5-ft-diam (1.5 m) test cell accommodates large-scale test articles.

The combination of operational range, long test times, and a large test cell results in the highest Reynolds number and makes Tunnel 9 the largest scale ground-test facility in the world, capable of simultaneously collecting continuous pitch-polar static force and moment, pressure and heat-transfer data during each run. Having the capability to test at flight-matched Reynolds numbers provides a significant risk reduction for the design and evaluation of hypersonic systems.

Tunnel 9 provides a useful and cost-effective environment for re-search and development test and evaluation (RDT&E) and for investi-gating the complex physics associated with hypersonic science and technology. Past testing includes aerodynamic, aerothermal, seeker window thermal-structural and aero-optic, shroud removal, hypersonic inlet, fundamental flow physics and computational fluid dynamics (CFD) validation experiments.

The National Full-Scale Aerodynamics Complex (NFAC) wind tunnel facility, located at NASA's Ames Re-search Center in Moffett Field, at Mountain View, Calif., is operated by Arnold Engineering Development Center. This facility is composed of two large test sections and a common, six-fan drive system. A wide range of available support systems combine with this unique facility to allow the successful completion of aerodynamic experiments that cannot be achieved anywhere else. Additionally, each of the test sections is acoustically lined for acoustic testing.

The 40- by 80-ft wind tunnel circuit originally constructed in the 1940s, is now capable of providing test velocities up to 300 knots and Reynolds numbers up to 3 million/ft. The 80- by 120-ft open circuit leg was added and a new fan drive system was installed in the 1980s. The 80- by 120-ft test section is the world's largest wind tunnel and is capable of testing a full-size Boeing 737 at velocities up to 100 knots at nominal unit Reynolds numbers of 1.1 million/ft.

A system of moveable vanes can be positioned so that air is either drawn through the 80- by 120-ft test section and exhausted into the atmosphere, or driven around the closed circuit through the 40- by 80-ft test section. A passive air exchange system is utilized in the 40 by 80 circuit to keep air temperatures below 125 F.

The new fan drive system is composed of six variable-pitch fans, each 40 ft in diameter, arranged in two rows of three. Each fan has 15 laminated wood blades and is powered by a 22,500 hp electric motor. The six fans rotate together at 180 rpm drawing 106 MW of electricity at full power while moving more than 60 tons of air per second.
Unique test-specific requirements are explored with each customer to guide the experiment design, and new systems are integrated into the facility as needed. Utility support systems that have been used for testing powered vehicles and components include variable-frequency electrical power, hydraulic power units, cooling water, 150-and 400-Hz electrical power and jet fuel systems. Rotor test beds incorporating electric motors and rotor balance systems are available for testing complete rotor and hub systems independent of the flight vehicle.

The 717th Test Squadron at Arnold Engineering Development Center (AEDC) is responsible for propulsion testing in the Engine Test Facility (ETF) test cells, which are used for development and evaluation testing of turbine-based propulsion systems for advanced aircraft. These test cells provide essential test and evaluation services in support of DoD, U.S. industry, and international programs. AEDC operates nine active test cells for atmospheric inlet and altitude testing.

AEDC test cells are used for testing in areas including performance, operability, aeromechanical, icing, corrosion, inlet pressure distortion, inlet temperature distortion, accelerated mission testing (AMT), engine-inlet dynamics, mission simulations, and engine component testing. Test cells are available in a range of sizes to meet customer needs. AEDC has the right test cell for virtually any requirement, whether the test article is a small cruise missile engine or a large turbofan engine for the airline industry.

The ETF contains instrumentation and controls infrastructure to acquire measurements from an extensive variety of instrumentation used in turbine-engine testing. The various sensors available can support the requirements of both production and development engines. Measurement capabilities include force, fuel flows, air flows, high-frequency-response pressures, displacement, acceleration, digitally-scanned temperatures, digitally-scanned pressures, and high-speed digital video. Measurement capabilities in the various test cells range from 600 channels to over 3000, with parameter recording options from 1 sample per second up to 10,000 samples per second. Control capabilities include up to 500 channels of control input/output using programmable logic controllers. Open- and closed-loop control functions can be monitored while testing and are merged in real time with instrumentation data. AEDC can provide exacting calibration services for force, fuel flow, and pressure measurements. Spectral structural analysis equipment provides real-time engine component health monitoring in conjunction with steady state and transient data. Our systems can be modified to accommodate the customer's digital or analog systems.

AEDC is a recognized leader in propulsion testing and our capabilities are constantly improved through targeted investment to provide customers with the highest-quality data. With five decades of experience, our specialists in ground testing can provide unrivaled assistance to your team, from pre-test planning through post-test analysis and evaluation. Our careful test planning and coordination with test customers ensures that test objectives are met and testing is streamlined and efficient.

Altitude Test Cells C-1 and C-2 comprise the Aeropropulsion Systems Test Facility (ASTF). This is a unique national asset designed to test large military and commercial engines in true mission environments. ASTF is part of the Engine Test Facility and has helped establish AEDC as the USAF center of expertise in turbine engine testing. C-1 and C-2 are each 28 ft in diameter and approximately 45 ft in length. Each cell is capable of testing up to Mach 2.3 and simulating altitudes of up to 75,000 ft. Either cell can provide engine inlet temperatures of up to 350 deg F and accommodate engines producing up to 100,000 Ib of thrust.

C-1 is normally used to conduct performance testing of large augmented turbine engines. C-2 can also be used to test large augmented turbine engines, but is has recently been used for performance testing of large turbofan engines. Aeromechanical testing, vectored-thrust testing, icing testing, and inlet pressure and temperature distortion testing may also be accomplished in ASTF.

Support systems in both cells include state-of-the-art digital steady-state and transient data acquisition systems capable of recording up to 3500 parameters. Multiple, remotely-operated Venturis and a multi-leg fuel system allow each test cell to make accurate measurements of engine airflow and fuel flow over the full range of engine operation. C-1 provides multi-component thrust capability for the measurement of axial, side, and vertical forces. This allows the determination of axial thrust as well as pitch and roll moments. C-2 provides axial thrust measurement and also has the capability of conducting icing testing at altitude, including the capability of transiently varying liquid water content and droplet size during a single cloud simulation. C-2 also has the capability of performing inlet temperature distortion testing.

In recent years, C-1 has principally tested F119 engines for the F-22A aircraft and F135 engines for the F-35 aircraft. C-2 has tested various large turbofan engines such as the GP7200 for the Airbus A380, the PW6000 for the Airbus A318, the Trent 1000 for the Boeing 787 and the XF7-10 for the Japanese P-X.

Test Cells J-1 and J-2 are altitude test cells sized for medium and large turbine engine testing. The cells are similar in capability to cells C-1 and C-2, but smaller in size. The cells are each approximately 44 ft in length, but J-1 is 16 ft in diameter while J-2 has a diameter of 20 ft. Both J-1 and J-2 are capable of simulating altitudes up to 75,000 ft and testing up to Mach 3.2 and Mach 2.6, respectively. J-1 can provide engine inlet temperatures of up to 720 F. The upper limit of J-2 is and 450 F. J-1 can accommodate engines that produce up to 70,000 Ib of thrust, while J-

2 is sized for engines that produce up to 50,000 Ib of thrust.

J-1 is normally used to conduct performance, aeromechanical and operability testing of medium augmented turbine engines, while J-2 is typically used for similar testing of larger augmented turbine engines. Core testing may also be accomplished in J-1.

Support systems in both cells include state-of-the-art digital steady-state and transient data acquisition systems capable of recording up to 2600 parameters in J-1 and 3500 parameters in J-2. Multiple remotely-operated Venturis and a multileg fuel system allow each test cell to make accurate measurements of engine airflow and fuel flow over the full range of engine operation. Both cells are also equipped with axial thrust stands allowing for accurate thrust measurement.

In recent years, J-1 has tested the F100 for the F-15 and F-16; the F110 for the F-16; the F118 for the B-2 and U-2; the F101 for the B-1B; and performed core testing on the Advanced Turbine Engine Gas Generator (ATEGG). J-2 has also tested the F110, F118 and F101 engines, as well as the F119 engine for the F-22A and the F135 and F136 engines for the F-35.

Sea-level Test Cells SL-2 and SL-3 provide the capability to economically conduct durability testing on large augmented turbine engines at near sea-level conditions (1000 ft altitude) by eliminating the cost of running inlet and exhaust plant machinery. The cells are each approximately 24 ft in height and width and 60 ft in length. In addition to running ambient pressure inlet conditions, they also provide the capability of using the ETF plant to run ram conditions (inlet pressures above ambient), allowing testing at up to Mach 1.2 when necessary to achieve test objectives. Inlet temperature capability extends from ambient to 120 deg F when running in the atmospheric inlet mode and from 20 to 270 F in ram mode. Both cells can accommodate engines that produce up to 70,000 Ib of thrust.

These sea-level cells are normally used for Accelerated Mission Testing (AMT). These tests evaluate engine durability and performance retention by repeatedly simulating the types of missions the engine will fly in service. The ram capability allows interspersed testing of atmospheric inlet and ram AMT during a single test program, and eliminates the expense of engine removal and installation into another facility. In addition to a more accurate representation of engine use, it saves the customer time and money by allowing the testing to be done with a single engine installation. Since atmospheric inlet testing in SL-2 or SL-3 does not require the plant machinery, test scheduling becomes very flexible, allowing rapid completion of test objectives. Either cell can accomplish up to 80 hrs of atmospheric inlet testing per week sustained capability, with higher surge capability.

Support systems in both cells include state-of-the-art digital steady-state and transient data acquisition systems capable of recording up to 1500 parameters in SL-2 and 2200 parameters in SL-3. Calibrated bellmouths and multileg fuel systems allow both test cells to make accurate measurements of engine airflow and fuel flow over the full range of engine operation. Both cells are equipped with axial thrust stands allowing for accurate thrust measurement. Additionally, SL-3 is equipped to perform specialized testing such as corrosion testing.

In recent years, SL-2 has tested the F100 engine for the F-15 and F-16 and the F119 engine for the F-22A. SL-3 has also tested the F100 engine, as well as the F135 engine for the F-35.

Altitude Test Cells T-3, T-4 and T-11 are a diverse mixture of cells with multiple test applications for testing small and medium turbine engines. Their sizes and capabilities are varied to accommodate a range of test articles. T-3 is 12 ft in diameter and 15 ft in length, T-11 is 10 ft in width and height and 17 ft in length and T-4 is 12 ft in diameter and 47 ft in length. T-4 is capable of testing at altitudes of 75,000 ft and Mach numbers of 2.5 while T-11 is capable of 55,000 ft and Mach numbers of 2.0. T-3 can simulate altitudes up to 100,000 ft and Mach numbers of up to 4.0. The maximum inlet temperature capabilities are 250 F for T-11, 400 F for T-4, and 1200 F for T-3. T-3, T-4, and T-11 can accommodate engines producing up to 20,000,50,000 and 30,000 Ib of thrust, respectively.
The F405 Engine for the T-45A Installed in T-4

These cells are used for a variety of types of testing. T-3 is used for high Mach number turbine engine testing, T-4 is normally used for performance and operability testing of medium turbine engines and T-11 is typically used for cruise missile engine testing. These three cells are not in continuous use at AEDC. Some activation time may be required prior to use.

Support systems include steady-state and transient data acquisition systems capable of recording up to 600 parameters in T-11,1100 parameters in T-3 and 1500 parameters in T-4. Venturis and/or calibrated bellmouths and multileg fuel systems allow each test cell to make accurate measurements of engine airflow and fuel flow over the full range of engine operation. T-3 is equipped with a multicom-ponent thrust stand, while T-4 and T-11 are equipped with axial thrust stands.

The F135 Combustor Rig for the F-35 Engine Installed in T-11

In recent years, T-3 has performed combustor core testing for Westinghouse and supersonic flight conditions for advanced engine designs; T-4 has tested the F100 engine for the F-15 and F-16, the F414 engine for the F/A-18E/F, the AE3007H engine for the Global Hawk and the F405 for the T-45A; and T-11 has tested the F107-WR402A engine for the JASSM-ER, the F415 engine for the Tactical Tomahawk cruise missile, the F107 engine for the BGM-109G cruise missile, the F112 engine for the ALCM, the JETEC engine demonstrator, and accomplished combustor segment testing for the F135 engine for the F-35.

The 718th Test Squadron, Space and Missile Systems, at Arnold Engineering Development Center (AEDC) is responsible for ground testing space and missile weapon systems from subsonic to hypersonic conditions reaching Mach 20. The 718th Test Squadron provides hypersonic, rocket propulsion and space environmental T&E services. This squadron coordinates testing in over 30 facilities that support the development of defensive ballistic and tactical missile interceptors as well as weapons systems such as theater, cruise missile, high-speed aircraft and launch vehicles.

Space test capabilities in this area include capabilities for evaluating infrared and visible sensor performance, mission simulation and other hardware-in-the-loop activities. This support includes testing and research for space systems in a thermal/vacuum environment from component level to full-scale, fight-qualified hardware. Additionally, for component scale hardware, testing to simulate full spectrum space environments is available and includes contamination, solar, atomic oxygen, outgassing, radiation and other effects.

The 718th Test Squadron is chartered with maintaining the nation's largest archive of missile and rocket hard-body and plume-infrared signature data in the Advanced Missile Signature Center (AMSC).

Hypervelocity Ballistic Range G is used to conduct kinetic energy lethality and impact phenomenology tests. The Range G launcher is the largest two-stage, light-gas gun system in the United States that provides unequalled "soft launch" (minimized acceleration loading) capability to launch extremely high-fidelity missile simulations at hypervelocity speeds. Quarter-scale testing is available at velocities from 4900 to 23,000 ft/sec (1.5- to 7-km/ sec). Recent improvements have extended the range of capabilities to near half scale.

The Range G launcher is capable of launching various types of projectiles at velocities up to 23,000 ft/sec (7.0 km/sec). Projectiles up to 8.0 in. (203 mm) in diameter are launched into a 10-ft (3-m)-diameter, 930-ft (283.5-m)-long instrumented tank that can be maintained at pressure altitude from sea level to 225,000 ft. Three sizes of interchangeable barrels; 3.3 in. (84 mm), 4 in. (102 mm), and 8 in. (203 mm), are available for use on the Range G launcher. A four-rail guidance system can be mated to the barrel in order to guide the projectile close to the target and provide increased hit-point accuracy.

The 3.3-in. (84-mm)-diam launch tube is typically used to support one-fourth scale testing (projectile and target one-fourth the size of the full-scale system), but in order to meet the lethality test requirements of missile defense programs, AEDC has developed the capability to launch larger scale projectiles up to 8 in. (203 mm) at higher velocities than those previously achievable at any ground-test facility. With this capability, AEDC is able to provide a greater level of projectile and target fidelity for tests conducted with two-stage light-gas guns.

The primary challenge in designing projectiles for gun range lethality testing is to develop a geometrically scaled projectile that matches the axial and radial mass distribution of the actual missile and is able to withstand the acceleration loads experienced during gun launch. The use of 3-D finite element analysis software (ABAQUS) coupled with the AEDC light-gas gun code provides a seamless projectile design capability.

The Range G facility has an extensive assortment of unique test instrumentation that can be located as required for a particular test. New instrumentation capabilities are currently under development to aid in kill assessment using multispectral/infrared signature measurements. A high-speed x-ray imaging system also being developed will provide a method for understanding post-impact debris dispersion.

The J-6 Facility provides ground-test simulations for solid-propellant rocket motors. J-6 has been used mainly for aging and surveillance and in testing of stages II and III for both Minuteman and Peacekeeper ICBMs. Additionally, J-6 has supported STAR37 motor qualification testing for the

Air Force's Global Positioning Satellite (GPS) constellation. AEDC has unique test capabilities for testing rocket propulsion systems with high-perfor-mance/high-area-ratio nozzles and those requiring altitude start and restart, stage separation and spin testing. J-6 is the largest of its kind in the world and provides the only altitude test capability for large rocket propulsion systems in the United States. Ambient (sea-level) testing of rocket propulsion systems designed for high-altitude operations can compromise engine performance data and potentially jeopardize the structural integrity of the exhaust nozzle. Ground testing under simulated altitude conditions in J-6 includes carefully controlled test environments with extensive instrumentation and photographic coverage to determine the operability and performance of a test article.

The J-6 digital data acquisition system is designed to acquire up to 500,000 samples/sec. Testing can also include an extensive array of sophisticated rocket diagnostic instruments obtainable only in a ground test configuration. State-of-the-art techniques such as wide-band infrared and ultraviolet radiometric coverage, emission/ absorption detection, laser-induced fluorescence plume surveys and real-time radiography are applications sometimes used in J-6 testing.

J-6 is designed to test large detonable solid-propellant rocket motors with up to 80,000 Ibs. Measuring 26 ft in diameter by 62 ft long, the horizontally oriented test cell is capable of testing rocket motors at simulated altitudes up to 100,000 ft. The temperature conditioning system can maintain the test cell at an air temperature within the range of 15 to 110 F (5 F) from motor installation until pre-fire pump down at altitude conditions.

J-6 supports long-duration altitude tests of high-area-ratio nozzle performance including deployment operation with dynamic loads, thermal ignition tests, stage separation testing, heat transfer, post-heat soaking and failure analysis. This facility can be used to test many different types of motors with either large quantities or advanced mixes of propellants. The facility is equipped with three interchangeable diffusers that can accommodate thrust ranges from 5000 to 500,000 pounds force. The test cell is connected to a 250-ft-diam by 100-ft-high concrete dehumidification chamber that collects, cools and conditions the resulting rocket exhaust products.

The AEDC arc heater facility is used to provide high-enthalpy test environments to test materials and other means of thermal protection. The AEDC arc-heated test facilities include two high-pressure, segmented arc heaters (H1 and H3) and one Huels arc heater (H2). Both types utilize an arc discharge to heat air to temperatures up to 13,000 R. 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.

The 30-MW 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. The unique segmented construction allows the arc to be held at a fixed length to optimize heater efficiency, total enthalpy at high pressure, and flow uniformity. Normal operating conditions for the heater are about 20,000 V and 1200 amp, providing heater chamber pressures up to 120 atm at high stagnation enthalpies. The H1 test cell is equipped with a multiple-strut, programmable rotary model injection system capable of positioning one to seven test models sequentially into the test freejet for preset dwell times.

The 45-MW 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 up to 120 atm. H2 utilizes an N-4 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 the exhauster makes possible high-enthalpy flows at Mach numbers from 5 to 9.

The 70-MW H3 arc heater was developed to provide a large, high-pressure arc facility with sufficient size and performance for testing of full- and large-scale missile and reentry samples and structures. H3 is a 12-mod-ule, 50-percent geometric scale-up of the H1 segmented arc heater and is designed to operate at over twice the available power level and mass flow of H1, with operational pressure up to 150 atm.

The Aerodynamic and Propulsion Test Unit (APTU) is a blowdown test facility designed for testing true temperature performance of propulsion, material, structures and aerodynamics of supersonic and hypersonic systems and hardware.

For 25 years APTU used its vitiated air heater (VAN) to conduct many successful test programs. The VAH used isobutane as the fuel to generate test conditions. Maximum pressure and temperature were limited to 300 psia (20.4 atm) and 2000 R (1111 K), respectively. From 1992 to 2005, over 275 runs were made for a wide range of system development programs for propulsion, aerothermal and aerodynamic issues. Significant improvements in test productivity were made during that time frame with as many as four runs per day.

Under the High-Speed/Hypersonic Air-Breathing Propulsion Test and Evaluation Capability (HAPTEC) program, APTU began a series of major upgrades in 2002 to provide a ground-test capability for supersonic and hypersonic systems up to Mach 8. Upgrades are planned through 2011 that will be implemented without interference to customer test schedules. Phase one of the upgrade, completed in 2004, modified the APTU utility supply systems (high-pressure air, isobutane, liquid oxygen and water) and replaced the air ejector system to increase the facility's altitude simulation capability. Phase two centered on replacing the VAH with a much more capable high-pressure, high-temperature combustion air heater (CAM). APTU in its CAM configuration reached initial operational capability (IOC) of Mach 6.75 in September 2007. Phase three will add a varying Mach number test capability from as low as Mach 2 to above Mach 5, with fixed area ratio nozzles being used above Mach 6.

The CAM was designed to operate over a range of total pressure from 200 psia to 2800 psia (13.6 atm to 190.5 atm) and a range of total temperature from 1200 R to 4700 R (667 K to 2611 K). Though it has been cleared for operations up to Mach 6.75, it is capable of generating Mach 8 test conditions with the appropriate nozzle. Five fixed freejet nozzles are currently available to produce test conditions from Mach 3.1 to Mach 7.2.

When completed, the HAPTEC upgrades will provide customers with a much needed ground-test capability for the research, development and acquisition of high-speed and hypersonic propulsion systems.

The AEDC 7V (7-ft diam by 21 -ft long) and 10V (10-ft diam by 30-ft long) sensor chambers are part of a state-of-the-art space environment simulation test facility designed to test interceptors and surveillance sensors. These chambers are configured to provide complete characterization and radiometric calibration of a visible and infrared (IR) sensor. This includes all categories of sensor characterization (flood, point, polarized source, spectral calibration and mission simulation). An assortment of source systems allows evaluation of sensor performance over a wide range of target conditions. Current generation sensor arrays mounted in the chambers provide independent source and background evaluation and target position. Both chambers are cooled using gaseous helium shrouds with an optically clean vacuum system. 7V is in a Class 1000 Clean Room, while 10V is in a Class 10,000 Clean Room. A 300,000-lb seismic mass allows vibration isolation of the optical bench and all optical elements. A radiometric calibration system allows for accurate calibration of source systems that is traceable to the National Institute of Standards and Technology (NIST).

The 10V Chamber sensor test facility features a high-fidelity target system containing multiple independent point-source systems to simulate target acquisition and tracking operations. An IR scene projection system is used to simulate objects in the sensor's field-of-view and provides simulation of the terminal phase of the interceptor mission. A visible projection system is used to simulate star shots and objects that appear in the visible spectrum. The 10V Chamber is configured to provide end-to-end closed-loop mission simulation capability for interceptor and surveillance sensor systems, providing simulation of the sensor mission from launch to intercept.
Mark I (42-ft diam by 82-ft high) is DoD's largest vertical space chamber and has tested full-scale satellites and space platforms. This facility has the capability to stay on conditions months at a time under thermal vacuum conditions of 1 0~7 using cyro pumps and a liquid nitrogen liner at 77 K. With over 1,500 test data channels and the necessary support infrastructure, this facility can support a variety of test sceneries.

The 12V Chamber is a 12-ft-diam by 35-fl-high thermal vacuum test facility. The facility has its own nitrogen thermal shroud and an optional gaseous helium liner that can be cooled to 10 K. The chamber is currently configured for high-power electric propulsion (EP) thruster plume analysis and integration effects.

Nuclear effects testing is accomplished using a small X-ray simulator. The Modular Bremsstrahlung Source (MBS) provides nuclear effects testing on cables and small satellite components.

The Advanced Missile Signature Center (AMSC) is a national facility supporting the Missile Defense Agency (MDA), Defense Intelligence Agency Missile and Space Intelligence Center (DIA-MSIC) and other DoD programs with analysis, modeling, measurement, archival and distribution services. The AMSC archives include target, threat and battlespace environment signatures for missiles and other vehicles. Staff expertise and supporting infrastructure are primarily focused on tactical and ballistic missile ultraviolet, visible and infrared plume signatures. These capabilities are leveraged to also address signatures associated with missile post-burnout and reentry, celestial and terrestrial backgrounds, and other battlefield targets such as mortars, small arms fire and fixed and rotary wing aircraft.

AMSC experts use state-of-the-art instrumentation and infrastructure to collect temporal, spectral, and spatial signatures during static, launch, sled, and free flight tests on test ranges in and outside the USA. Sensors are calibrated to National Institute of Standards and Technology (NIST) pedigree and deployed for expert digital data collection, processing and quick-look products.

Complementing the measurement capabilities are expertise and computational tools for enhanced data processing, data analyses and physics-based modeling and simulation. AMSC maintains a suite of image processing/analysis tools and JANNAF-standard codes to exploit measured data and confidently extrapolate to signatures in the flight envelope that are not readily measured. This extrapolation process anchors the modeled signatures to measured data. Thousands of modeled signatures are then coupled with an AMSC processing methodology to generate a hypercube of high-fidelity flight envelope signatures that are readily accessible for real-time, hardware-in-the-loop applications.

The AMSC efficiently manages digital data, documents and other non-digital media such as film and video at multiple classification levels. All documents are converted to softcopy text searchable form for information search and retrieval. For key digital data sets, primary data and metadata are merged into a common standard archive format that permits data recipients to quickly access and exploit data content. Film and video media in 16-, 35- and 70-mm film formats and all of the major video formats can be digitized, and image processing tools can be applied to further exploit collected data. Catalogs and certain program data sets are also available through access-controlled websites.

The Arnold Engineering Development Center supports a robust and versatile Applied Technology & Analysis Program focused on three primary disciplines: Mod-eling and Simulation (M&S), Instrumentation and Diagnostics (I&D) and Facility Enhancements and Test Tech-niques (FE&TT). A team of engineers, scientists and support personnel provide expertise to develop and adapt complex computational models, nonconventional diagnostic systems, advanced facility capabilities, test techniques and engineering-level facility models to ad-dress customer testing and AEDC facility infrastructure requirements.

The goal of the M&S focus area is to provide vali-dated, computationally-efficient tools that can be transitioned to support test engineers in their efforts to optimize test matrices and test facility configurations, in¬cluding placement of critical diagnostic instrumentation. Post-test CFD simulations provide insight for diagnosing and correcting data anomalies and extrapolating ground test data to flight scenarios.

Aerodynamic flow models predict environments surrounding complex aerodynamic vehicles. Interactions of the free stream flow with control surfaces and the separation of stores from aircraft bays and pylons are significant aerodynamic concerns addressed by computational fluid dynamic (CFD) methodologies. Physics-based CFD models are also applied to predict internal flow streams passing through turbine engine rotating components and to simulate highly energetic combustion phenomena occurring inside propulsion systems. Specialized facility models predict the thermo/fluid dynamic behavior of ground test facilities and provide insight for optimizing facility operations.

The goal of the I&D focus area is to provide AEDC test engineers and customers with state-of-the art diagnostic techniques which minimize measurement uncertainties, reduce diagnostic hardware interferences with interrogated flow environments, and provide high-reso-lution, real-time flow field characterization. The high-quality measurements are used to validate numerical models, guide model improvements and enhancements and provide test customers with unique insights into test article behavior.

Both intrusive and nonintrusive techniques are being developed and used to acquire quantitative, spatially resolved flow-field measurements and qualitative flow vi-sualization across the full spectrum of test environments. Significant ongoing efforts are focused on innovative designs, fabrication techniques and stringent calibration requirements of specialized probe systems for applications in harsh environments. Currently, diagnostic probes have been used successfully to quantify Mach number, temperature, pressure and flow angularity in high-enthalpy flow streams, including Mach numbers approaching 7. Probe sampling systems have been developed which chemically quench flow samples entering the probe in order to quantify both gaseous and particulate species. Innovative probe designs and state-of-the-art fabrication techniques have been developed for embedding miniaturized cameras and Micro Electro Mechanical Systems sensors within the probe tips, allowing visualization of combustion phenomena occurring inside turbine engine combustion chambers and augmentor components. Improvements in probe design for survivability at higher temperatures, pressures and Mach number conditions continue to be addressed.

Nonintrusive optical diagnostic systems are being developed and applied to quantify and visualize flow environments inside AEDC test cells. Specialized active optical techniques which stimulate and measure exhaust emission features have been successfully demonstrated. These measurements are used to derive spatially resolved flow-field properties including temperature, multiple velocity components and chemical specie concentrations within the flow. These techniques have been successfully demonstrated for monitoring test facility flow quality and for acquisition of quantitative flow-field properties on a noninterference basis.

The goal of the FE&TT focus area is to work enhancements closely with test engineers in developing and demonstrating specialized simulation hardware, facility systems and ground-test methodologies to address the challenges of providing realistic and efficient flight simulation conditions in ground-test environments.

The scope of technology efforts supporting FE&TT includes development and improvements of test facility systems and engineering-level facility models for the Propulsion, Aerodynamic and Space and Missile Systems areas. Specifically, this focus area supports identification of required technology development to support future test facility requirements and address T&E deficiencies, analysis of facility performance and durability issues and the development of advanced test methodology concepts.

In summary, the Applied Technology and Analysis Program combines technical expertise in M&S, I&D and FE&TT to support the Integrated Test and Evaluation (IT&E) process at AEDC. AEDC maintains dedicated technology investments to enhance these capabilities to support challenging requirements and address identified shortfalls in order to eliminate technical risks and uncertainties associated with ground testing and data integration and analysis.

In addition to extensive test and evaluation capabilities, AEDC can provide a full range of other services for its customers.

AEDC understands that confidentiality of customer test and evaluation information is paramount, so AEDC has an active security program. AEDC can perform DoD classified testing and provide test preparation areas, test facilities, control rooms and data systems that are secure.

AEDC's precision machine shop has a full complement of skilled machinists and a complete range of modem machines, from conventional to six-axis computer-numerically controlled (CMC), as well as electrical discharge machine tools. Heat treatment, chemical cleaning and welding facilities are also available. The machine shop maintains coordinate measuring equipment for precise measurement of complex contours to allow 100-percent inspection and recording of all dimensions.

The Metallurgical/Nondestructive Evaluation Laboratory provides metallurgical test and evaluation services including stress and tensile strength testing, welder certifications, radiographic inspections, and other nondestructive test services. The Chemical Laboratory provides chemical analysis of various components including fuels, oils, soils, liquid-rocket propellants, exhaust gases, water, and various other liquids and gases.

AEDC maintains the Precision Measurement Equipment Laboratory (PMEL), which is certified by the Air Force Metrology and Calibration (AFMETCAL). The PMEL provides calibration of test measurement instrumentation such as voltage measurement, pressure, temperature, and dewpoint standards at the appropriate intervals to ensure measurements that are traceable to the National Institute of Standards and Technology (NIST).

The Aerothermodynamic Measurement Laboratory (ATML) provides technical expertise, analytical tools, and calibration/characterization facilities for applied research in aerothermal test measurement techniques. ATML services include specialization in heat transfer and transient temperature measurement for application to space and atmospheric high-speed flight models. Specialized instrumentation is designed, fabricated, calibrated, and installed in supersonic and hypersonic test articles and facilities.

High-Performance Computing (HPC) computational resources are provided to support customers with time-critical mission support via rapid data analysis and the capability to computationally test high-fidelity physics models in a shorter time, thus saving resources. HPC computers are primarily used to provide computational fluid dynamics (CFD) solutions to customer requests and to develop numerical algorithm and physics modeling improvements.

As World War II was ending in Europe, General of the Army Henry H. "Hap" Arnold and Hungarian-born aerodynamicist Dr. Theodore von Karman met to discuss America's future requirements for air power. General Arnold, alarmed by the Germans' development of advanced jet aircraft and rockets, asked Dr. von Karman to convene a group of scientists to work out guidelines for air research for the next 20 years or more.

Dr. Frank Wattendorf, a member of this Scientific Advisory Group, proposed the creation of an Army Air Force center that would provide new directions and major new national capabilities for research and development programs. The primary purpose of the new center was to help the U.S. lead technological developments, not merely keep up with them. In keeping with a larger blueprint for the future of the U.S. Air Force, the Scientific Advisory Group's study "Toward New Horizons" was published in December 1945.

In 1949, Congress passed Public Law 81-415: The Unitary Wind Tunnel Plan Act of 1949 and the Air Engineering Development Center Act of 1949. The laws were enacted to promote the national defense by authorizing a unitary plan for the construction of transonic and supersonic wind-tunnel facilities and the establishment of an Air Engineering Development Center.

Congress selected Middle Tennessee as the site for the new center because of its availability of land, water and power. Construction of the center began in 1950. President Harry S Truman dedicated the center on June 25, 1951, to the memory of General Arnold as the Arnold Engineering Development Center, on what would have been General Arnold's 65th birthday.

Over the last 55 years, as new military systems have been developed, their components

- engines, airframes, stores, sensors and more
- have made their way to AEDC facilities.

In the center's jet engine and rocket motor test cells, transonic, supersonic and hypersonic wind tunnels and ballistic and impact ranges, AEDC engineers and scientists have pushed these systems to the edge of simulated flight.

Almost every high performance aircraft flown by the Air Force, Navy and Marines can trace part of its roots to AEDC. The technological advances achieved in the last 55 years at the center have helped put man on the moon, established America's air dominance, deterred aggression, saved American lives on the battlefield and helped prosecute the global w.ir on terror.

AEDC stands out from other bases because of its distinctive work force - 84 percent contractor employees and 13 percent government personnel.

Since the center's inception in 1951, contractors have been utilized to save money and grow and foster an experienced group of people who would make their careers at AEDC.

This philosophy has worked. The average age of the contractor and government civilian work force is 47.8, with an average of 14.3 years of experience at the center. The average age of the active-duty military portion of the work force is 37, with an average of two years at the center.

AEDC employed 2,785 people in fiscal year 2008. This number includes active-duty military personnel from the Air Force and Navy, DoD civilians and contractor personnel. Active-duty military members made up less than 3 percent of the work force.

AEDC's government staff is composed of military personnel and civilian employees who provide management direction, resource allocation, oversight and contractor administration.

TVA Model Estimates for AEDC As of Sept. 30, 2008
Direct Employment at AEDC

Military	68
DoD Civilian	258
Non-appropriated Fund	48
ATA	2,325
Other	86
Base Exchange, Commissary, Ascend Federal Credit Union, tenant organizations, other contractors	
Total	2,785
Secondary Jobs Created	1,892
Total Employment Impact	4,677

The contractor for fiscal year 2008 was ATA, a joint venture of Jacobs, Computer Sciences Corp., and General Physics.

Technical excellence has always been a hallmark of AEDC; however, cost reductions and acquisition policies have driven the center to a greater focus on efficiency of operations. While efficiency is vital to the center's operations, it had softened the focus on technical rigor.

For that reason, leadership designed an initiative for AEDC to get back to the basics.

This initiative focused on developing and implementing methods to re-establish technical excellence amongst military, civilian and contractor personnel. By doing this, AEDC would instill a technical excellence culture.

Thus, the center established the AEDC Technical Excellence Board (TEB). The TEB, chaired by Dr. Ed Kraft, AEDC's chief technologist, is responsible for developing policies and practices to enhance technical excellence at AEDC and alleviating any barriers keeping the center from achieving technical excellence.

The TEB took a multi-faceted look at education, job experience, mentoring, recruiting and other areas to — come up with ways to ensure our customers that AEDC has a robust, technically sharp, respected work force now and in the future.

In December 2007, AEDC held its first technical forum. During the forum, the AEDC community gathered and discussed technical ideas and issues affecting the center and their work environment.

In 2008, after determining the best course of action, AEDC began executing the various aspects of the technical excellence initiative. This includes, but is not limited to, employee development, education, career broadening initiatives, technical achievement awards, recruitment activities, technical review forums, validation of research topics, participation in Technical Review Boards, technical publications, reviews of AEDC's technology program and much more.

AEDC has seen some benefits from its competitive contract award, including more definitive Air Force control of the operation, more effective cost control and improved responsiveness of the contractor to Air Force and AEDC customer needs.

In October 2003, Aerospace Testing Alliance (ATA) became the new contractor to provide the personnel and services for operating and supporting the center's test facilities and infrastructure. ATA is a joint venture of Jacobs, Computer Sciences Corp. (CSC) and General Physics. The contract has a possible length of 12 years in one-year increments and is worth up to $2.7 billion. ATA supports the center with a wide range of services including: operational maintenance of a wide variety of unique aerospace test facilities; information technology; desktop operation and maintenance; center communications; test utility operations; environmental, safety, industrial health and quality assurance; calibration, chemical and photo laboratories; civil engineering; transportation; materials management; fire protection; security services; emergency management; food services; custodial; and public affairs.

Six subcontractors help to make up ATA's organization.

ATA provides AEDC strong technical enhancement with its approach to management and operations.

One distinct feature setting AEDC apart from other military installations is its contractor work force. At AEDC, contractors represent almost 85 percent of the work force and perform almost 90 percent of the work.

A military work force is by design transient. Roughly every two to three years, new personnel transfer in or out, making it difficult to build corporate knowledge.

The original rationale for operating AEDC with private sector personnel was based on the limited availability of qualified technical personnel in the Air Force, either as military or civilians. Also recognized was the flexibility afforded by the use of private companies who could hire and terminate employees more easily than the federal government. In addition, a private company has a greater ability to tailor its pay scales or even individual salaries to market rates, thereby allowing them to recruit personnel with special skills who the government may not be able to attract.

The decision to use a for-profit corporation has proved beneficial. Although the original contracts were cost-plus-fixed fee, the contracts over the last 28 years have been cost-plus-award-fee. The award fee feature has enabled the Air Force to use the profit motive to incentivize contractors to continually improve productivity and quality while controlling costs.

White Oak

Due to the unique nature of the Hypervelocity Tunnel 9 test capability, utilization has been at record levels in recent years. Test income from fiscal year 2004 through fiscal year 2008 has continued at capacity level. Customers from each sector of the mission including missile defense, strategic systems and space access have performed testing events at Tunnel 9 located at Silver Spring, Md. All DoD agencies, Defense Advanced Research Projects Agency (DARPA) and |Missile Defense Agency (MDA) were represented. In addition, the future looks solid for testing |from research labs, Small Business Innovation Research (SBIR) programs, private aerospace; companies and NASA. In fiscal year 2008, the Hypervelocity Wind Tunnel 9 completed 74 days of testing representing near-full capacity. Test programs were successfully completed for the U.S. Air Force, U.S. Navy, NASA and Lockheed Martin.

Mission Statement

Responsible for management and oversight of all aspects of the AEDC White Oak site. Manages the testing and evaluation of high-speed/hypersonic systems. Serves as the primary customer interface and center planning and execution agent for performing hypersonic system testing. Responsible for develop-ing and communicating the strategic roadmap for all aspects and support to the hypersonic product area. Responsible for all aspects of the test mission including budgeting, business development, test planning, test execution and data analysis and reporting. Directs high-speed/hypersonic analysis and evaluation program. Reports to the Commander of the 704th Test Group coordinating test planning, resourcing, execution and reporting activities.

Fiscal Year 2008 Highlights

The High-Alpha Reusable Launch Vehicle (RLV) test program investigated the aerodynamic and aerothermal performance characteristics of reentry vehicle configurations designed to enter the atmosphere at high angles-of-attack. Data acquired during these tests will form the basis for a new database that will enable design of higher performance trans-atmospheric vehicles and a design space for replacements of the current U.S. Space Shuttle. Testing concluded in October 2007 meeting all test objectives.

The U.S. Navy Reentry Systems Nose-tip test program provided characterization of several reentry body ablated nose-tip shapes. Aerothermal characterization was performed at Mach 8 on several nominal and ablated geometries. Data from this test entry will provide accurate design verification on candidate nose-tip materials for use in future reentry systems. All primary and secondary objectives were met.

The NASA Orion Crew Exploratory Vehicle (CEV) Aerothermal test program focused on investigating surface roughness-augmented heating at simulated hypersonic atmospheric reentry test conditions. Data acquired during these tests will be used by NASA to understand the heating environment which the vehicle will need to survive during atmospheric reentry. Testing concluded in the summer of 2008, with successful completion of 32 runs which met all primary and secondary test objectives.

The goal of the Reentry Nose tip Aero Trim test effort was to acquire empirical data to validate computational fluid dynamic (CFDJ codes that characterize the effects of asymmetric nose tip shapes on tri-conic reentry bodies at low angle of attack and low altitude conditions. Force, moment, surface pressure and surface temperature/heat transfer data were acquired from -3 to +3 degrees angle of attack at a Mach 8 free stream and high Reynolds number condition. Flowfield Schlieren/ shadowgraph imagery was also obtained. By the end of the fiscal year, a total test matrix of six runs was successfully accomplished. Data reduction and analysis began in fiscal year 2009.

Scheduled maintenance activities were successfully completed during the summer of fiscal year 2008 to maintain the facility in a mission ready status. The actual readiness and performance metrics for this capability were exceeded with a 100 percent availability and more than 97 percent success rate for test execution. The design of a new control room for the facility was completed and scheduled for installation during the first half of fiscal year 2009.

Fiscal Year 2009 Forecast

Tunnel 9 will begin a scheduled outage during the first two quarters of fiscal year 2009. Major construction of the federal property is to begin in October 2008 which will require suspending operations until complete. During that time, backlogged maintenance will commence and the new control room will be installed and verified. Once complete, testing is NFAC The National Full-Scale Aerodynamics Complex (NFAC), located at NASA Ames Research Center in Moffett Field, Calif., was reactivated in 2006 as an AEDC-operated facility. This wind tunnel testing facility - which closed in 2003 due to budget pressures - underwent two years of refurbishment before attaining full operational capability (FOC) in early 2008.

Fiscal Year 2008 Highlights

During the fiscal year, the U.S. Army, Defense Advanced Research Project Agency (DARPA), NASA and Sikorsky Aircraft Corporation tested at NFAC.

In December 2007, NFAC supported space exploration with the successful dynamic loads and development testing of NASA's Mars Science Laboratory parachute. The parachute - which is used to slow down spacecraft during entry, descent and landing - holds more air than a 3,000-square-foot house and is designed to survive loads in excess of 81,000 pounds. During testing, the parachute was attached to a launch arm, mounted on a swivel base inside the 80-by-120-foot wind tunnel, so it could be tested under conditions simulating entry into the Martian atmosphere.

After undergoing two rounds of testing, data concluded that the parachute could successfully survive while descending into the Martian atmosphere.

In early 2008, NFAC achieved FOC for rotorcraft testing which allowed the wind tunnel complex to conduct its first military test entry since its reactivation.

The first test article, Boeing Corporation's, Smart Material Actuated Rotor Technology (SMART) helicopter rotor, was tested in the 40-by-80-Foot Wind Tunnel to study the system’s forward flight characteristics and collect baseline data to validate cutting-edge aero-acoustic analysis codes. Furthermore, the information obtained from the rotorcraft testing helped advance DARPA's Helicopter Quieting Program. DARPA is utilizing the data to advance design tools for the next generation of the Department of Defense's service platforms.

In fiscal year 2008, the NFAC team was awarded the San Francisco Chapter of the American Helicopter Society 2008 award for Outstanding Contribution to the Powered-Lift Field Vertical Take-Off and Landing (VTOL). The award recognized the multi-service and industry team who completed a five-month detailed check-out of the UH-60 rotor system mounted on NASA's Large Rotor Test Apparatus (LRTA) in NFAC's 80-by-120-foot wind tunnel. This test enabled the first forward flight rotor test in the facility since 2003.

Revenues for fiscal year 2008 were approximately $1.5 million. Fiscal Year 2009 Forecast
During fiscal year 2009, NFAC will continue its focus on rotorcraft testing using the LRTA to evaluate the benefits of the Individual Blade Control (IBC) Technology for performance and acoustic enhancements.

Additionally, NASA's Mars Science Laboratory will return for a final series of testing before launching the satellite system in 2011.

ARNOLD ENGINEERING DEVELOPMENT CENTER—AEDC Arnold AFS, Tennessee

The unique wind tunnels and space simulators at AFDC support research, development, test and evaluation of aerospace systems. These facilities provide support to both military R&D programs as well as those of NASA and other government agencies.

BG Jessup D. Lowe, #1971
Col Robert W. Chodister, #1997
Col. Michael Panarisi**,** #2010

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The unique wind tunnels and space simulators at AFDC support research, development, test and evaluation of aerospace systems. These facilities provide support to both military R&D programs as well as those of NASA and other government agencies.

Arnold Engineering Development Center, located at Arnold AFB, Tenn., is the most advanced and largest complex of flight simulation test facilities in the world. The center operates 58 aerodynamic and propulsion wind tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other specialized units.

Twenty-seven of the center's test units have capabilities unmatched elsewhere in the United States; 14 are unique in the world. Facilities can simulate flight conditions from sea level to 300 miles and from subsonic velocities to Mach 20.

The AEDC is an Air Force Materiel Command facility and an important national resource. It has contributed to the development of practically every one of the nation's top priority aerospace programs including the Atlas, Titan, Minuteman and Peacekeeper ICBMs, the space shuttle, space station, and Projects Mercury, Gemini and Apollo.

Aircraft include the F-35 Lightning II Joint Strike Fighter, F-22A Raptor, A-10 Thunderbolt II, F-14 Tomcat, F-15 Eagle, F-16 Fighting Falcon, F/A-18 Hornet and F/A-18 Super Hornet, F-105 Thunderchief, F-111 Aardvark, F-117A Nighthawk, C-5 Galaxy, C-17 Globemaster III, C-141Starlifter, B-1B Lancer, B-2 Spirit, B-52 Stratofortress, B-58 Hustler, X-15, X-29, X-32 and X-33, X-35, XB-70 Valkyrie.

Satellites include NAVSTAR GPS, MAPS and GOES-M weather satellite.

Missiles include the Polaris, Poseidon and Trident submarine-launched ballistic missiles, the Minuteman ICBMS plus the Tomahawk and Air-Launched Cruise Missiles and the Advanced Medium-Range Air-to-Air Missile.

Customers include the Department of Defense, Army, Navy and Air Force organizations; the National Aeronautics and Space Administration, both domestic and foreign private industry, allied foreign governments and educational institutions.

AEDC is named for the man responsible for its conception -- General of the Air Force Henry H. "Hap" Arnold. Shortly before the end of World War II, General Arnold asked Dr. Theodore von Karman, one of history's great aeronautical scientists, to form a Scientific Advisory Group to chart a long-range research and development course for the future U.S. Air Force. AEDC was a result of that plan.

AEDC strives to:

· Test and evaluate aircraft, missile and space systems and subsystems at the flight conditions they will experience during a mission to: help customers develop and qualify the systems for flight, improve system designs and establish performance before production, and to help users troubleshoot problems with operational systems;

· Conduct a research and technology program to develop advanced testing techniques and instrumentation and to support the design of new test facilities. The continual improvement helps satisfy testing needs and keeps pace with rapidly advancing aircraft, missile and space system requirements;

· Maintain and modernize the center's existing test facilities.

Arnold Engineering Development Center. Air Engineering Development Division established as a separate operating agency, I January 1950; redesignated Arnold Engineering Development Center, 2 August 1951.

Arnold Engineering Development Center (AEDC), located at Arnold Air Force Base (AFB), Tenn., is the world's largest and most advanced collection of flight simulation test facilities in the world. AEDC currently operates 58 aerodynamic and propulsion wind tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other specialized units. Twenty-seven of the center's test units have capabilities unmatched elsewhere in the United States; 14 are unique in the world.

The base, dedicated on June 25, 1951, by President Harry S Truman, sits on 40,000 acres in Middle Tennessee. Since its dedication, AEDC has tested virtually every high-performance aerospace system the Department of Defense has developed.

Arnold AFB is the only active-duty Air Force base in Tennessee.

Our Mission

To provide our customers with the world's
most effective and affordable aerospace
ground test and evaluation products and services.
To ensure AEDC test facilities, technologies
and knowledge fully support today's and
tomorrow's customers

LINEAGE

Established as Air Engineering Development Division, 1 Jan 1950
Redesignated Arnold Engineering Development Center, 3 Aug 1951

STATIONS

Wright Patterson AFB, OH, 1 Jan 1950-14 Nov 1950

ASSIGNMENTS

HQ USAF
Air Research and Development Command, 1 May 1951

COMMANDERS

HONORS

Service Streamers

Campaign Streamers

Armed Forces Expeditionary Streamers

Decorations

EMBLEM

EMBLEM SIGNIFICANCE

MOTTO

NICKNAME

OPERATIONS
This was the Air Force's first separate operating agency.

Established as Air Engineering Development Division, with status of a separate operating agency directly controlled by HQ USAF, on 1 January 1950
Reassigned to Air Research and Development Command on 1 May 1951, losing SOA status
Redesignated Arnold Engineering Development Center on 3 August 1951

Air Force Order of Battle
Created: 23 Nov 2010
Updated: 21 Aug 2013

Sources
AFHRA