AEDC HIGHLIGHTS

Commercial Success Stories

Arnold Engineering Development Center
An Air Force Materiel Command Test Center

Electronic version of ***AEDC Commercial Success Stories*** is available on the AEDC World Wide Web home page: at http://www.arnold.af.mil/

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Arnold Engineering Development Center

"The cost of development and maintenance of facilities like AEDC is going to overburden the average business whether it is General Electric, Pratt & Whitney or Allison. It makes sense to centralize the capabilities for handling all levels of technology whether it's extremely high airflow engines like the PW4084 or the GE-90, or whether we get into hypersonics with Mach 7 requirements. Industry is not going to be able to shoulder the responsibility of individual corporate test facilities; they have become too complex. If there was not an AEDC, then there would need to be a facility like AEDC."

Dennis Enos,
Engineering Manager,
Pratt & Whitney's F100-PW-229 program.

Arnold Engineering Development Center (AEDC) is the most advanced and largest complex of flight simulation test facilities in the world. AEDC was born in 1951 when, after World War II, U. S. officials became aware of the advances the Germans had made in developing high-performance jet aircraft and rocket-powered missiles. They realized that the U.S. had narrowly escaped a crushing defeat had the German military deployed this capability. The visionary leaders of the time declared that the U.S. would never again be surpassed in aerospace technology.

During the past four decades, the center's customers have been the U.S. military and NASA. While commercial testing had been available during these years, defense department regulations limited AEDC availability for commercial ventures. Two major environmental changes forced Arnold officials to rethink the role of AEDC: 1) increased government budget pressures and 2) global competition in the aerospace industry. Decreasing budgets and reduction of new weapons programs makes it increasingly difficult for AEDC to sustain the massive infrastructure and advanced technology so vital to developing next generation weapons systems. With fierce global competition, the U.S. industry is finding that maintaining in-house state-of-the-art test and evaluation capability is a burden that greatly impacts its competitive position. Arnold officials realized that government and industry could both benefit from encouraging commercial use of the center. Industry could have access to the most advanced test and evaluation capability available in the world, offering a competitive advantage they could not afford to build and maintain themselves. AEDC could benefit from the commercial workload to sustain the capabilities for the benefit to the nation. These factors led to the establishment of partnerships between AEDC and commercial aerospace industries.

Expediting the venture into the commercial test arena, Congress passed a series of legislation between fiscal years 1994 and 1999 encouraging industry to use underutilized capabilities at Department of Defense Major Range Test Facility Base (MRTFB) installations like AEDC. The law's purpose was to preserve MRTFB capabilities by keeping them in use; to reduce costs to all MRTFB customers by spreading sustainment costs over a broader revenue base; and to support U. S. commercial competitiveness in the international market.

Additionally, the legislation reduced commercial testing prices, bringing them closer to government testing rates. The results of this new arrangement for commercial use of DoD test facilities was enhanced cooperation and collaboration in aerospace technological development.

Commercial testing at AEDC is just one part of a larger national response to this national challenge. AEDC is now properly positioned to be a vital part of this nation's competitive strategy in the aerospace research, development, test, and evaluation marketplace. AEDC personnel can provide the expertise and resources necessary to support commercial customers. They possess world-class expertise in determining test feasibility, developing ground test requirements, conducting long-range test planning, scheduling and budgeting, designing, building and installing specially required test hardware and equipment, acquiring, processing and analyzing test data and correlating ground-to-flight data and performance.

Already, because of commercial testing, AEDC has been able to provide improved support to numerous defense and military efforts critical to the nation's defense. Arnold Center has maintained its unique capabilities and expertise in the field of aerospace ground testing.

"We need to preserve that part of the defense industrial base which will give us a technological advantage, but we have to do it at a reduced cost and, therefore, at increased efficiency of procurement. We have to take dramatic action which allows us to integrate the defense industrial base with the commercial industrial base, creating thereby, one single national industrial base."

Former Deputy Secretary of Defense,
Dr. William J. Perry

There are two indirect benefits to the nation: 1) technology transfer between the commercial and DoD sector and 2) direct use by DoD of commercial products.

Technology transfer itself manifests both in the form of knowledge of test and evaluation methodology and in the form of investments in specialized equipment furnished to AEDC. Gains in technology are promoted through the utilization of AEDC facilities to produce better DoD products as well as better commercial products. An appropriate mix of commercial and military testing benefits all AEDC customers by maintaining a strong, talented work force in world-class test facilities.

The following are but a few illustrations of successes already realized from the government/industry partnering at AEDC. ■

Arnold Engineering Development Center

Located on a 40,000-acre site in southern Middle Tennessee at Arnold Air Force Base, Arnold Engineering Development Center (AEDC) is the most advanced and largest complex of flight-simulation test facilities in the world. Of the center's 58 aerodynamic and propulsion wind tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other specialized research test facilities, 27 are unmatched anywhere in the world.

They can simulate flight conditions from sea level to outer space altitudes, and speeds from stationary to more than 20 times the speed of sound. AEDC ground-based testing saves lives, money and produces better products by identifying and eliminating problems.

Tests Ensure Certification for Engine Companies

Turbine engine tests conducted at AEDC played a major role in ensuring Federal Aviation Administration (FAA) certification for Rolls-Royce and Pratt & Whitney engines on the Boeing 777. Component testing at AEDC provided simulation of multiple flight environments without the equipment and personnel risks associated with flight testing, saving time and hundreds of thousands of dollars.

"This testing not only helps our company, but also affects airline ticket prices and airline safety," said Ron Henson, a Pratt & Whitney vice president in charge of engineering testing. "If you see all the rigorous testing these engines go through at AEDC and our Pratt facilities, you've got to feel very safe about flying."

The extended-range, twin-engine operations (ETOPS) certification rating extends the aircraft's emergency flying time if one engine fails. Without this certification, an aircraft experiencing engine failure must be able to reach an airport where it can safely land within 60 minutes. ETOPS certification extends the time up to 180 minutes, giving the airlines the ability to fly across oceans, remote areas and barren terrain three hours from the nearest suitable airport. These tests also allowed Boeing to became the first airplane manufacturer to receive both ETOPS and type certification on the same day, and were instrumental in the Boeing 777 setting two world records for speed and distance during certification flight.

Boeing 777
(Photo courtesy of Boeing).

Obtaining this certification means an airframe/engine combination, as well as the airline's flight operations and maintenance, must be certified for reliability. Through AEDC testing, the Rolls-Royce Trent 800 engine, three of the Pratt & Whitney PW4000 family of engines and the Boeing 777 airframe successfully met the FAA reliability testing and validation requirements and certification criteria.

The FAA certified the 90,000-pound thrust PW4090 in 1996, and in July 1998, they certified the PW4098, the launch engine for the Boeing 777-300.

AEDC Support to ETOPS Certification

- **149 hours of developmental testing of the Rolls-Royce Trent 800 engine.**
- **450 hours of testing on the PW4084. All of the altitude testing completed at AEDC.**
- **56 hours of testing on the PW4090 for the Boeing 777-200 Increased Gross Weight aircraft.**
- **364 hours of combustor development, engine performance and operability testing for the PW4098 engine, which replaces the PW4084 to power the Boeing 777-3000.**

Pratt &Whitney 4090 engine installed in AEDC Test Cell C-2.

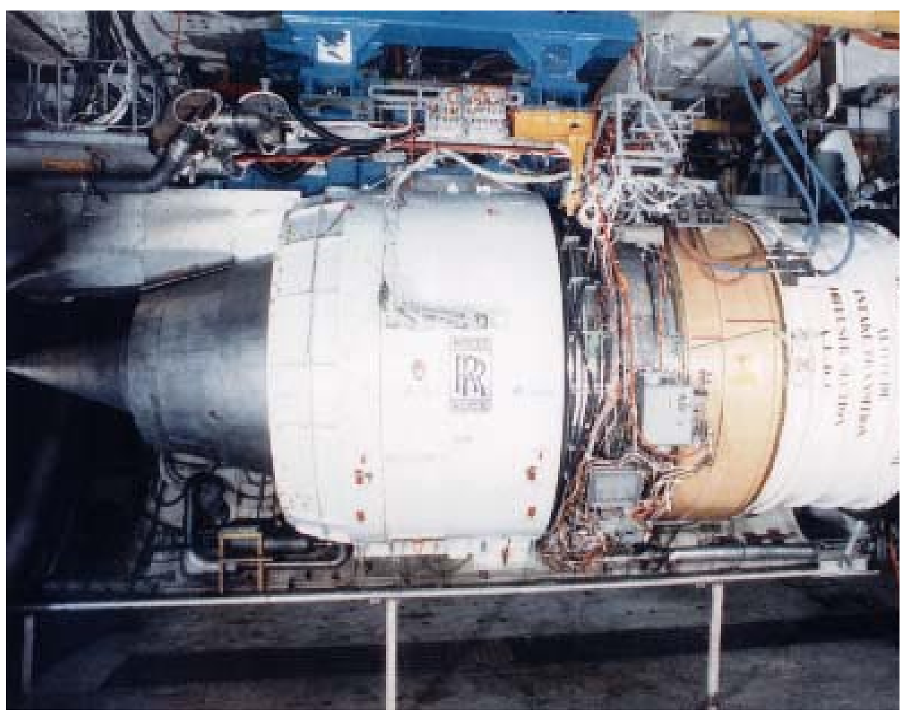
safety, comfort and overall appeal to the flying public."

These outstanding achievements were possible through more than 750 hours of testing at AEDC. However, customers weren't the only beneficiaries. Simulated altitude testing on commercial engines maintained critical test capabilities and skills in the center's premiere large thrust engine test cells C-1, C-2, T-4 and in aerodynamic propulsion wind tunnel 16T. The four-year span of testing provided a steady workload at the center, providing an economic boost to the multi-county area surrounding AEDC and generating revenues for sustaining these test facilities.

Through ongoing alliances with major customers like P&W, Rolls Royce and Boeing, AEDC will remain a viable entity in the international aerospace testing industry throughout the next century. ■

In 1997, powered by the Rolls-Royce Trent 892 engine, the Boeing 777-200 set two world records for speed and distance and received engine certification for 180-minute ETOPS approval by the FAA three weeks ahead of schedule. Trent 800 engines have achieved more than 290,000 service hours and 88,000 cycles and are in service with 39 aircraft worldwide. In 1998, the Boeing 777-300 received both ETOPS and type certification, marking the first time any airplane manufacturer had received both certifications in one day.

"Receiving type certification for the 777-300 says volumes about our product - its safety, reliability and performance," said Ron Ostrowski, vice president and general manager of the 777 program. "All of this means better value to the airlines and increased



Rolls-Royce engine installed in AEDC Test Cell C-2.

Arnold Helps Give Major Rocket Company Big Boost

Delta III rocket ready for launch. (Photo courtesy of Boeing).

While helping Boeing expand the global reach of the Loral Skynet commercial communications satellite system, Arnold Engineering Development Center is providing valuable developmental data for the nation's newest fleet of heavy payload launch vehicles, the Evolved Expendable Launch Vehicle program.

Tests conducted at AEDC made possible the April 21, 1999, launch of an Orion 3 satellite aboard a Boeing Delta III rocket and enabled Hughes Space and Communications Services to obtain vital insurance coverage on the satellite. Also, data obtained during these tests are being used in the evolution EELV from the Delta program.

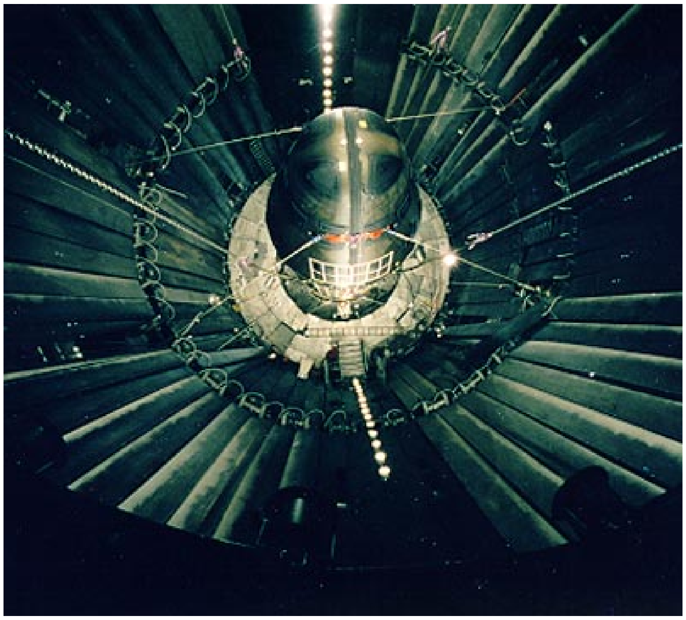
"Delta III is very critical to that (through Delta IV) evolution, and we're here at AEDC to make sure that it is as effective as we believe it is," said Jay Witzling, Vice President, Delta II and Titan Programs.

Loral's Skynet three-satellite communications fleet transmits network television programming, live video feeds for news reporting, direct-to-home and pay-per-view programming, distance learning, educational and other business television services. The current system provides coverage to the continental United States, Alaska, Puerto Rico, the U. S. Virgin Islands, the Caribbean, Istanbul, Kiev, Tallin and parts of Canada and Latin America. Addition of the 4-1/2 ton Orion 3, the largest payload ever launched by a Delta III launch vehicle, will increase coverage area to Russia, Japan, Korea, China, Australia, India, Southeast Asia, Oceania, Hawaii, the Middle East and the remaining parts of Latin America.

The Delta III rocket is a heavy launch vehicle used to place larger payloads into Earth's orbit. Based on historic configurations of the Delta II vehicle, it uses a Pratt & Whitney RL10B-2 as the upper stage propulsion system to provide the second-stage, high-performance thrust that enables the rocket to place payloads such as the Orion 3 into geosynchronous orbit. AEDC engineers conducted 22 extensive development and qualification tests on the RL10-B2 and its extended nozzle system between 1995 and 1998.

In August 1998 the first Delta III launch failed due to a roll-control mode unaccounted for in the control systems and resulted in a change in the system's software. During the investigation of the launch failure, Boeing's Delta III design team recommended ways to further improve the vehicle's reliability. Their recommendations included evaluation of the second-stage engine nozzle deployment. "Although we recognize the significance of this launch as the return to flight for Delta III, our No. 1 priority is supporting our customers and ensuring the success of their mission," Witzling said.

Boeing took advantage of a window of opportunity before the April 1999 launch and returned to AEDC for the additional testing. Based on results from these RL10-B nozzle deployment tests, Boeing modified the system to ensure the booster's second-stage extendible nozzle would deploy properly in the event only one of its two drive motors was operating.



Delta III Fairing Test in Mark I Chamber.

During the five-month program, AEDC engineers conducted a series of three tests designed to verify analytical thermal models and to check the effect of extremely cold environment on the nozzle deployment system. The Boeing team provided designs for a zero-gravity deployment system, AEDC engineers designed and fabricated an interstage simulator that fit into AEDC's Test Cell J-4, and the AEDC team provided the expertise needed to ensure the Delta III launch's success.

In December, with only a single test planned, engineers chilled the nozzle to its lowest level before performing the deployment test. However, the nozzle did not deploy as planned and data from the test prompted Boeing to modify components of the deployment system. The modifications included increasing the size of an interstage vent door, placing shrouds around the nozzle deployment drive-belt system that was directly exposed to the flow of cold gas during second-stage engine chill-down and shortening the chill-down period of the engine during post-boost phase. Afterwards, Boeing requested two additional tests to accurately portray the temperature gradients among the deployment system components.

"Because there could be a 20 to 30 degree difference in temperatures between components, we want to run a test that will deploy the nozzle under flight-like conditions," said Dan Collins, Delta II return-to-flight program lead.

In February 1999, AEDC engineers completed the final test confirming the modified system deployed as specified. "We found a problem, corrected it, and proved the solution in test—all within about a month," said Mark Berger, Boeing project engineer. "Once again, AEDC did a great job."

J-4 Test Team members qualified this Boeing RL10B-2 engine and its carbon-carbon nozzle extension in AEDC's upgraded Rocket Propulsion Development Test Cell J-4. The test program supported the Delta III launch in August 1998.

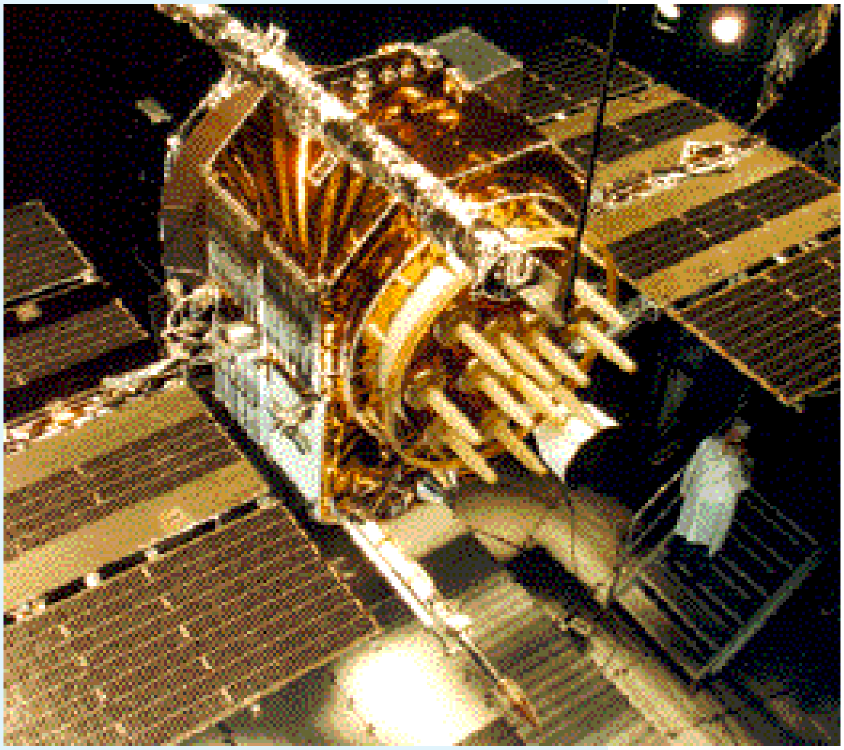
Commercial Satellite Company Selects "Space" at Arnold

When the test contractor for Space Systems/Loral decided to close its facility in 1998, the giant communications satellite manufacturer turned to AEDC to test their systems.

Although the California-based company owns a test facility, its annual satellite production exceeded their facility's capacity. By taking advantage of the accessibility and availability of AEDC's unique test chamber and skill, Loral avoided expenditure of millions of dollars it would have cost to build an additional facility.

Costs to build and launch a commercial satellite are enormous, so the in-orbit reliability and performance of the satellite is critical to the customer.

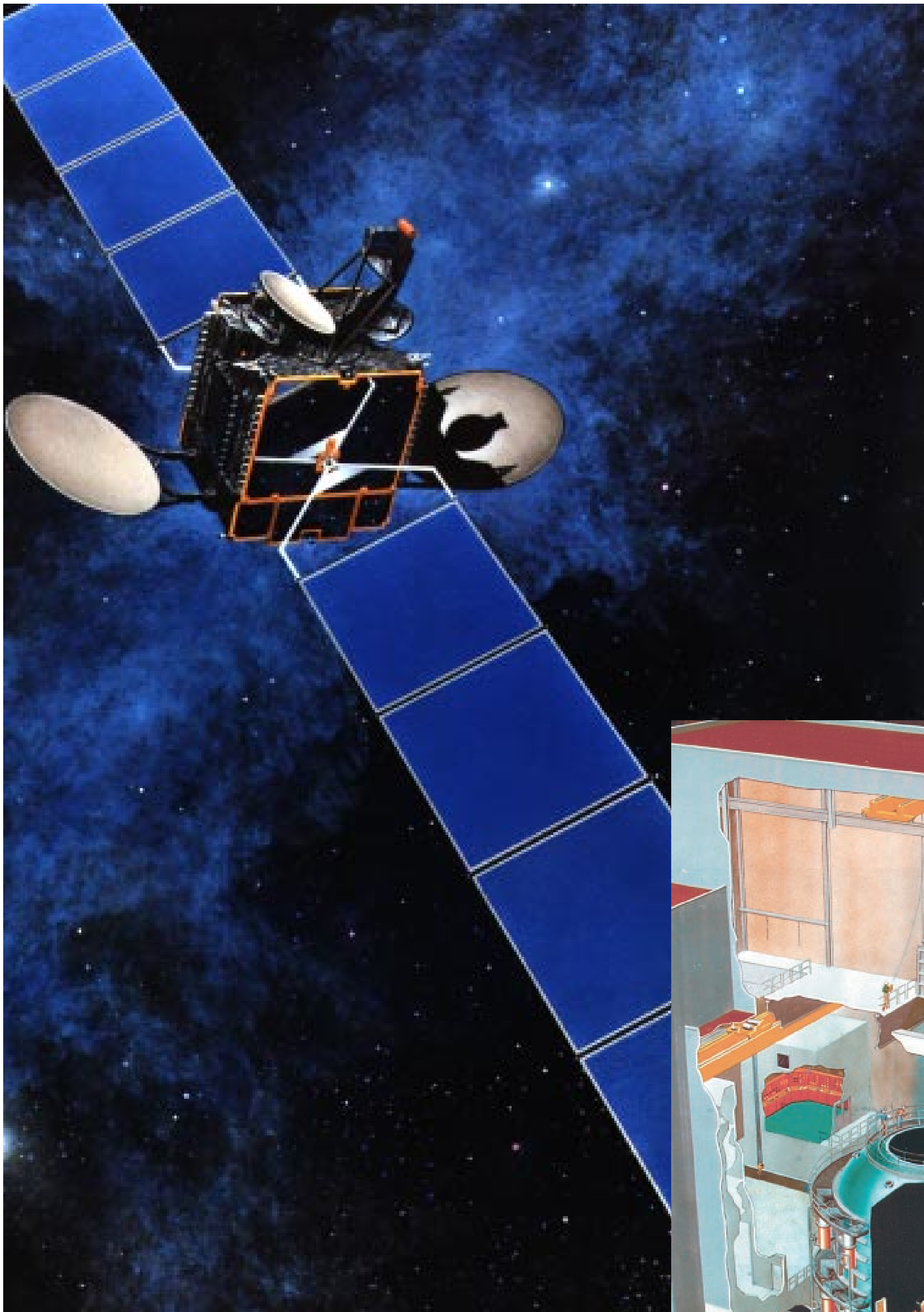
Space Systems/Loral is one of the world's leading manufacturers of satellites and advanced satellite-based multimedia communications systems and services with more than 40 years of spacecraft development. Headquartered in Palo Alto, Calif., the company designs, builds, tests and operates satellites, subsystems and payloads used for commercial communications services including cellular telephones and television systems. Since 1960, the company has designed or built some 190 satellites. AEDC engineers will test between 30 and 40 of these new satellite systems for Loral during the contract period.



Global Positioning Satellite undergoes testing in Mark I facility.

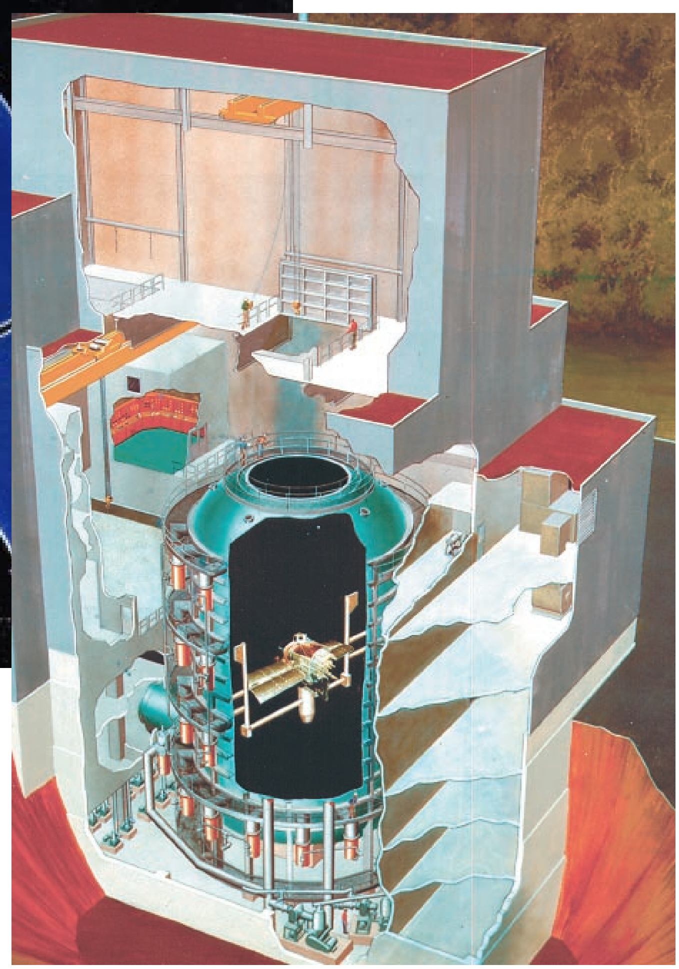
The 10-year contract funds testing an average of three to four satellites per year, which officials say translates into about $30 million. It also includes $1.5 million for a significant capability upgrade to AEDC's Mark I Space Environmental Chamber. These improvements will make the 82-feet-high by 42-feet-diameter chamber a prime facility for testing Department of Defense and commercial industry space systems in the future.

AEDC employees even went the extra mile to solve transportation issues to get the 15,000-pound satellite systems from California to Tennessee. An arrangement was made for transport via a USAF C-5 cargo plane and oversized trucks. With the imminent reopening of the AEDC airfield (see page 14), the test ar-



Artist's drawing of Loral Skynet satellite.

ticles can be flown directly to the test site at Arnold Air Force Base. This mutually beneficial partnership provides Space Systems/Loral a ready facility for satellite testing and sustains a world-class facility for support of U. S. government programs.



Artist's drawing of AEDC facility Mark I.

World's Largest Aerospace Company Selects Arnold

Headquartered in Seattle, Wa., Boeing is the world's largest aerospace company, the U.S. leading exporter of commercial jetliners and military aircraft and the nation's largest NASA contractor. The company serves more than 145 countries, operates in 27 states and employes about 231,000 people.

Of the 12,000 jetliners in the world fleet, 10,000 are Boeing products. As of May 31, 1999, Boeing had delivered more than 12,716 commercial jet transports since manufacturing began—1,211 were 747s.

In an increasingly competitive, $585 billion, commercial jet aircraft market, total sales and operating revenue reached $56,154 million in 1998 with a commercial airplane segment operating profit margin at 0.2 percent.

To remain competitive, Boeing officials began exploring plans in 1996 for a derivative of the Boeing 747 aircraft.

Since design requirements including operational cost effectiveness, performance, passenger comfort and safety determine how attractive the aircraft is to the airline customer, they played a major role in Boeing's plans.

The proposed 747MD was tested in AEDC's Large Transonic Wind Tunnel 16T.

The aircraft design determines the aerodynamic drag that directly affects fuel consumption, speed, flight range and payload capabilities that subsequently influence the aircraft's operational costs. To be successful, the design must also exhibit appropriate stability and control characteristics affecting airline passenger safety and comfort.

Based on customer requirements, The Boeing Company proposed a multi-million-dollar major derivative of its popular commercial aircraft. The new 747MD would seat 550 passengers in three classes with a flight range of more than 8,000 miles, making it capable of non-stop service to Pacific Rim customers, while operating about 10 percent more efficiently than current designs.

Before guaranteeing this product to their customers, the company needed to validate their proposed design with wind tunnel test data. This required a large transonic wind tunnel with exceptional flow quality that was immediately available to meet a demanding accelerated test schedule.

According to Roger Pomeroy, Boeing Principal Designer for Aerodynamics, the two-and-a-half-month test series in 16T confirmed the design parameters for the 747MD. The test set a milestone for the AEDC- Boeing Commercial Group Alliance and exceeded Boeing's expectations for efficiently producing high-quality data.

Boeing engineers also gained significant insight into other areas beneficial to their future aircraft development program. Using the wind tunnel data and AEDC test support, Boeing redesigned, fabricated and tested a new wing for the airplane model before the test series was completed. This eliminated a redesign phase, reduced development cycle time by several weeks and was applicable in future aircraft designs. Considering the multi-million-dollar daily costs incurred during developmental stages, integrated design and test and evaluation like this can result in enormous cost savings.

Following the AEDC tests, due to current and projected market conditions, Boeing officials decided not to develop the Boeing 747MD. "The decision to launch a program is based on many factors," Pomeroy said, "including the business case, the customer requirements and the resources available."

Nevertheless, he said, "This test was both very successful and valuable to The Boeing Company. With AEDC's help, Boeing confirmed the target lift-over-drag ratio and desired airplane performance and handling characteristics were achievable at the design cruise speed."

The test series validated 16T for future Boeing development programs, provided a baseline database and verified the tunnel's high productivity, data quality and repeatability. The Boeing-AEDC team also developed a new test section access door allowing quicker access to the test cell. The door has been used on virtually every test in 16T since. In addition, teamwork during test preparations developed several process improvements that significantly reduced model configuration change times and overall test cycle time. These improved processes, such as getting the tunnel started faster, continue to benefit all 16T tests.

These process and infrastructure improvements resulted in estimated testing cost savings of $373,600 in 1996. Since then, an average annual savings of $283,000 has been realized and is expected to remain steady during future testing. Finally, the commercial test workload helped maintain AEDC's unique facility capabilities and work force expertise. These benefits are shared by all AEDC customers. ■

Artist's drawing of Boeing 747.
(Photo courtesy of Boeing).

AEDC Helps Deliver Nation's Satellite Orbit Kick

Inertial Upper Stage solid rocket motor attached to TDRS is prepared for launch. (Photo courtesy of NASA).

When the Space Shuttle launches satellites into geosynchronous orbits, chances are the upper-stage placing it in orbit is an offspring of the **I**nertial **U**pper **S**tage solid rocket motor developed in 1976 with the help of AEDC.

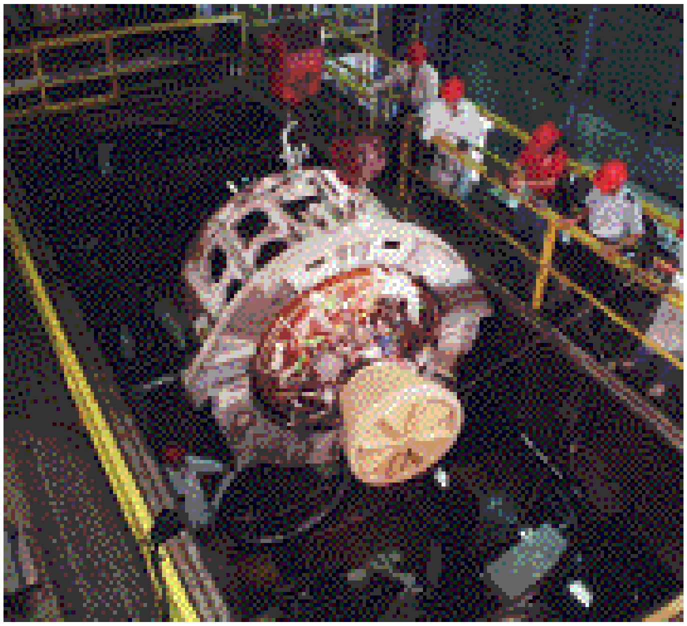
The IUS is a two-stage solid rocket propelled spacecraft used to lift heavy payloads into high orbits. At approximately 17 feet long and 9.25 feet in diameter, it weighs approximately 32,500 pounds. It generates 44,000 pounds of thrust and can lift 5,100 pounds into geosynchronous orbit—approximately 22,300 miles above Earth where a satellite appears stationary in respect to the ground.

Originally designed to be a temporary stand-in for the NASA Space Transportation System until reusable space launch vehicles could be developed, the IUS has been used in more than 25 missions to ensure military and commercial satellite systems reached their intended high-Earth orbit. Through 1998, all spacecraft launched by the IUS reached their operational orbits. Furthermore, NASA's Magellan, Galileo and Ulysses planetary missions were successfully placed into interplanetary trajectories by the IUS.

Manufactured by Boeing, the IUS is a critical component of the National Space Transportation System developed by the Air Force and NASA. It provides spacecraft users an upper-stage booster with designed flexibility and adaptability that allows integration with the Space Shuttle and Titan IV heavy launch vehicles. United Technologies Chemical Systems Division (CSD) manufactures the system's two solid rocket motors.

Arnold Engineering Development Center played a key role in the IUS evolution. Capitalizing on the unique test facilities and expertise, CSD called on engineers at AEDC to design validation, developmental and qualification testing programs during the original development program. Following development, AEDC engineers conducted motor qualification and flight proof test programs. From 1979-82, 12 small, 24,000-pound-thrust, and 12 large, 50,000-pound-thrust IUS motors were tested at simulated altitude conditions to assess performance and operation of the motor's systems.

As a result, the first IUS successfully flew on a Titan 34D launch in 1982, placing a Department of Defense satellite in orbit. In April 1983, during the Space Shuttle STS-6 mission, the IUS's second motor, SRM-2, experienced a nozzle gimballing malfunction, resulting in an un-



AEDC Test Cell J-5 supports space systems payload systems such as IUS, Pam D-II and STAR.

planned orbit for the Tracking and Data Relay Satellite. The TDRS was the first to be deployed from the Space Shuttle by an IUS.

The malfunction brought the IUS back to AEDC for four additional tests at simulated altitudes of 100,000 feet. These tests led to the discovery and elimination of a design flaw not found until the system was deployed.

Since very strategically important satellites are flown on the IUS system these tests were considered AEDC's priority test programs at the time.Indeed, these tests were the pioneering efforts for our use of X-ray diagnostics applied to solid rocket motors while they operate.

Throughout the past 15 years the IUS program has received numerous awards and citations. In 1991, it received the Federation Aeronautic International Diploma D'Honneur for Astronautics, "For the design, development, manufacturing and successful operations achievements of the IUS...."

The latest mission is the deployment of NASA's newest space telescope, the Chandra X-Ray Observatory. The Chandra was launched this summer aboard a Titan IV launch vehicle. It provides unprecedented X-ray images from space and allows scientists to study detailed physics of the universe and its many components.

Clearly, the IUS remains a viable part of the nation's defense and commercial industry. Through stringent early-development test requirements AEDC honed and sustained an expert team of solid rocket motor testing and analysis engineers and craftsmen that remain today a critical component in maintaining the center's infrastructure to support both industry and government customers. ■

Space Shuttle Columbia lifts off from Kennedy Space Center. (Photo courtesy of NASA).

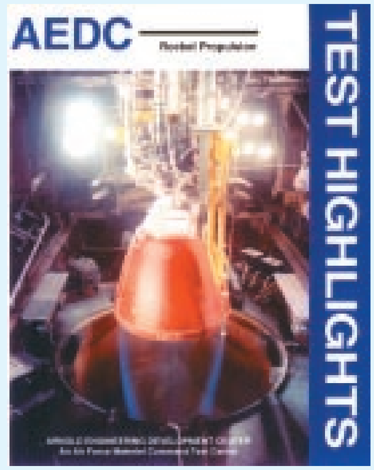
Reactivation of the AEDC Airfield

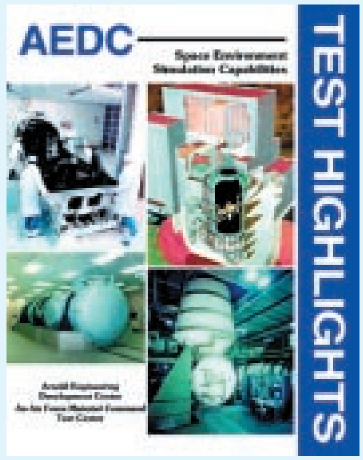
AEDC has recently reopened its base runway to regular traffic. The runway had been closed since 1995.

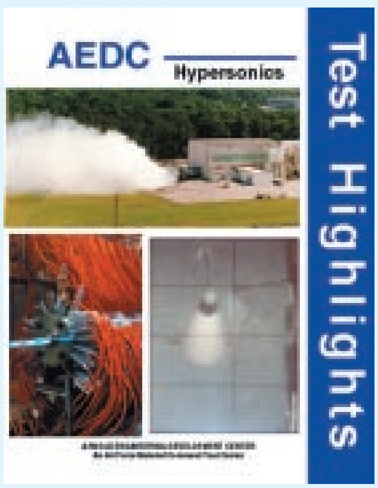
The AEDC airfield is located on the AEDC reservation approximately two miles from the test facility site. The runway is 6,000 ft. long with 1,000 ft. overruns. The airfield has night lighting and a beacon. A small parking ramp will accommodate cargo or passenger aircraft up to and including the C-5. Fuel, fire and emergency equipment, and heavy lift and handling equipment are available.

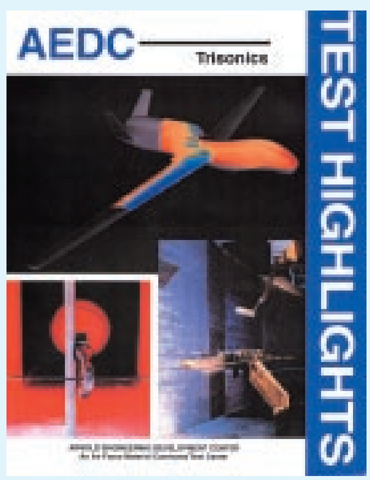
The runway is available on a Prior Permission Required basis for test hardware pickup and delivery and visiting personnel. This is especially convenient for customers who desire to fly large, delicate or classified test articles, such as sophisticated spacecraft and satellites into AEDC. Use of the runway for AEDC access eliminates the need for supplemental ground transportation over public roadways.

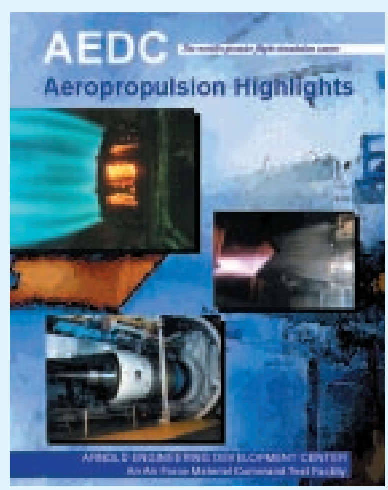
Related AEDC Test Highlights











AEDC Web Site:
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