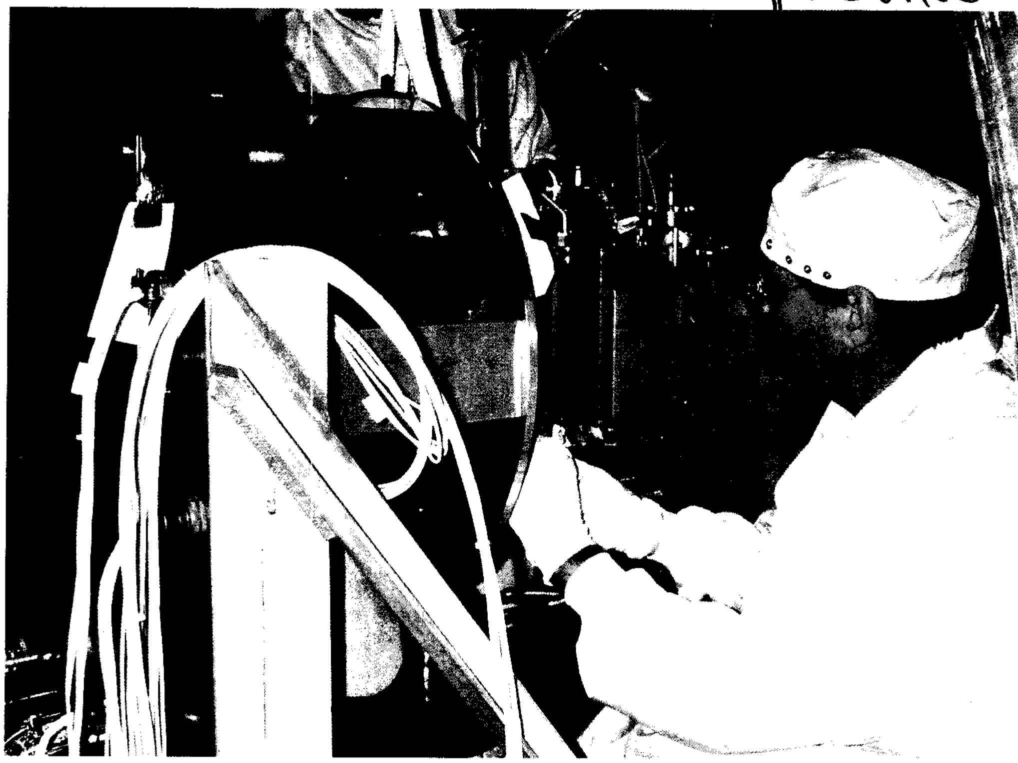
Dec. 2002

Ground Testing Technical Committee

Hypersonic Program Info: p13



Ground testing of the High Altitude Observatory (HALO) upgrade for the Missile Defense Agency at AEDC.

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Chairman's Message

I'd like to welcome y'all to this 15th edition of the American Institute of Aeronautics and Astronautics (AIAA) Ground Testing Technical Committee (GTTC) newsletter. Each edition of the newsletter gets a little better and offers something new, which is a lot like the GTTC. We are always looking for new ideas to keep the GTTC worthwhile and technically relevant to the ground testing community, and I think we did make some great additions to our group this year, in terms of new members and new parts of the organization. As you read through this edition, you'll get the details on all the happenings associated with the GTTC, but I do want to highlight a couple of key items.

- A new subcommittee was added to the GTTC organization, the International Liaison Subcommittee. As the AIAA becomes a global organization, it is important to ensure that we are communicating and exchanging ideas and information on an international basis. This subcommittee was chartered to help exchange information relative to ground testing between various international organizations.
- The GTTC working groups are going strong: three have completed recommended practice documents and two new working groups are being formed. The working groups provide the GTTC with a means to harness technical expertise from the ground testing community to address specific technical issues.

These are just two examples of the ongoing activities within the GTTC. In addition, the GTTC membership is responsible for many other activities such as conference planning, developing technical paper and discussion sessions, creating technical short courses, administering the annual Ground Testing Award, and publishing this newsletter. None of these tasks could be completed without the professionals who staff the GTTC. Our members are the most important part of the GTTC, and without them, we could not make such a positive contribution to the ground testing community.

I hope y'all enjoy this issue of the GTTC newsletter. If you have questions or comments about the GTTC, or are interested in joining, please feel free to contact me directly at Earnest.A.Arrington@grc.nasa.gov or by phone at 216-433-8507. Or check out our Web site: http://www.aiaa.org/tc/gt/gttchome.html.

to Rolls-Royce's needs by accomplishing 80 hours of testing in five test periods over 10 calendar days. The engine operated at simulated flight conditions from sea level to 45,000 ft at speeds up to Mach 1.2 to establish engine performance and handling characteristics. The MK951 is an upgrade of the Adour, which is a midsize, dual-spool, low-bypass turbofan engine with a nonafterburning fixed-area nozzle.

Previous versions of this engine are used primarily in the BAE SYSTEMS Hawk and the U.S. Navy Boeing T-54 Goshawk trainer aircraft.

visualization system (AVS) program. During these runs, the material samples will be exposed to heat loads and exposure times typical of those expected for the maneuvering RV terminal dive phase.

These tests will provide data on candidate heat shield material survivability and thermal insulation properties of materials exposed to the high temperatures and pressures that occur during flight at relatively low altitudes where aerothermal heating is most severe.

Upgraded Arc Heaters Test Future Defense Systems at AEDC

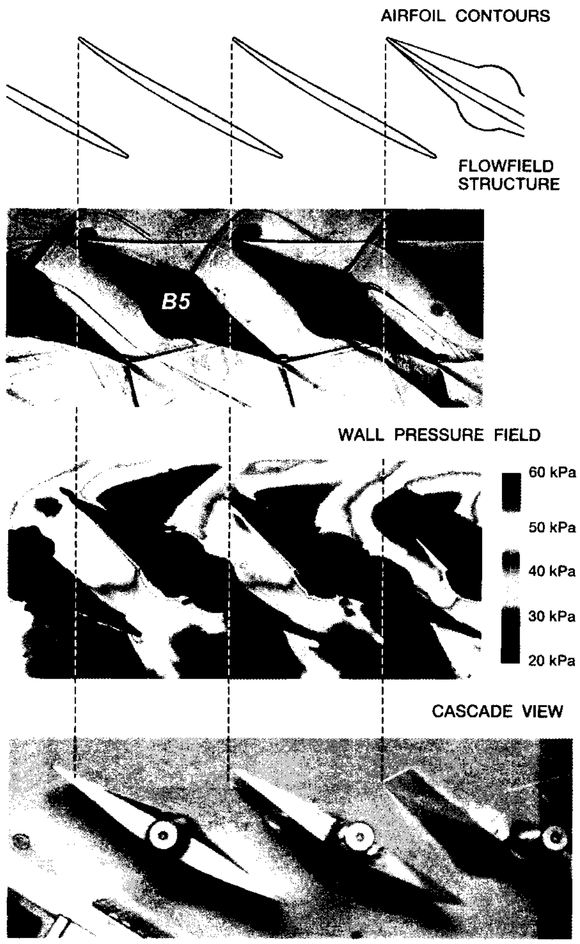
Contributed by Tina Barton

A recently upgraded arc heater facility (H2) at AEDC is providing heat shield material testing for the potential successor of the Minuteman III Intercontinental Ballistic Missile (ICBM), the Minuteman IV (MMIV). MMIV is under study by the Air Force Space Command as a possible next-generation ICBM system.

Arc heaters simulate the extreme pressure and temperature encountered by ballistic missile reentry vehicles. AEDC's arc facilities have unique test capabilities not available anywhere else. During the most recent test, the AEDC test team exposed multiple flow-field calibration probes to the arc freejet and exposed two prototype heat shield material samples to material surface temperatures up to 4,000 ∞F during 10- to 15-sec exposure times, simulating the high-temperature and high-pressure arc jet conditions a vehicle would experience upon reentry.

According to 1LT Tim Budke, AEDC Directorate of Space project officer for the arc facilities, one option under consideration for the MMIV reentry vehicle (RV) is maneuvering capability to provide additional mission flexibility. However, because maneuvering RVs can fly a variety of reentry trajectories with long glide segments, onboard thermal protection materials are subjected to extremely high total heat loads.

The recent H2 nozzle facility upgrade, funded by the Reentry Vehicles Application Program (RVAP) sponsor, provides a key segment of the maneuvering reentry trajectory simulation envelope previously not available to DOD RV designers for thermal protection material development. During fiscal year 2002, the Hill Air Force Base RVAP office is sponsoring a series of three nozzle calibration runs for the new H2 nozzle flow field, followed by eight test runs in H2 to evaluate preliminary candidate materials for the advanced

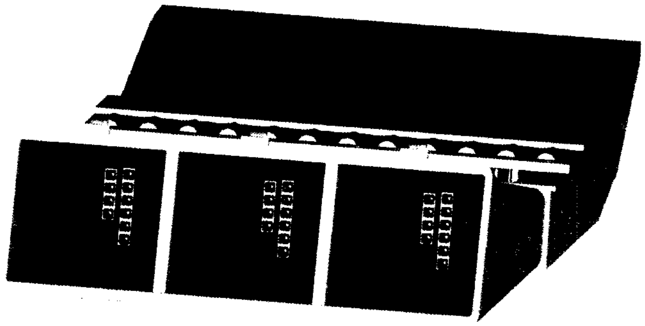


At NASA Glenn's Transonic Flutter Cascade facility, a facility dedicated to unsteady aerodynamics of oscillating airfoils, research is being conducted to determine the effects of one fluttering blade tip on the surrounding blades at low-, medium-, and high-amplitude oscillations. Some blades are equipped with Kulite transducers (Kulite Co., Basingstoke, Hampshire UK) to measure dynamic data, while others have static pressure taps. This research is applicable to turbofan engines with highly loaded, low-aspect-ratio fan stages with transonic or low-supersonic relative velocities in the blade-tip region. This figure shows a section of the cascade in a drawing, a schlieren photo during a run, a computational fluid dynamics solution, and a photograph.

AEDC Wind Tunnel Test Provides Critical Data for New Fleet of Military Aircraft

Contributed by Danette Duncan

Data from AEDC testing will help reduce risk for future weapon integration of new small munitions on the next generation of combat aircraft, including the F-22 Raptor, the F-35 Joint Strike Fighter, and the Unmanned Combat Air Vehicle. The center tested a 1/15-scale model of the Low Cost Autonomous Attack System (LOCAAS) on a sting in the center's four-foot transonic wind tunnel. The sting positioned the LOCAAS to simulate separation from the F-111 aircraft during wind tunnel testing. During the test, engineers examined the release of small munitions from aircraft with supersonic capability and with internal weapon bays.



Integrated System Test of an Airbreathing Rocket (ISTAR) hypersonic engine.

Hydrogen Peroxide Rocket Engine Testing for the ISTAR Program

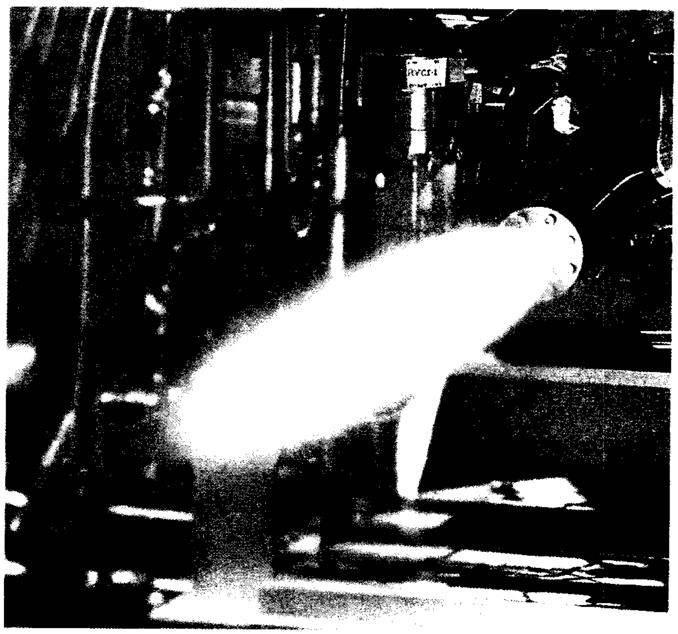
Contributed by Brian Robbers and Brian Ballen

The Integrated System Test of an Airbreathing Rocket (ISTAR) hypersonic engine uses a rocket-based combined-cycle approach where vertical arrays of small rockets located in struts within the ram-scram flow path provide the initial thrust needed to get to ramjet speeds. The propellants are 90-percent hydrogen peroxide (HTP) and JP-7 hydrocarbon jet fuel. The JP-7 is used by both the rocket and air-breathing modes. The HTP is used by the rockets for an oxidizer and by catalyst bed gas generators to drive the turbopumps. Each thruster, with a chamber diameter of just over 1 in., will provide 486 lb of thrust and operate at a chamber pressure of 1500 psia.

The rockets are currently under development at Aerojet's Sacramento facility. The test facility known as J-zone has recently been upgraded for the testing of rocket engines using up to 98-percent HTP. Three HTP tanks, 8 gallon up to 10,000 psia, 50 gallon up to 6,000 psia, and 530 gallon up to 3,100 psia, provide flow rates up to 150 lbm/sec. A 400-gallon, 5,600-psia fuel tank, compatible with hydrocarbon and storable propellants, provides flow rates up to 200 lbm/sec. Two thrust stands, J-5A and J-5B, are rated from 1 to 8,000 lbf and 10 to 100,000 lbf, respectively, and are capable of testing from sea-level conditions to 120,000 ft. Data acquisition of up to 128 channels at 108,000 samples per second complete the facility.

Historically, HTP rocket engines completely decompose the liquid HTP into hot oxygen and steam using a catalyst bed before introducing it into the rocket combustion chamber, where the fuel is injected. This requires large-diameter injectors and chambers to handle the flow of low-density decomposition products. This is not practical for ISTAR rockets, which need to be compact to fit within the struts. The ISTAR rocket engine will use a trifluid injection approach where only a fraction of the total liquid HTP (25 to 35 percent) will be decomposed and used as an ignition source while the rest is injected into the chamber as a liquid along with the JP-7.

The first of a series of tests was performed in July and August 2002. The tests were to demonstrate the trifluid concept and characterize the use of HTP as a combustion chamber film coolant. A total of 32 hot-fire tests were performed. Twenty-six tests with an uninstrumented heatsink chamber were required to establish a reliable start sequence. The remaining tests were conducted with heatsink chambers fitted with



Integrated System Test of an Airbreathing Rocket (ISTAR) development at Aerojet.

thermocouple rakes to obtain thermal data. The thermocouple profiles are currently being analyzed.

The next test series scheduled for February 2003 will use a water-cooled calorimeter chamber to accommodate heat flux measurements and longer duration tests.

New Space Propulsion Test Capability at AEDC

Contributed by Tina Barton

A large thermal vacuum space chamber at AEDC has a new capability for conducting electric ion propulsion testing for satellite thrusters and reached a new chamber record for vacuum levels.

"This new capability will allow our customers to conduct ground testing to understand the effect of electric propulsion thruster plumes on satellite systems," said CPT Lance Baxter, AEDC program manager.

Electric propulsion is a class of technologies used for in-space satellite propulsion and orbital guidance. According to Baxter, while ammonia or hydrazine arcjets are currently the most common type of propulsion used to maneuver satellites in space, recent advances in electric thrusters using gaseous xenon have shown that these thrusters can provide superior performance over chemical propulsion for certain satellite stationkeeping and orbit transfer tasks.

"Electric propulsion advantages include lower launch cost from using the lower mass of the components, increased fine control of orientation because of the low thrust level, a much longer low thrust level, and a much longer orbit life from the higher fuel efficiency," Baxter said. "This new testing capability leverages off of our historic expertise on chemical thrusters and allows us to contribute as the space community transitions to electric propulsion."

In January, a year after conducting their first checkout firing, AEDC personnel fired their third electric ion propulsion satellite thruster in Thermal Vacuum Chamber 12V and validated a new suite of plume diagnostic instrumentation. The test was the final phase of the facility checkout sequence following an upgrade to provide electric propulsion test capabilities for thrusters used to help satellites maintain their orbit.

The upgrades are part of a 10-year agreement signed between AEDC and Lockheed Martin Space Systems Company (LMSSC) in December 2000 to accomplish product research and development testing, and engineering manufacturing development testing of LMSSC electric propulsion systems at AEDC.

Prior to the test, employees pumped down the chamber to a record vacuum level ($1\times10(-8)$ torr) and cooled it to -260 °C (-434 °F), simulating conditions in space. During the test, the AEDC and General Dynamics Aerospace Corporation team fired a General Dynamics BPT-400 Hall-effect thruster down from the top of the vertical space test chamber. Special baffles inside the chamber deflected and funneled exhaust gas atoms to the bottom of the chamber, where they cooled and were frozen to the cryopump surfaces.

The test validated the pumping capacity of 12V's new cryogenic pumps and confirmed the successful operation of new software and equipment. This equipment measures the density of electrons on a pathway between the transmitter and receiver and helps characterize the thruster's plume to determine the effect of the plume on satellite components.

"Data obtained during this checkout test validated AEDC's diagnostics capabilities and confirmed AEDC's Space Thermal Vacuum Chamber 12V as a world-class electric propulsion test facility," said Albert Dawbarn, project manager for AEDC test contractor, Jacobs Sverdrup. "Without the support of Army LTC James Hesson, Captain Baxter, Norma Taylor, then chief of space systems testing, the University of Tennessee Space Institute, and the hard work of the Jacobs Sverdrup (AEDC test support contractor) test team, this milestone could not have been achieved."

Facility Checkout Tests Verify AEDC Is Ready for Scramjet Testing

Contributed by Tina Barton

Checkout test runs completed at the end of August in the Aerodynamic and Propulsion Test Unit (APTU) at AEDC verified facility capacity to support testing of high-speed air-breathing propulsion systems including ramjets and scramjets at speeds from Mach 3.5 to 4.1 and temperatures up to 1,440 °F.

According to 1LT Tim Budke, AEDC project manager for APTU test programs, an ongoing major upgrade to the APTU's liquid oxygen (LOx) supply system and an upcoming test program dictated the necessity for the test runs.

The purpose of the test runs was twofold. First, the tests verified completion and operational readiness of the LOx system upgrade. Second, the test series duplicated the test conditions for the upcoming test on the Navy's Dual Combustor Ramjet (DCR). Advanced AEDC-developed diagnostic systems were used to measure the performance of the facility.

Dwayne Carver, test engineer for APTU test programs, said the new LOx system operated as designed and exceeded expectations in two key areas. "The new LOx system has a much faster chill-down rate than the old system," Carver said. "Getting the hardware cold quickly translates directly into reduced test costs since you don't have a crew standing around waiting for the LOx system to chill down to the required temperatures. The new system is also better insulated. The old system could store LOx for no more than a day, but the new system recently held LOx for more than 3 days without significant loss."

Conditions for the checkout runs were selected with the Navy's DCR test in mind. According to Sharon Rigney, test contractor project manager for APTU test programs, the DCR will be tested at Mach 3.5 and 4.1 this fall. "We duplicated the test conditions specified for the DCR to measure critical flow quality data required by the Navy customer," Rigney noted.

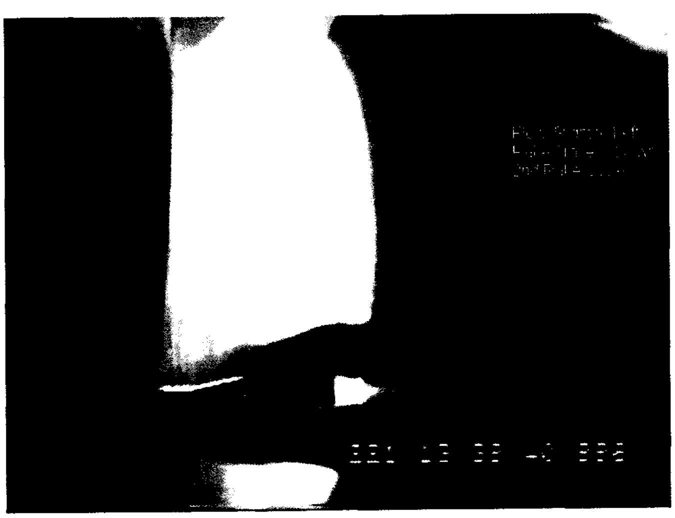
During the checkout, the test team obtained flow quality data using advanced intrusive and nonintrusive measurement systems developed at AEDC. The systems included a multiple-probe rake, a gas sampling system, and a flow visualization system using a laser sheet to illuminate any particles in the flow.

The probe rake was used to measure pitot pressure, total temperature, and flow angularity at the APTU freejet nozzle exit. According to Robert Hiers, chief engineer for intrusive diagnostic systems, the probe rake can operate in the high temperature and velocity of the APTU test medium by using cooling water at pressure exceeding 1,000 psia.

The gas sampling system used a mass spectrometer and a MultiGas Analyzer (Gas Measurement Instruments Ltd, Renfrew, UK) to sample the hot gas in the APTU stilling chamber upstream of the freejet nozzle. The system provided measurements of nitrogen, oxygen, water vapor, carbon dioxide, and argon, the major constituents of air, plus the trace gas species resulting from the air heating process. The gas sampling system provided continuous measurements at ambient conditions before the test up to the maximum stilling chamber pressure and temperature of 200 psia and 1200 °F.

"Since APTU heats the test medium up to 1,540 °F by burning isobutane in air, it is important for the test customer to know how this flow differs from the air that the system will fly in," said Paul Jalbert, AEDC gas sampling engineer. "We were able to show the APTU test medium is not significantly different than air at these operating conditions."

The flow visualization system provided a sheet of laser light just downstream of the freejet nozzle exit, illuminating any particles in the high-velocity flow. "Because the flow is heated by combustion, water vapor is always present in the test medium," said Ron Porter, laser systems operator. "When the flow is accelerated to supersonic velocities in the freejet nozzle, the temperature of the test medium is low enough to cause the water vapor to condense out and form small droplets. The laser light illuminated these droplets, giving us an image of the uniformity of the flow exiting the freejet nozzle."



Aerodynamic Propulsion Test Unit (APTU) checkout at AEDC.