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Ground Testing Technical Committee

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Chairman's Message

Hello and welcome to the 19th installment of the AIAA Ground Testing Technical Committee (GTTC) newsletter. This newsletter is just one of the ways the GTTC shares information about activities from the TC and from the ground test community in general. I think you will find this newsletter interesting, entertaining, and informative.

With the New Year comes new members. Our winter meetings are when we select new members to participate on our committee, and we rotate off the "experienced" members who have served their time – I mean term. We continually stress that our membership is the key to the success of the GTTC. Our folks are dedicated to strengthening and fostering the ground testing community, and they put in a lot of their own time to ensure the success of meeting the GTTC goals and objectives.

Aside from the normal tasks we do, like supporting conferences, recognizing outstanding achievements in ground testing, and, of course, publishing this newsletter, a large part of the GTTC efforts are dedicated to the working group activities. A highlight of this year is that the GTTC Standards Subcommittee, in conjunction with the CFD Committee on Standards, has labored over several years to prepare a proposed Editorial Policy Statement on both numerical and experimental accuracy. At the 2002 January meeting of the Editors-in-Chief (EICs), an Editorial Policy Statement on numerical accuracy was proposed. The EICs were in favor of improving the existing Publication Policy Statement and they liked the proposed statement on numerical accuracy that was presented. However, they recommended that a parallel statement on experimental accuracy should also appear in the journals. They requested that a proposed experimental accuracy statement be developed and, when complete, they should both be presented to the EICs. If the proposed statement, or some modified version of it, is ultimately approved by the EICs, it would replace the existing statement in all of the journals of the AIAA. We are on the agenda at this conference to do just that – look for the outcome in the next GTTC newsletter.

I hope you enjoy this issue of the GTTC newsletter. Please keep in mind that we are always looking for ways to make the GTTC more effective and increase its value to the aerospace ground testing community. I invite you to send any comments, suggestions, or ideas directly to me at nancy.swinford@lmco.com or by phone at 408-743-1443..

About the GTTC

The GTTC is one of over 60 technical committees sponsored by the American Institute of Aeronautics and Astronautics (AIAA). It is made up of about 35 professionals working in various areas of the ground testing world. Our membership addresses important technical issues that affect ground testing through several means, including the development of guides and standards, dissemination of information through technical sessions at conferences, and the development and sponsorship of short courses. The GTTC also participates in Congressional Visits Day, which is a vital tool for making sure that aeronautics and space-related research and testing is supported at required levels.

One of the primary functions of every technical committee is the sponsorship and development of conferences and technical sessions. The GTTC supports two conferences each year. Every January, the GTTC meets at the Aerospace Sciences Meeting, where we have a dozen or so technical sessions. In the summer, the GTTC alternates between the Joint Propulsion Conference (odd-numbered years) and the Advanced Measurement Technology and Ground Testing Conference (even-numbered years).

GTTC Working Group News

As part of the Aerodynamic Measurement Technology and Ground Testing Conference, an invited presentation session was conducted by the GTTC to provide an update and status report on working group activities. This marks the third such invited session to be held at an AMT/GT conference and is just one of the methods that the GTTC uses to share information with the ground testing community.

The session was organized and co-chaired by Allen Arrington (QSS Group, Inc. at NASA Glenn) and David Cahill (Aerospace Testing Alliance at AEDC). Six presentations were made covering recently completed working groups as well as working groups that are still developing products. The main goal of the session was to provide a general overview of each working group, including its origins, operation, objectives and products.

The presentations made and presenters are listed here:

- Calibration and Use of Internal Strain Gage Balances by David Cahill: This was the second working group started under the GTTC, and the first to complete its goal of publishing and AIAA standard, AIAA-R-091-2003: Calibration of Wind Tunnel Strain-Gage Balances.
- Wind Tunnel Test Management and execution by Mark Melanson (Lockheed Martin): The first of the GTTC working groups, Test Processes WG was a learning experience for everyone, but paved the way for each of the working groups that followed. This WG completed the second GTTC sponsored standards document, the two-volume AIAA-R-092-2003: Recommended Practice for Successful Wind Tunnel Testing; Part I, Management Guide and Part II, Practitioners Volume.
- Wind Tunnel Calibration and Flow Quality by Allen Arrington: The tunnel calibration working group used the lessons learned from the two previous WGs to get up to speed quickly and focus in on very specific goals. Their final product was AIAA-R-093-2003: Calibration of Subsonic and Transonic Wind Tunnels.
- Experimental Uncertainty by David Cahill: The experimental uncertainty work was carried out by the GTTC Standards Subcommittee. While not a technically a working group, the Standards Subcommittee does work closely with the working groups and has performed some of the same functions, such as publishing technical standards, the first being AIAA-S-071A-1999: Assessment of Wind Tunnel Data Uncertainty and more recently AIAA-G-045-2003: Guide for Assessing Experimental Uncertainty - Supplement to AIAA S-071A-1999
- Wind Tunnel Test Nomenclature by Guy Kemmerly (NASA Langley): One of the new set of working groups, Test Nomenclature is off to a fast start. The overall goal of this group is to establish an agreed upon set of parameter names that can be used in any wind tunnel test around the world.
- Thrust Stands Working Group Status by Ray Castner (NASA Glenn): This working group is taking a slightly different path than the others. While the membership is working on a AIAA recommended practice covering calibration and use of thrust stands in propulsion systems tests, they are also doing an excellent job of bringing the members of the ground test community that use thrust stands together through the use of invited technical sessions. This allows these technical experts to share ideas and methodologies relevant to thrust stands with the rest of the personnel in that area.

The slides from each of these presentations are available on the GTTC website: http://www.aiaa.org/tc/gt/gttchome.html. Once you hit the homepage, look down the left had margin table of content under “Handbook” and click “VII Working Groups”. The link to a zip file containing all six presentations is given just under the table that lists each working group.

One of the common themes from these presentations was the overall success of each of these working groups in bringing together the experts from around the country in each of these technical areas. Even if no documents were published, these working groups would have been considered success because they achieved their first priority which was the sharing of knowledge within the ground testing community. The WGs facilitated the experts in balance techniques, tunnel calibration, thrust stand usage, etc. to meet and openly exchange ideas in an environment that was built on trust and respect.

Since this was a GTTC event, we always have to try something different. This year, we offered a door prize at this session. A complete set of the AIAA Standards documents was presented to the winner of the random drawing. Frank Jackson (Aerospace Testing Alliance at AEDC) was the lucky winner of the documents.

As a follow-up to this session, it was suggested that a more technically focused overview of each of the published standards documents should be presented. Tentative plans are in the works to conduct such a session at the 2005 Joint Propulsion Conference in Tucson, AZ.

A complete set of the AIAA Standards documents was presented to Frank Jackson (Aerospace Testing Alliance at AEDC) a lucky winner !

GTTC Best Paper

The recipient of the GTTC best paper for 2003 was awarded at the 24th AIAA Aerodynamic Measurement and Ground Testing Conference in Portland, Oregon.

“Diode laser Absorption Diagnostics for Measurements in Practical Combustion Flow Fields” (AIAA-200304581) JTC Liu, JB Jeffries, and RK Hanson, Stanford University, S Creighton and JA Lovett, Pratt & Whitney, and DT Shouse, Air Force Research laboratory, WPAFB.

GTTC Outstanding Papers

The GTTC Awards Subcommittee has selected two papers from the 24th AIAA Aerodynamic Measurement and Ground Testing Conference in Portland, Oregon, June 2004 as recipients of the outstanding paper awards:

“A Hybrid Methodology to Evaluate the Effects of Trip Discs on Transonic Wind Tunnel Models,” (AIAA-2004-2613). K Mejia, JD Crouch, K Kusunose, R Melvin, Boeing Commercial Airplanes, Seattle, WA, and VS Kosorygin, AD Kosinov, Institute of Theoretical and Applied Mechanics, Novosibirsk, Russia.

“Automatic Image Registration for Optical Techniques in Aerodynamic Test Facilities,” (AIAA-2004-2400). W Ruyten, Aerospace Testing Alliance, Arnold Engineering Development Center, Arnold AFB, TN

GTTC Ground Testing Award

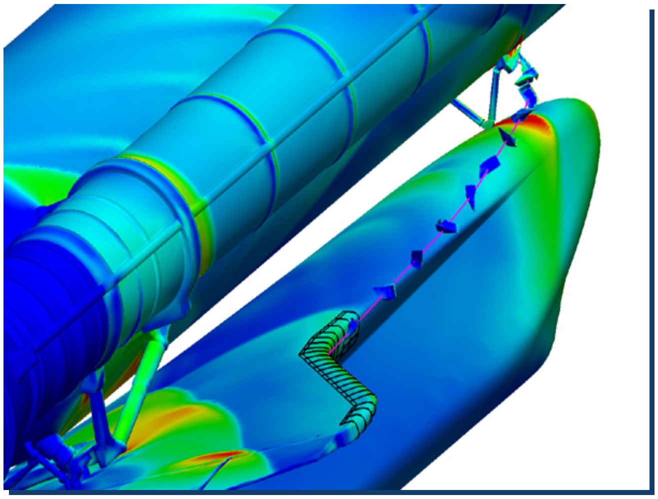
The Awards Subcommittee is accepting nominations for the Ground Testing Award. Established in 1975, this award is presented for outstanding achievement in the development or effective utilization of technology, procedures, facilities, or modeling techniques for flight simulation, propulsion or, aerodynamic testing. The award is presented in odd-numbered years at the AIAA/ASME/SAE/ASEE Joint Propulsion Conference, and in even-numbered years at the AIAA Aerospace Ground Testing Technical Conference.

At the 24th AIAA Aerodynamic Measurement Technology and Ground Testing Conference, Portland, Oregon The Ground Test Award recipients Dr. W. Glenn Steele, Jr., of Mississippi State University and Dr. Hugh W. Coleman of University of Alabama, Hunstville, “For their pioneering efforts in experimental uncertainty analysis with significant methodology advances and effective dissemination of knowledge through a straight-forward engineering approach in their text and short courses.”

Space Shuttle Test at Ames Supersonic Wind Tunnel

Norbert Ulbrich

The STS-107 Space Shuttle accident was attributed in part to debris from the bipod foam ramp impacting the Orbiter. As a result of this finding, the bipod attach structure of the orbiter is currently being redesigned in order to replace the previously used bipod foam ramps with electric heaters.



The figure shows the location of the bipod on the external tank of the orbiter.

It is expected that the redesigned bipod attach structure will change the air loads on the liquid oxygen (LOX) feed line and support brackets of the orbiter. Therefore, wind tunnel tests of a 3% scale model of the shuttle launch configuration were conducted in the Ames 9x7 Supersonic Wind Tunnel (SWT) in July 2004 in order to verify engineering model and CFD predicted air loads for the new bipod design.

Wind tunnel model of the orbiter installed in the NASA Ames 9x7 SWT

The wind tunnel model of the shuttle launch configuration was mounted on the Ames 9x7 SWT strut support system using a sting that Boeing supplied. The model had a length of 66 inches, a wingspan of 28 inches, and a reference area of 4.21 sq ft. The model was tested over a Mach number range from 1.5 to 2.5, a Reynolds number range from 2.0 to 5.0 millions/ft, a dynamic pressure range from 470 to 860 psf, an angle of attack range from -7deg to +7deg, a sideslip angle range from -8deg to +8deg, and a total pressure range from 800 to 2500 psf.

Overall, the wind tunnel model of the shuttle launch configuration is very complex. It has a total of six 6-component balances on the LOX and cable tray lines of the external tank, one 3-component wing balance, and on the order of 1500 surface pressure orifices.

During the wind tunnel tests air loads on the first segment of the LOX feed line were of primary interest. In addition, tests should also confirm that no adverse unsteady aerodynamic effects are introduced by the new bipod design.

Pressure Sensitive Paint (PSP) was applied during the test on the forward external tank, forward orbiter, and in the LOX/cable tray area in order to study surface pressures on the wind tunnel model in the vicinity of the new bipod design. Most of the required PSP equipment, i.e., lights, paints, and data acquisition system were supplied by Ames. Cameras for PSP measurements were provided by AEDC.

During the test close to 600 runs were completed. This included a total of 25 PSP runs. After completion of the successful test at the Ames 9x7 SWT the wind tunnel model of the Shuttle launch configuration was shipped to AEDC where similar tests in the transonic flight regime are planned.

Paraffin-Fuel Rocket Motor Tested at Stennis Space Center

HANCOCK COUNTY, Miss. – NASA Stennis Space Center (SSC) recently tested a rocket motor powered by fuel most people have in their homes: paraffin, the waxy material used in common candles.

In the past, paraffin was thought to be too weak and unstable to use as rocket fuel, but a research team at Stanford University in Palo Alto, Calif., found it to be twice as strong as conventional solid propellants. It also burns at a higher combustion rate, is safer, cheaper and very friendly to the environment, producing water vapor and carbon dioxide.

Lockheed Martin – Michoud Operations designed and fabricated the hybrid motor in collaboration with Space Propulsion Group Inc., which was formed by the Stanford team. The motor tested at SSC fired for the full planned duration and produced more than 5,000 pounds of thrust.

"The testing demonstrated that paraffin has a much higher regression rate when compared with HTPB (hydroxyl terminated polybutadiene). If the paraffin technology can be scaled up to even larger sizes this higher regression rate has the potential for improved hybrid propulsion performance. We will be looking at paraffin fueled hybrids for future applications," said Tim Knowles, Lockheed Martin's principal investigator for hybrid rocket motors.

The paraffin motor test at SSC was the last of four tests conducted as part of the Hybrid Technology Test Project.

Hybrid motors combine solid and liquid materials. An oxidizer such as oxygen is generally used with all rocket fuels to aid burning. Conventional rocket fuels are either solids, like what is used in the Space Shuttle boosters, or liquids, like what is used in the Space Shuttle Main Engine. Hybrid motors are not new, they have been in development for about 50 years, but have not produced enough thrust to power heavy space launch vehicles. Paraffin shows promise because tests at Stanford and at NASA Ames Research Center have shown it burns at a rate three times greater than other hybrid fuels.

In hybrid motors, liquid oxygen is gasified before injection into the motor's combustion chamber containing the solid fuel. When the oxygen ignites, it flows over the fuel surface to produce sustained combustion.

The Stanford researchers found that paraffin burns faster because as the oxygen gas blows across the melted surface, waves form and are pulled off as a spray of droplets. That spray burns very rapidly, increasing the fuel's combustion rate.

News releases provided by NASA's Stennis Space Center are available at www.ssc.nasa.gov/~pao/news/newsreleases/2004.

Paraffin-Fuel Rocket Motor Tested at Stennis Space Center

NASA Grows Ice for Space Shuttle Tests

HANCOCK COUNTY, Miss. –NASA is simulating conditions typical of Space Shuttle launch days to see what kinds of ice and frost form on the foam insulation of the super-cooled External Tank.

Engineers are trying to understand better how much ice can safely accumulate on the tank without becoming a debris hazard. The tests are under way at NASA's Stennis Space Center, Miss. Because debris from the Space Shuttle Columbia's External Tank led to the loss of the orbiter, NASA initiated an effort to determine sources of debris that could impact the Shuttle orbiters and cause critical damage. Data from all the tests at Stennis will be used in that analysis and, in turn, will also be used in making launch day decisions, beginning with next year's Return to Flight mission, STS-114.

During preparations for Space Shuttle launches ice and frost can form depending on weather conditions on the External Tank during pre-launch cryogenic loading. That's when the Shuttle's super-cold liquid hydrogen fuel flows from the External Tank through the three Space Shuttle Main Engines. To simulate those conditions, engineers at Stennis mount four 2-foot-by-2-foot panels on a metal frame, then freeze them with liquid helium or liquid nitrogen over an 8-hour period.

The experiment is being conducted in a facility that was specially constructed for the tests. Just three weeks before foam tests panels were delivered Oct. 27, the facility was an empty parking lot. An 8-foot-by-40-foot moveable building was relocated to the site and then modified to accommodate equipment to control the temperature and humidity and to monitor the tests.

Lockheed Martin Space Systems Co. (LMSSC), Michoud Operations is providing the panels and monitoring the tests to determine whether ice and frost formations created during the test are visually similar to those seen on the External Tank before a launch.

The dimensions, hardness, quality (consistency and uniformity) and density will be recorded. Nine sensors attached to the back of each panel send data to a control center where LMSSC personnel monitor.

"This is one series of many tests that are being performed throughout the country to ready the External Tank for a safe Return to Flight. Facilities at NASA centers like Stennis, as well as many Defense Department and university facilities are being utilized to obtain timely and cost effective results," said Sandy Coleman, External Tank project manager at NASA's Marshall Space Flight Center, Huntsville, Ala. Ice and frost samples of sufficient size (2 inches by 2 inches by 4 inches) will be shipped to Dr. Erland Schulson at Dartmouth College's Thayer School of Engineering in Hanover, N.H., for testing and analysis. Schulson directs the Ice Research Laboratory, which performs research on the physics and mechanics of ice.

"This is a data-gathering exercise," External Tank Foam Test Project Manager Gary Benton said. "We're trying to replicate launch pad conditions." Video of the testing and interview sound bites will be available on the NASA TV Video File. NASA TV is available on the Web and via satellite in the continental U.S. on AMC-6, Transponder 9C, C-Band, at 72 degrees west longitude. The frequency is 3880.0 MHz. Polarization is vertical, and audio is monaural at 6.80 MHz. In Alaska and Hawaii, NASA TV is available on AMC-7, Transponder 18C, C-Band, at 137 degrees west longitude. The frequency is 4060.0 MHz. Polarization is vertical, and audio is monaural at 6.80 MHz.

News releases provided by NASA's Stennis Space Center are available at www.ssc.nasa.gov/~pao/news/newsreleases/2004.

NASA Grows Ice for Space Shuttle Tests

Boeing Propulsion System Nails Critical Defense System Tests

John Mitchell

ST. LOUIS, November 16, 2004 - A new propulsion system built by The Rocketdyne Propulsion & Power business unit of the Integrated Defense Systems of The Boeing Company has demonstrated its unique capabilities. Called a DACS for divert and attitude and control system this propulsion system will provide maneuvering capabilities for the Missile Defense Agency's Terminal High Altitude Area Defense (THAAD) ballistic missile defense system, for which Lockheed Martin Corporation is prime contractor.

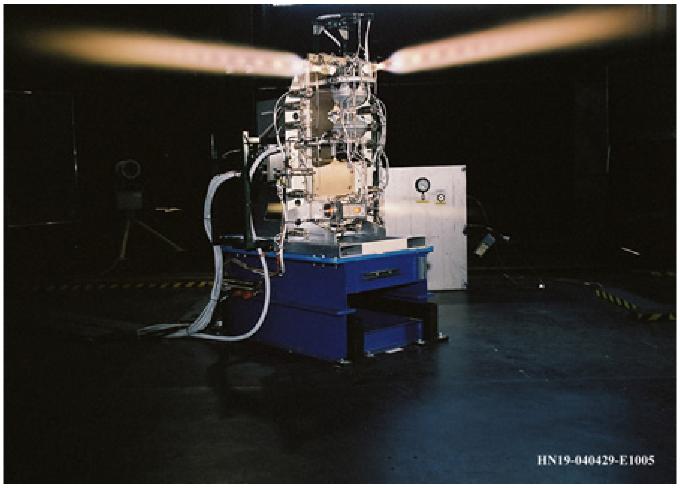
In mid-July, and again in late August of this year, the DACS successfully completed two demanding hot-fire performance trials called the System Flight Certification Unit - or SFCU - tests. The tests were conducted in cold temperatures and vacuum conditions for a full "mission" simulation, with over 2000 thruster pulses and 70-plus firing sequences, confirming compliance with all Block 4 THAAD requirements.

"This recent success underscores Boeing's leadership in liquid-fueled thruster systems, and is the latest milestone in a capability that goes back for more than three decades," said Byron Wood, vice president and general manager of Rocketdyne Propulsion & Power. "The tests demonstrate the kind of performance and reliability we can - and do - achieve."

The summer test series follows successful testing of the individual liquid-fueled rocket thrusters, as well as a successful hot-fire design verification test of the entire DACS, which emulated a typical enemy missile intercept mission. Those tests were conducted at the Air Force Research Laboratory at Edwards Air Force Base, Calif.

Detailed post-test analysis of the SFCU data is in progress and expected to demonstrate that the DACS design is in full compliance with its specified system level requirements. The completion of these tests is a significant milestone on the path to flight testing the THAAD weapon system.

THAAD is a critical element of the Missile Defense Agency's Ballistic Missile Defense System and is designed to intercept incoming ballistic missiles at very high altitudes, far away from the critical military and civilian assets it is intended to protect.



Boeing's new propulsion system tested for THAAD

Boeing to Begin Testing of Experimental Rocket Engine

John Mitchell

ST. LOUIS, November 18, 2004 - With an eye toward revolutionary new rocket engine systems, engineers from The Rocketdyne Propulsion & Power business unit of the Integrated Defense Systems of The Boeing Company have begun final preparations for testing a futuristic engine at the Stennis Space Center (SSC) in Mississippi. The engine, dubbed the Integrated Powerhead Demonstration, or IPD, combines the very latest in rocket engine propulsion technologies. Following system checkout, an ambitious "hot-fire" testing program will begin in earnest in this January.

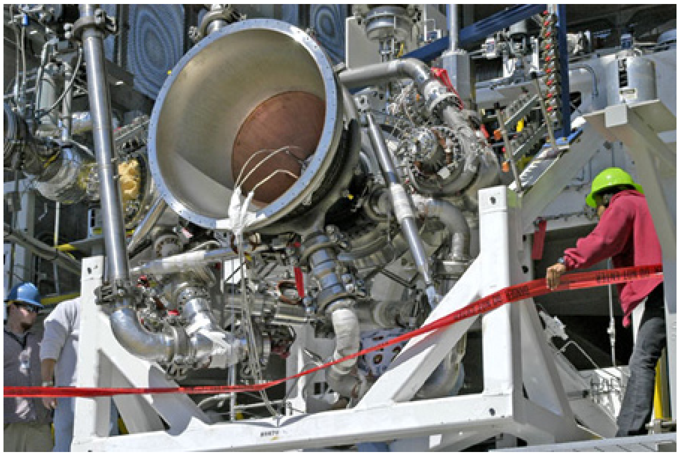
The IPD has been developed and built over the last ten years through the combined efforts of Rocketdyne and GenCorp's Aerojet, and under the direction of the Air Force Research Laboratory (AFRL) and NASA's Marshall Space Flight Center (MSFC). Its technologies are directed at achieving the goals of the Integrated High Payoff Rocket Propulsion Technology, or IHPRPT, program.

"Our intent is to validate new propulsion technologies that can be used in a new generation of rocket engines," said Don McAlister, Boeing IPD program manager. "The IPD itself will not be flown, but its components and systems could find their way into future rocket engines. These technologies may be especially valuable for the Vision for Space Exploration."

Added Rocketdyne vice president & general manager Byron Wood, "IPD is a critical program that fully demonstrates how NASA, the Air Force and industry can work together. That's something that will be very important as this country's leadership in space continues."

Capable of generating about 250,000 pounds of thrust, the IPD ranks as a booster-class engine and is the first full-flow, staged-combustion engine produced in the U.S. It has been designed as a re-usable engine system, and features hydrostatic bearings – already being implemented in the Boeing/Mitsubishi Heavy Industries MB-XX engine – as well as exotic new materials.

Rocketdyne provides the turbopumps, thrust chamber assembly and system components, and serves as the lead system integrator, while Aerojet is responsible for all preburner and nozzle work. Program management is handled by AFRL, with support from MSFC.



Boeing's Integrated Powerhead Demonstrator, IPD

Stennis Space Center Helps NASA Return to Flight

HANCOCK COUNTY, Miss. – Engineers at NASA's Stennis Space Center (SSC) in Mississippi have tested the Space Shuttle Main Engines (SSMEs) that will carry the next Space Shuttle into orbit. The test July 16th, 2004 was the first complete SSME that will be used on the Return to Flight mission The engine also tested Aug. 19, 2004. The SSMEs will be shipped to NASA's Kennedy Space Center in Cape Canaveral, Fla., for installation on Space Shuttle Discovery, readying it for STS-114 mission that is headed to the International Space Station.

Designated as the Shuttle's Return-to-Flight mission, STS-114 is expected to launch no earlier than next spring. The tests ran for 520 seconds, the length of time it takes a Space Shuttle to reach orbit. Initial indications are all test objectives were successfully met.

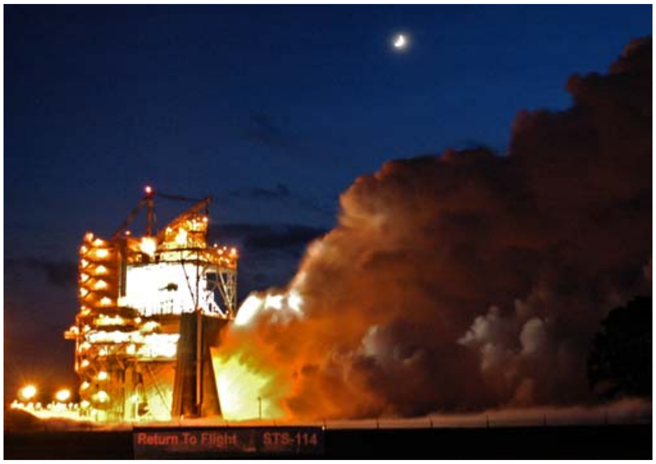
"Our NASA and contractor team has continued to work hard over the past year and a half to make sure this incredible piece of machinery maintains its impeccable safety record," said Miguel Rodriguez, director of the Propulsion Test Directorate at SSC. "All the effort will pay off when we see the Space Shuttle Discovery lift off next spring. To know we had such a big part in returning the orbiter to flight will be a great reward. We are all very proud.

"Engineers conduct rigorous testing to verify that an engine is ready to fly. Developed in the 1970s, the Space Shuttle Main Engine is the world's most advanced liquid-fueled rocket engine ever built and the first reusable one.

Temperatures inside the engines reach 6,000 degrees Fahrenheit -- hot enough to melt iron -- and the pressure mounts to as high as 6,000 pounds per square inch. During the eight-and-a-half minutes the Shuttle's three Main Engines burn, they produce energy equivalent to 23 Hoover Dams - about 37 million horsepower. Each engine is 14 feet long, weighs about 7,000 pounds and is seven-and-a-half feet in diameter at the end of its nozzle. It generates almost 400,000 pounds of thrust. "The successful completion of this test is a significant milestone in our efforts to return the Space Shuttle safely to flight," said Gene Goldman, manager of the Space Shuttle Main Engine Project Office at NASA's Marshall Space Flight Center in Huntsville, Ala.

"There has been a tremendous effort by the team at Stennis, both civil servant and contractor, to ready the engines for flight. Their diligent attention to detail is critical to the safe and reliable performance of the engines. The Rocketdyne Propulsion and Power division of The Boeing Co. of Canoga Park, Calif., manufactures the Shuttle's Main Engines. Pratt and Whitney, a United Technologies Company of West Palm Beach, Fla., builds the high-pressure turbopumps. NASA's Space Shuttle Main Engine Project Office administers the main engine program. SSC conducts engine tests.

News releases provided by NASA's Stennis Space Center are available at www.ssc.nasa.gov/~pao/news/newsreleases/2004.



Space Shuttle Main Engine Test July and Aug 2004

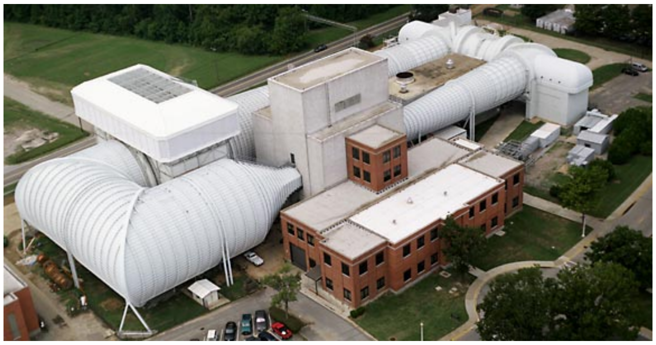
Historic Tunnel's Final Test

Marny Skora
Bill Uher

After 63 years of research across the entire flight range, NASA Langley Research Center's 16-Ft. Transonic Wind Tunnel is running its final test. This test, a NASA-Air Force-Boeing cooperative study of a single-engine test demonstrator launch configuration, underscores the tunnel's legacy: research from propeller-driven aircraft through scramjets.

Retiring the tunnel is part of a national initiative to optimize government-owned wind tunnels. A NASA-Department of Defense alliance studying investment planning in wind tunnel assets recommended the shutdown in 2002.

Since November 1941, the tunnel has supported Agency initiatives, all major aircraft companies and most major military programs in their development stages and in ongoing propulsion integration research. Its heritage reads like a "Who's Who" of famous aircraft and spacecraft: Corsair, Bell X-1, Buffalo, Thunderbolt, Hustler, Aardvark, Eagle, Hornet, Harrier, Galaxy, X-15, Apollo, Reusable Launch Vehicle, Shuttle, Tomcat, B-1, B-2, X-43, to name a few. The 16-Ft. tunnel tested everything from high-speed propellers to the shapes of the first atomic weapons to today's scramjet-powered vehicles.



NASA LaRC’s 16 ft Tunnel

Single-engine test demonstrator launch configuration.

Aiolos Test Facilities News

http://www.aiolos.com/news/news_latestnews.asp

Automobile development at Kia has already benefited from state-of-the-art test facilities, now that Kia is a member of the Hyundai Motor family. Aiolos-built wind tunnels, including the Hyundai Aeroacoustic wind tunnel operational in 1998, have been highlighted in marketing articles.

Aiolos announces the award of a 4-year contract with Boeing Integrated Defense Systems to design and supply an Aircraft Environmental Test Facility (ETF) for the Agency of Defense Development of South Korea. This facility will provide precise simulation of extreme climatic conditions, including Arctic cold, desert heat, solar radiation, rain, wind, and snow. Aiolos has previously supplied Boeing with engineering services, in support of the wind tunnel in Austria and the Hyundai Motor Snow & Rain climatic wind tunnel in Korea.

Modern Design of Experiments Used to Calibrate Wind Tunnels at NASA Langley Research Center

Matthew N. Rhode
Richard DeLoach

Wind tunnel calibrations tend to occur relatively infrequently, largely because calibrations must compete with production or research testing for finite resources. A resource-minimal calibration strategy is sought that will facilitate more frequent calibrations. One such strategy exploits the efficiencies that can be achieved through a calibration procedure that relies on formal experiment design principles. Such principles have been incorporated into a unified experiment design, execution, and analysis process at Langley Research Center, under the name of Modern Design of Experiments (MDOE). MDOE methods have been applied in numerous wind tunnel tests and also in experiments in a wide array of laboratory settings, with typical resource savings of a factor of two or more. These methods are being applied to design a calibration of the 20-Inch Mach 6 Tunnel at NASA Langley, following the recent successful calibration of the Mach 10 Tunnel using this approach.

MDOE is particularly well-suited for calibration activities because of its relatively small test matrices and its focus on both quality assurance and quality assessment. In the Mach 6 tunnel calibration, for example, both spatial and temporal randomization, as well as blocking and replication (standard MDOE quality assurance tactics) are being used to minimize unexplained variance. Sufficient residual degrees of freedom are specified to drive uncertainty below target levels that were established before the calibration began, assuring a calibration that meets quality standards with the expenditure of minimum resources. The magnitude of the unexplained variance is monitored throughout any MDOE experiment, and additional data points are specified in real time if quality goals are not being met.

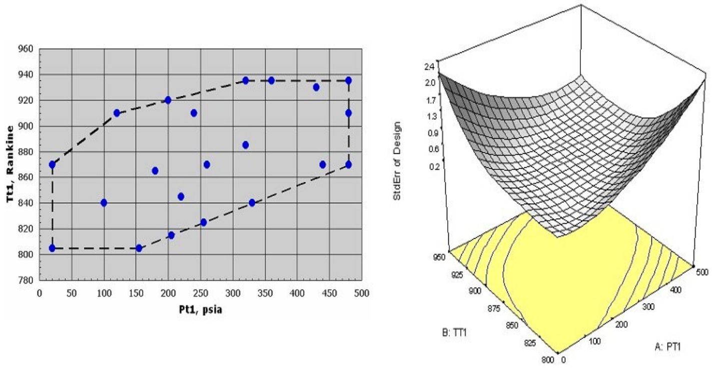
The left side of the figure below shows pressure/temperature combinations that minimize prediction errors in a regression model fitting the data acquired during the calibration. These points are acquired at different levels of a third calibration variable, streamwise displacement in the test section. Some of them are replicated, to provide a direct measure of data variability. Certain combinations of high temperature and low pressure, or low temperature and high pressure, cannot be set due to tunnel operating restrictions. The dashed line encloses permissible temperature/pressure set-point combinations. The MDOE design process selects set points consistent with these restrictions.

Note that these points do not correspond to the orderly rectilinear array of variable levels that is common in conventional experiment designs. This is because a rectilinear array generally will not produce fitted regression models with the smallest and most uniformly distributed prediction errors, especially over irregular regions such as in the figure.

The right side of the figure shows the distribution of standard calibration errors for the points on the left. These are regression prediction errors for all temperature/pressure combinations at a fixed streamwise displacement in units of "sigma", the standard deviation in replicated response measurements. Note that these errors are generally low and uniform over permissible temperature/pressure set-point combinations. Significant increases in prediction error in two of the corners reflect the fact that the design specifies no set-points in these forbidden regions. Response predictions for points that might have been acquired in these regions will therefore be relatively uncertain. Within permissible temperature/pressure regions, however, prediction standard errors are generally less than one standard deviation, reflecting the fact that more points are specified than are necessary to fit a particular response model.

Only 10 degrees of freedom are required to fit the calibration equation in this case, but 32 data points are specified (the unique points in the figure plus replicates of a subset of them.) The fact that there are 22 residual degrees of freedom – over twice the minimum number required to fit the model – accounts for the relatively low prediction errors. Twelve additional confirmation points are included in the design for further quality assessment purposes, so that the entire calibration features only 44 points. This is a relatively compact test matrix by conventional wind tunnel test standards, but it is more than ample to meet calibration quality objectives established in the pre-test planning.

The same MDOE methods have reduced force balance calibration times at Langley from about four weeks to about 3 days, with substantial reductions in calibration uncertainty over conventional calibration methods used previously. The combination of high quality and low cost may now make it practical to conduct wind tunnel calibrations on a relatively more frequent and regular basis.



20-Inch Mach-6 Tunnel Calibration. Left: Temperature/pressure set-points for 2nd-order D-optimal design with inference subspace restrictions. Right: Corresponding distribution of standard errors in the calibration equation.

NASA GRC Full Annulus Test

The goal of the Full Annulus Test in the Low Speed Axial Compressor Facility (LSAC) was to perform a series of active flow control experiments on the first stage stator to be used to develop technologies needed to implement a future intelligent engine research program. Specific objectives included assessing the impact of injection on flow turning, assessing the ability to manage 3-D aerodynamic blockage field using steady injection on stator suction side and demonstrating closed-loop feedback control of blade row suction-side separation at mid-span in full-annulus configuration.

NASA GRC Full Annulus

Though a stereolythography process, flow control blades were made of DuraForm polyamide material to have hollow internals allowing for air injection into the rig from the blade surface. 42 of 52 first stage stator blades of the compressor were replaced with these flow control blades as pictured above. Air was routed to the LSAC via two manifolds with ports configured to deliver air to 21 blades each. Tubing was routed from each manifold port, over and under various casing obstructions, to the corresponding blade and mounted with Swagelok fittings and custom blade caps.

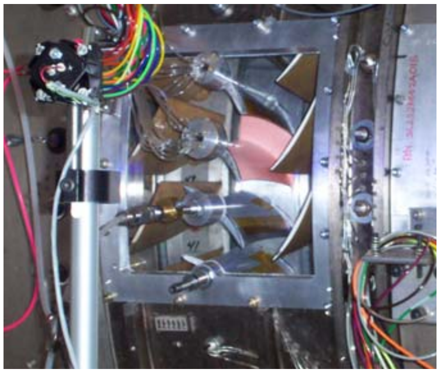
Major accomplishments of the Full Annulus Test include demonstrating increased static pressure rise capability in the 1st stage using closed-loop feedback control and completing testing of two increased blade loading configurations (-3 and -4 degree stagger angles) with flow injection of 1.0%, 0.9%, 0.74%, 0.56% and 0% of compressor through-flow.

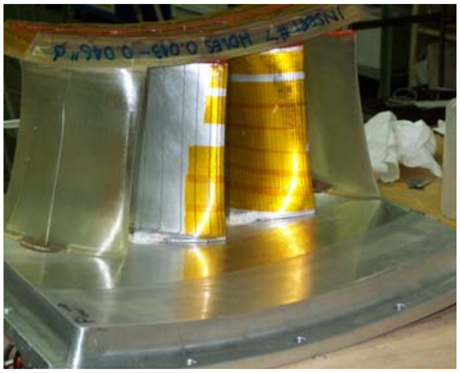
NASA GRC Hub Blowing Experiment

The objective of the Hub Blowing Experiment in the Low Speed Axial Compressor Facility was to investigate the impact of steady blowing on aerodynamic blockage and loss production in a stator passage.

NASA GRC Hub Blowing Experiment

The third stage stator sector of the LSAC was designated as the testing area due to its accessibility via a window access port. At the window access port, the stator ring contains a cavity which accepts inserts that can be designed with various hole/slot surface patterns. One of the four blades installed in the insert is used to feed air into the footring insert which exits through the surface pattern. A variety of hub blowing inserts were fabricated out of aluminum, DuraForm polyamide (SLA process) and Accura SI-40 resin (SLA process).





A variety of hub blowing inserts

The major accomplishments of the testing included establishing a 7% corrected loss reduction with the injected air at 0.82% of the through-flow rate, completing testing of nine hub blowing configurations and designing and developing hub units with an integral blade to eliminate air leakage.

Advancements in Flow Diagnostics at AEDC Tunnel 9

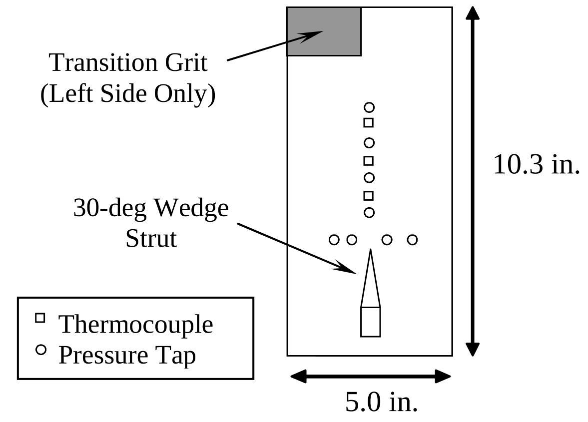
AEDC Hypervelocity Wind Tunnel 9 is currently developing a wide variety of flow diagnostic tools for testing. These measurement techniques include advances in flow visualization, non-intrusive diagnostics and global surface measurements. The application of these advanced techniques in a large hypersonic T&E facility has traditionally caused significant difficulty. The staff at Tunnel 9 has recently improved or applied the following measurement capabilities; Temperature Sensitive Paints (TSP), Coherent Anti-Stokes Raman Spectroscopy (CARS), and high-speed Schlieren Photography. Each of these techniques provides a new “window” to the hypersonic flow in Tunnel 9 by providing data that was previously unattainable.

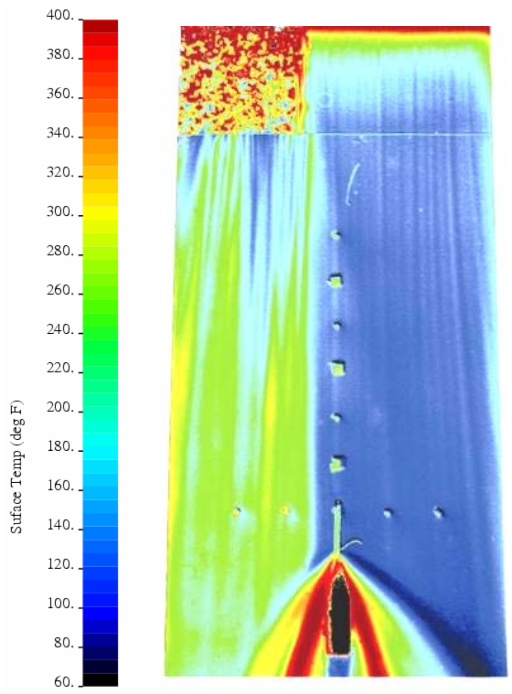
Temperature-Sensitive Paint System Development

AEDC Hypervelocity Wind Tunnel 9 is currently developing a temperature-sensitive paint (TSP) measurement system to acquire global heat transfer measurements on the surface of a test article. The requirements placed on such a system (high-quality data, acquisition of data on a pitching model, data rates on the order of milliseconds), coupled with the unique testing environment in Tunnel 9 (high temperature and heating rates, non-oxygen medium), exceed the capabilities of typical existing TSP systems. Feasibility tests were performed that assessed the potential of adapting a TSP system for meeting these requirements. In one such test, the surface temperature on a 16.75-deg inclined flat plate was measured in Tunnel 9 using a new 400 deg F TSP formulation. Higher temperatures are observed on the left side of the wedge where transition grit was applied and caused the boundary-layer to trip from a laminar to turbulent state. High temperatures are also observed on the rear of the plate due to the strut induced shock wave/boundary-layer interaction.

Successes of these tests include paint survivability under exposure to extreme conditions and the ability to globally map complex flow features such as shock wave/boundary-layer interactions, laminar and turbulent boundary-layer heating, and vortex footprints. The results of these studies have prompted further efforts toward developing a production-grade TSP system. Future development efforts will include developing a non-oxygen pressure-sensitive paint system for use in Tunnel 9’s nitrogen environment.

Reference: Norris, J. D., *et al*, “Adapting Temperature-Sensitive Paint Technology for use in AEDC Hypervelocity Wind Tunnel 9,” AIAA Paper 2004-2191, 24th AIAA Aerodynamic Measurement Technology and Ground Testing Conference, Portland, OR, 28 June – 1 July 2004.

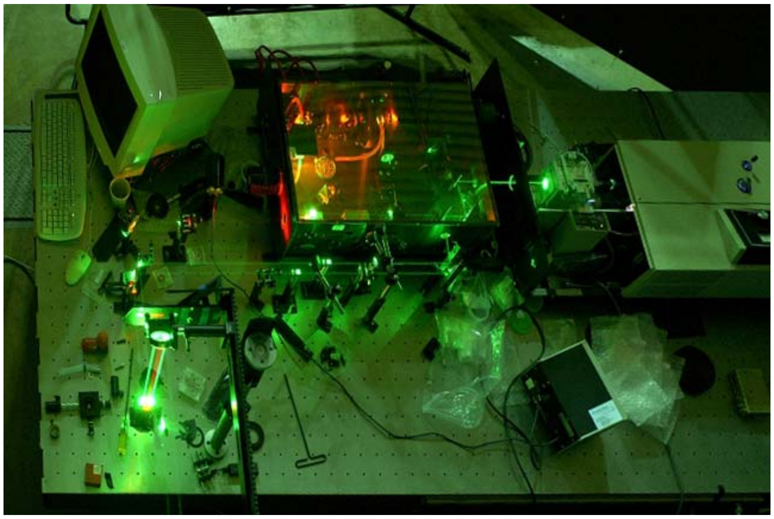




The 16.75-deg inclined flat plate TSP test article geometry. A TSP image acquired at Mach 14, unit Reynolds number = 1.3×10^6 /ft .

CARS Measurements

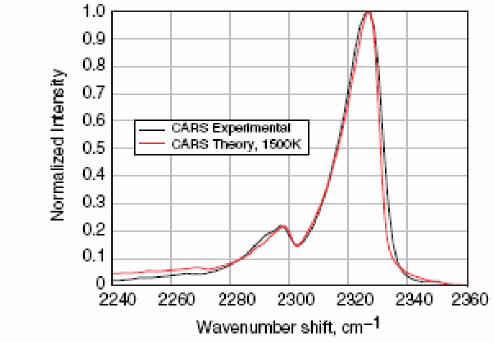
In order to validate the absence of thermal nonequilibrium in the Tunnel 9 facility, broadband Coherent Anti-Stokes Raman Spectroscopy (CARS) measurements were made during Mach 10 (0.5×10^6 Re/ft and 1.1×10^6 Re/ft) and Mach 14 (1.1×10^6 Re/ft, 0.5×10^5 Re/ft, and 0.1E6 Re/ft) runs. The CARS technique was selected because of its coherent behavior and its extremely strong signal intensity as compared to other methods. Two pump beams from a frequency-doubled Nd:YAG laser (532 nm) and the broadband output from a dye laser (607 nm) were focused to a common point resulting in the generation of a CARS beam (473 nm) which varies quadratically with density and linearly with temperature.

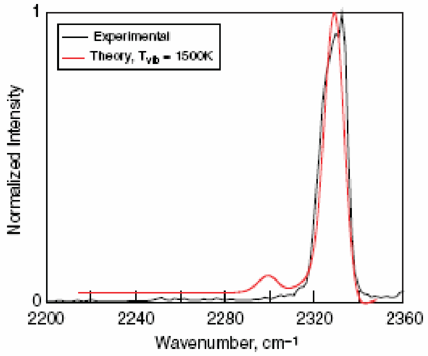


CARS System Layout

Shown below is an overlay of an experimental CARS flame spectrum and a theoretical prediction illustrating the resolution and sensitivity of the system. Also shown is a sample Mach 14, 1.1×10^6 Re/ft CARS spectrum overlayed with theory. Examination of the data collected during all tunnel runs showed no evidence of thermal nonequilibrium since only one peak is present in the experimental spectra.

Reference: Smith, M. S. and Coblish, J. J., "Measurements to Assess the Degree of Thermal Nonequilibrium at AEDC Hypervelocity Wind Tunnel No. 9," AIAA Paper 2004-2399, 24th AIAA Aerodynamic Measurement Technology and Ground Testing Conference, Portland, OR, 28 June – 1 July 2004.



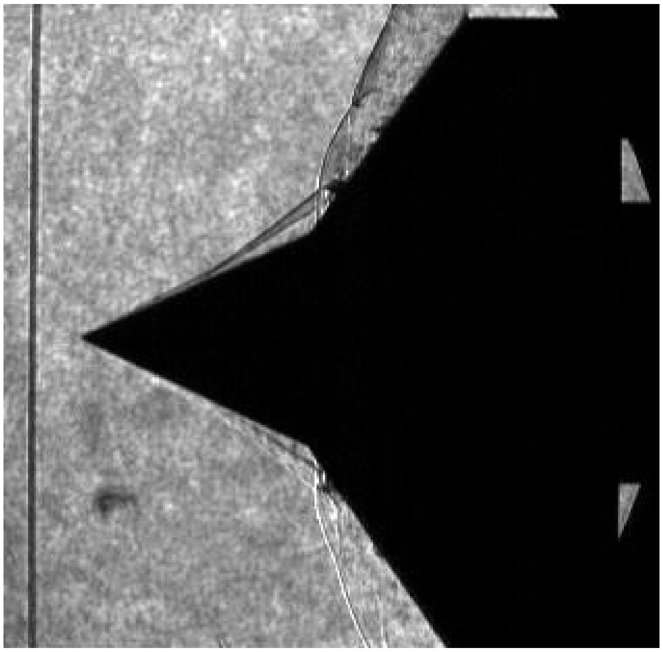


Thermal nonequilibrium is present in the combustion byproducts of the laboratory flame as indicated by the dual peaks in the CARS Spectra, and not observed in CARS spectra of the Tunnel 9 freestream at Mach 14.

High-Speed Schlieren Development

AEDC has recently upgraded the primary flowfield optical visualization system for Tunnel 9. This is a single-pass system with parabolic primary mirrors, each with 175 inch focal length and 36 inch diameter. The recent upgrade has replaced the standard low rate spark light source, the analog video camera and the high speed film camera. The new light source is a fiber-optic coupled Oxford Lasers Model LS20-50 copper vapor laser with a pulse width of approximately 25 nanoseconds and total pulse energy of 2 mJ with 60% of the energy at 510.6 nm and 40% of the energy at 578.2 nm. The laser produces pulses at repetition rates of 10 – 50 kHz. Detection of the flowfield image is accomplished with a new Redlake Model HG-100K high-speed 10-bit-dynamic range CCD camera with spatial resolution of 1504 pixels x 1128 pixels at 1000 frames per second and 416 pixels x 312 pixels spatial resolution at 10,000 frames per second. The copper vapor laser light source is externally triggered via a synchronization pulse from the camera’s electronic shutter circuit. The combination of the copper vapor laser and high-speed CCD camera system produces near-instantaneous Schlieren images as well as allowing for flow visualization to the minimum Reynolds numbers and densities in Tunnel 9.

The system was implemented in May of 2004. High-speed Schlieren images were collected during a test of a 25/55-degree double cone geometry at 10000 frames per second at Mach 14, low and high Reynolds number test conditions. The high-speed Schlieren video captured a highly unsteady shock wave boundary layer interaction flowfield surrounding the test article. A sample image from this test is shown below.



The high-speed Schlieren of 25/55-degree double cone geometry at 10000 frames per second at Mach 14

Reference: Coblish, J. J., *et al*, “Double-Cone Experiment and Numerical Analysis at the AEDC Hypervelocity Wind Tunnel No. 9” AIAA Paper 2005-0902, 43rd AIAA Aerospace Sciences Meeting, Reno, NV, 10– 13 Jan. 2005.

Portland Golf Outing

What's a summer conference without a golf outing? Well, the GTTC is not willing to find out, as we had let another hack-fest following the AMT/GT conference in Portland. While we did not have a huge turn-out, we certainly had a lot of fun. There were only six duffers from the GTTC on the course this year, as some of the normally faithful players skipped the event, claiming they actually had work to do (and all these years I've been making up lame excuses to get out of work to go play golf).

Through internet searching and a bit of dumb luck, we found a great course very near to the conference site. Broadmoor (6156 yard par 72 from the white tees) was a great track and in very good condition, at least it was before we started playing. If you are ever in Portland and are looking for a well-maintained, pretty and user friendly golf course (and reasonably priced), then this is a good place to go.

We split into two teams and played some silly game that required a calculator and 6 engineers to figure out (unfortunately, all we had were the six engineers). First off the tee was Team Hack, captained by GTTC chair Nancy Swinford, along with John Lafferty and Tim Bressler. Their strategy seemed to be "anyone can play from the fairway, but it takes real talent to play from the trees". Team Yank, comprised of captain Jeff Haas, Allen Arrington and Dave Minto, worked more to the theme of "why hit one putt when three will do".
Haas led the field with a 82 (net 68 for that sandbagger); everyone else was in the 90's, except for Ms Swinford, who won the lowest cost per stroke award. Highlights were the birdies collected by Arrington and Haas (or would those be ducks, since we were in Oregon).

Team Hack rode a pile of handicap strokes to victory over Team Yank in the net team score game (without strokes, the lower handicap players of Team Yank eeked out a narrow win). But winning and loosing is not the point; everyone had a good time playing a little golf and visiting with their GTTC compatriots.

GTTC golfers (L to R): Allen Arrington, John Lafferty, Jeff Haas, David Minto, Tim Bressler and Nancy Swinford.

"No, the other left!"

Best Wishes to Old Members! Welcome (back) New Members!

GTTC new members (L to R): Rich Danforth, Dan Gramer, Mark Melanson, Norbert Ulrich, Andy Garrell, Sebastiano Caristia, Pete Wilcox, and Bob Keener.

GTTC Leadership

At the Jan 2004 Allen Arrington of QSS Group, Inc., at NASA GRC, handed the gavel to the incoming chair Nancy Swinford of Lockheed Martin.

Calendar of Events

2005

March	Congressional Visits Day
April 15	Nominations due to AIAA for Associate Fellow
May	Abstracts due for ASM conference
May 15	Input due for GTTC newsletter
July 10-13	41st Joint Propulsion Conference in Tucson, AZ
Aug. 1	Input due for Aerospace America Highlight December issue.
Oct. 1	Nominations due for AIAA Ground Testing Award
Nov. 1	Nominations due to AIAA for TC membership
Nov. 15	Input due for AIAA GTTC Newsletter
Nov.	Abstract due for AMT and Ground Testing Conference
Dec. 1	Aerospace America Highlights issue

2006

Jan. 9-12	44th AIAA Aerospace Sciences Meeting and Exhibit; Reno, Nevada
March	Congressional Visits Day
April 1	Input Due for AIAA GTTC Newsletter
April 15	Nominations due to AIAA for Associate Fellow
May	Abstracts due for ASM conference
Summer	AIAA Aerodynamic Measurement Technology and Ground Testing Conference
Aug. 1	Input due for Aerospace America Highlight December issue.
Oct. 1	Nominations due for AIAA Ground Testing Award
Nov. 1	Nominations due to AIAA for TC membership
Nov. 1	Input due for AIAA GTTC Newsletter
Dec. 1	Aerospace America Highlights issue

2007

Jan. 10-13	45th AIAA Aerospace Sciences Meeting and Exhibit; Reno, Nevada

2006

Jan. 9-12	44th AIAA Aerospace Sciences Meeting and Exhibit; Reno, Nevada

GTTC Membership

GTTC Officers

Chairman
Nancy Swinford

Vice Chairman

Secretary
Phil Stitch

Aerodynamics Subcommittee
Greg Addinton
John Magill

Propulsion Subcommittee
Jeff Haas

Awards Subcommittee
Ray Castner

Conferences Subcommittee
Jeff Haas

Membership Subcommittee

Publications Subcommittee
John Hamm

Standards Subcommittee
Dick DeLoach

Steering Committee
Nancy Swinford

Student Activities Subcommittee
Ray Castner

International Liaisons Subcommittee
John Edwards
James Buzzell

Technical Working Groups

Flow Quality Working Group
Mark Kammeyer

Test Nomenclature Working Group
David Cahill

Thrust Stand Working Group
Ray Castner

Dynamic Testing Working Group
John Magill

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Request for Membership Information

The purpose of the Ground Testing Technical Committee (GTTC) is to advance the state of the art and technologies associated with ground testing and ground testing facilities. The scope of the committee's interests includes duplication and simulation of aerodynamic and aerospace flight environments for the testing of aerospace systems, subsystems, and components. The ground test facilities of interest include wind and shock tunnels, ballistic and high-speed test track ranges, space environment facilities, and aero propulsion test facilities.

The GTTC is composed of over 40 AIAA professionals from commercial, government, and academic sectors representing the technical spectrum for state-of-the-art ground testing of aerodynamic, propulsion, and space systems. The Committee continually seeks members from all parts of the ground testing community.

The membership term on the GTTC is 4 years with approximately 25 percent of the membership rotating off each year. Prospective members should be willing to make a commitment to GTTC activities and attend the semiannual GTTC meetings. If you are interested in receiving further information concerning membership in the GTTC, please fill out the form below and mail to

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Title: ____
Company:
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Phone: ______________________
E–mail: ______________________________
Professional responsibility: ______________________________
Years experience: ________
Professional membership: AIAA _____ SAE _____ ASME _____ ITEA _____ Other ______________
Educational background (degree, discipline, year): ______________________________
Prior service on AIAA Technical Committees: ________________ Name ______________
Prior experience organizing conferences, sessions, short courses: ______________________
Area of interest: Aerodynamics ________ Aero propulsion ________ Space systems ________
Does your company currently support other AIAA Technical Committees? ____________________
Other Comments: ____