PROPULSION DIRECTORATE

Monthly Accomplishment Report
June 2001

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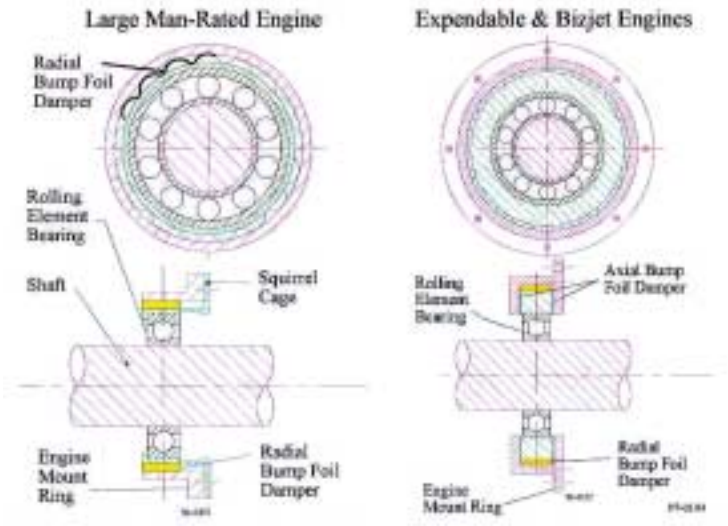
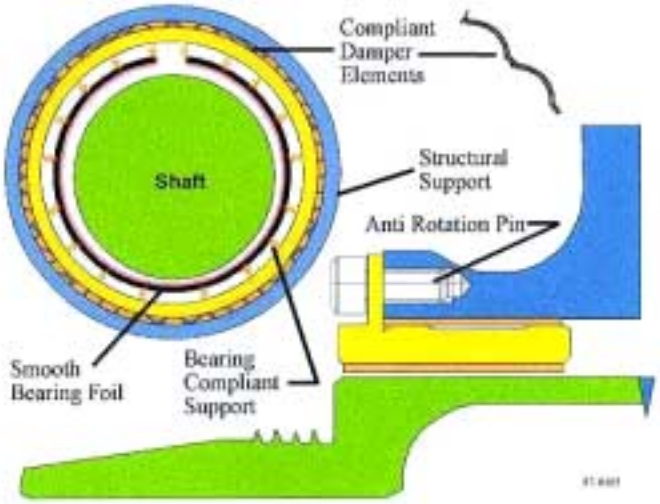
COMPLIANT FOIL DAMPERS FOR GAS TURBINE ENGINES: Mohawk Innovative Technology, Inc (MiTi) recently completed the technical effort for a Propulsion Directorate sponsored Phase II SBIR contract. The objective of this effort was to develop a lightweight, compact, low-cost, high temperature damper capable of operating in either dry (unlubricated) or Vapor Phase Lubricated (VPL) conditions. The damper is applicable to rolling element bearings, foil bearings, and backup bearings for magnetic bearing supported rotors. Two test rigs were developed and used by MiTi to develop and characterize the dampers. Operation at simulated Joint Expendable Turbine Engine Concept (JETEC) engine conditions (from 75°F to 1000°F) was accomplished, and testing with varying levels of rotor imbalance was performed in both dry and VPL conditions. In addition, a damper assembly was provided to the Air Force for evaluation in a bearing test rig. Transition of this technology to the Integrated High Performance Turbine Engine Technology (IHPTET) Program has been proposed via PRDA VII with Allison Advanced Development Company (AADC). This Compliant Foil Damper technology is considered crucial to the successful operation of the AADC auxiliary bearing for the magnetic bearing supported rotor of the Advanced Turbine Engine Gas Generator (ATEGG) XTC77/1 demonstrator. (M. Wagner, AFRL/ PRTM, (937) 255-7406)



Compliant foil damper configurations for ball bearing support and damping



Damper configuration for compliant foil bearing

VELOCITY DATA COLLECTED IN TVC: Scientists and engineers from the Propulsion Directorate's Combustion Science Branch (AFRL/PRTS), Innovative Scientific Solutions, Inc (ISSI), and General Electric Aircraft Engines (GEAE) have successfully collected velocity measurements in the cavity region of the 6-inch Trapped Vortex Combustor (TVC). The TVC is a unique turbine engine combustor concept that offers reduced emissions and improved performance in a small, simple, low cost package. These TVC tests were conducted during the week of 7 May 2001 in the Atmospheric-Pressure Combustor Research Complex at Wright-Patterson AFB, Ohio. The technique used for these velocity measurements was Particle Image

Velocimetry (PIV). In this technique, particles are seeded into the combustor, illuminated with two laser sheets, and two successive images of the particles are taken from which speed and direction of the particles can be determined. Velocity data were taken for the purpose of comparison with GEAE's computational fluid dynamics (CFD) models to examine how well the models predict flow patterns in this region. A significant portion of the NO_x generated in the TVC is generated in the cavities; therefore, knowledge of the flow behavior is critical to improving mixing and lowering NO_x. (V. Belovich, AFRL/PRTS, (937) 255-4229 and J. Gord, AFRL/PRTS, (937) 255-7431)

The 6-inch Trapped Vortex Combustor installed in PR's Atmospheric-Pressure Combustor Research Complex

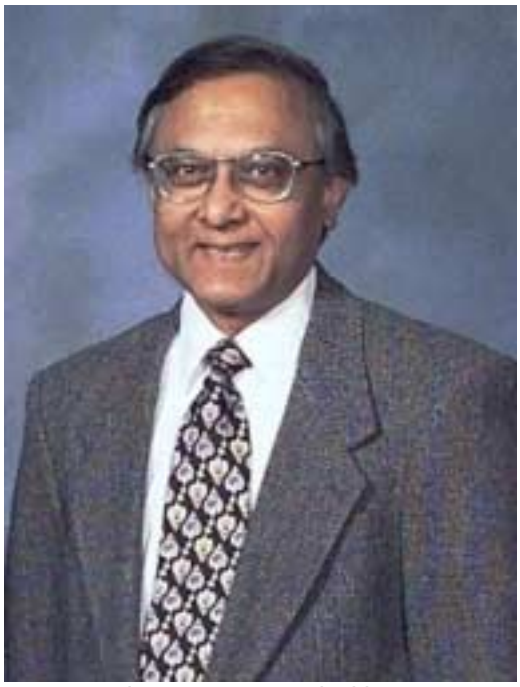
OFFICER HONORED FOR VOLUNTEER WORK: 1Lt Michelle Quitugua of the Propulsion Directorate's Contracting Division (AFRL/PRK) received an Air Force Angel Award on 25 April 2001. Eunice Welch, wife of former Air Force Chief of Staff General Larry Welch, created the Angel Award in 1988. This worldwide award program honors volunteers for their outstanding support and dedication to the military community. Whether lending a helping hand to a co-worker behind schedule or volunteering with a community charity, Lt Quitugua's sincere concern for those around her is always apparent and an inspiration to others. Her genuine desire to help others is reflected in the number and variety of volunteer activities in which she participates. The list of organizations that benefit from her generosity include the WPAFB Catholic Church Hospital Ministry, the American Red Cross, the Project Helping Hands Charity, the Super Saturday Event for under-privileged children, the USAF Museum, and the 2000 WPAFB/Fairborn Chamber of Commerce Easter Egg Hunt. Lt Quitugua is a shining example of the spirit of volunteerism. (R. Mullins, AFRL/PRKB, (937) 255-4818)

Lt Quitugua was recently named an Air Force "Angel"

IPD TURBOPUMP TESTING CONTINUES: Cold flow testing of the Integrated Powerhead Demonstrator (IPD) liquid oxygen (LOX) turbopump continued in June 2001. Cold Flow Test #3 was successfully completed on 3 June 2001 at NASA's Stennis Space Center. The test was successful in spite of an anomaly with the pump end hydrostatic bearing. It was discovered that

the pump end hydrostatic bearing feed ports had not been machined into the hardware, thus providing no flow to that bearing. However, this anomaly proved the robust design of the pump as it ran to 13,000 rpm with no ill effects. A low cost/low risk fix to this anomaly has been identified and is in work. By incorporating the lessons learned in this testing in subsequent designs, it is expected that the cost of future turbopumps will be decreased. The IPD Program contributes to Integrated High Payoff Rocket Propulsion Technology (IHPRPT) goals of doubling cryogenic booster thrust-to-weight, achieving Mean-Time-Between-Overhauls of 100 missions, and reducing hardware costs by 35%. It further provides critical propulsion technologies for the Air Force Space Operations Vehicle (SOV) concept and NASA's 2nd Generation Reusable Launch Vehicle (RLV). (R. LeClaire, AFRL/PRSE, (661) 275-5198)

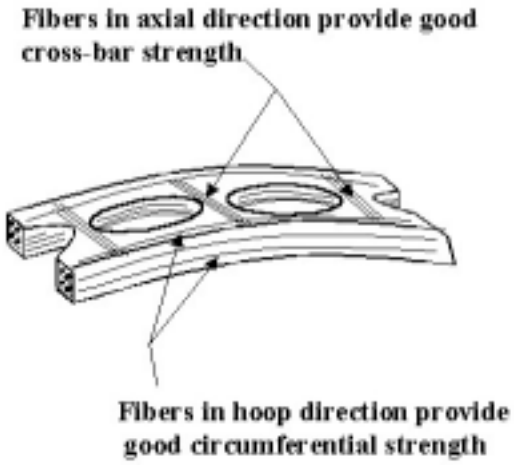
GANGULY HONORED BY AIAA FOR PLASMA RESEARCH: Dr. Bish Ganguly of the Propulsion Directorate's Electrical Technology and Plasma Physics Branch (AFRL/PRPE) was recently honored by the American Institute of Aeronautics and Astronautics (AIAA). Dr. Ganguly was presented with the Outstanding Technical Contribution Award at the AIAA Dayton-Cincinnati Section Annual Awards Banquet held in Dayton, Ohio, on 22 May 2001. This award recognized Dr. Ganguly's research efforts to explore the phenomena of plasma induced drag reduction. This innovative research may provide the technical breakthrough needed for supersonic and hypersonic vehicle development. As a result of this research, several new conclusions have been put forward to the scientific community. (J. Weimer, AFRL/PRPE, (937) 255-6235)

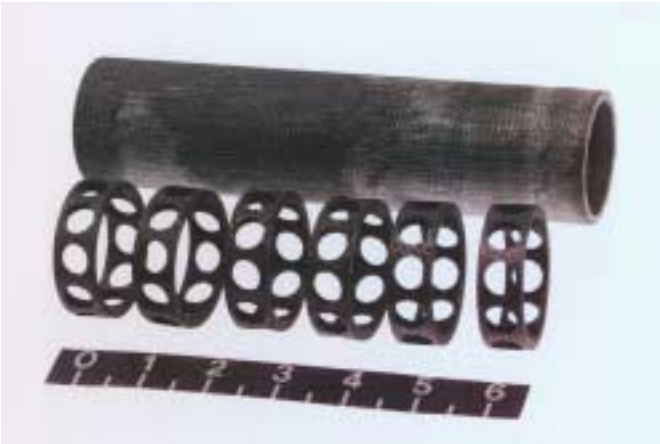

Dr. Ganguly was presented with AIAA's Outstanding Technical Contribution Award

IHPRPT TECHNOLOGY FINDS POTENTIAL AIRCRAFT APPLICATION: Monopropellant technology developed under the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Program is finding application for aircraft. The F-16 and Reconnaissance System Program Offices (SPOs) at Wright-Patterson AFB are sponsoring a program with the Propulsion Directorate to determine the feasibility of using IHPRPT monopropellant approaches as substitutes for hydrazine in F-16 and U-2 Emergency Power Units (EPUs). There is interest in replacing hydrazine because it poses special environmental hazard problems in terms of storage, handling, and disposal. Two main tasks will be addressed in this project: (1) the initial evaluation and reformulation of prospective AFRL monopropellant options, and (2) the determination of catalytic reactivity, safety characteristics, and physical properties for the EPU monopropellant candidates. The results of the project will be highly beneficial in gauging the potential applicability of IHPRPT monopropellants for EPUs. The kick-off meeting for this program is scheduled for July 2001. (T. Hawkins, AFRL/PRSP, (661) 275-5449)

Advanced IHPRPT monopropellants are being considered for use in both F-16 and U-2 EPUs

CARBON-CARBON CAGES FOR FUEL-LUBRICATED BEARINGS: The Propulsion Directorate is collaborating with Williams International on an IRAD program to investigate the benefits of Carbon-Carbon (C-C) composite cages in fuel-lubricated bearings. Fuel-lubricated bearings with 1000 hours of life are required for application in the Joint Expendable Turbine Engine Concept (JETEC) III demonstrator, but cage friction has been an obstacle to extended life operation. C-C cages have been developed in-house by PR's Mechanical Systems Branch (AFRL/PRTM) for use in marginal lubrication applications, such as vapor phase lubrication, but this is the first time they have been used with fuel lubrication. The goal of this test is to demonstrate 1000 hours of bearing life in a Williams International bearing test rig at simulated JETEC III conditions. Two test bearings were provided by PRTM, and they include T15 steel races, silicon-nitride balls, and C-C cages. Both bearings are run in the rig simultaneously and are lubricated with ambient JP-8 fuel, which is under-race fed. The test speed is 40,000 rpm (1.2 MDN). Testing that was initiated on 27 April 2000 was suspended due to test facility availability on 5 June 2000 after 212 hours of successful operation. At that point, C-C cage life had already far surpassed the life limitations of previously tested cage materials. Testing was resumed in May 2001. The bearing ran smoothly around the clock from 14 May 2001 until the test was suspended again on 25 May 2001. The bearing has



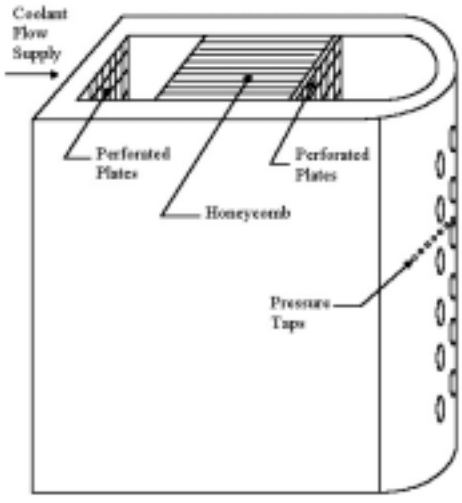


Carbon-Carbon cages developed by PRTM are undergoing testing at Williams International

now accumulated 457 hours of service, which is approaching the midpoint of the 1000-hour goal. Testing is scheduled to resume in June 2001, and the 1000-hour goal should be reached in July 2001. (M. Wagner, AFRL/PRTM, (937) 255-7406)

NEW THERMAL BATTERY TECHNOLOGY FOR F-16 APPLICATION: At a recent meeting hosted by the Propulsion Directorate's Energy Storage & Thermal Sciences Branch (AFRL/PRPS), the Emergency Power Unit (EPU) of the F-16 aircraft was presented as a possible application for new thermal battery technology. The principal speakers at the meeting were Dr. David M. Ryan (PRPS) and Mr. Tom Haydon of Lockheed Martin Fort Worth (LMFW). Mr. Haydon related in detail how thermal batteries could serve as an EPU prime power replacement for the existing hydrazine monopropellant, given that hydrazine poses special environmental hazard problems in terms of storage, handling, and disposal. An additional speaker, Mr. Tom Velez of Lockheed Martin Space (LMS), further described a LMS project utilizing thermal batteries for powering space shuttle steering nozzles. The thermal battery technology planned for this space application is from a fledgling battery company, ENSER, of Pinellas Park, Florida. Attendees of this meeting included members from the ASC Engineering Directorate (ASC/EN), the Reconnaissance SPO (ASC/RA), and the F-16 SPO (ASC/YP), as well as Brian Hager and Dr. John Erbacher of PRPS. This meeting was helpful in relating how thermal batteries are environmentally supportive replacements to hydrazine. (D. M. Ryan, AFRL/PRPS, (937) 255-7770)

EXPERIMENTAL MEASUREMENTS AID IN TURBINE COOLING DESIGN: Researchers in the Propulsion Directorate's Turbine Branch (AFRL/PRTT) recently completed experiments to measure the discharge coefficients of film cooling holes on a cylindrical leading edge model. These experiments were executed in the Turbine Aerothermal Basic Research Laboratory at Wright-Patterson AFB, Ohio. Turbine inlet temperatures of modern gas turbines are far beyond allowable metal temperatures, which necessitates cooling of the turbine blades. Film cooling from discrete holes is an efficient way to protect the surface of turbine airfoils from the hot gas stream and keep the airfoil temperatures at acceptable levels. Since the film effectiveness strongly depends on the ejected coolant flow rate, designers need reliable data on discharge coefficient of the film holes across the operating range of the gas turbine to prevent underfeeding and overfeeding of the film holes. Underfeeding leads to reduced cooling effectiveness and results in airfoil areas with high thermal loads while overfeeding is an inefficient use of turbine working fluid. The discharge coefficient depends on many geometrical and aerodynamic parameters, such as hole geometry, film hole length, pressure ratio, Reynolds number of the coolant flow, and external and internal cross flows. As part of this investigation, experimental results were successfully compared with computational fluid dynamics (CFD) calculations of a similar



Schematic of the model used to measure discharge coefficients of film cooling holes

geometry. The results of these investigations into discharge coefficients will provide data critical to the effective design of film cooling for advanced turbine airfoils. (S. Ou, AFRL/PRTT, (937) 255-6043)

BEST PRESENTATION AWARDS RECOGNIZE OUTSTANDING RESEARCH: The American Institute of Aeronautics and Astronautics (AIAA) Dayton-Cincinnati Section held their annual awards banquet on 22 May 2001. At this ceremony, Best Technical Presentation Awards were given for each of the 16 technical areas featured at the 26th AIAA Dayton-Cincinnati Aerospace Science Symposium held in March 2001. Propulsion Directorate government employees and PR contract researchers with Innovative Scientific Solutions, Inc (ISSI) won 5 of the 16 awards presented. The award winning papers are listed below along with the technical area in which each award was given (the award recipient is identified by **bold** type):

in "Heat Transfer and Thermal Management"
Marc Polanka, Matt Meininger, William Nilson (AFRL/PRTT), and C. Joe (Pratt & Whitney), "Installation Effects on Heat Transfer Measurements for a Turbine Vane."

in "Fuels"
2Lt Sofya Rozenzhak and Chris Bunker (AFRL/PRTG), "Chemometrics Applied Toward the Development of a Fuel Thermal Stability Model."

in "Turbomachinery"
Jordi Estevadeordal (ISSI), William Copenhaver (AFRL/PRTF), W. Ng, and C. Carter (Virginia Tech), "A PIV Study of a Flow Control System in a High Turning Stator Cascade."

in "Instrumentation"
Michael Brown (ISSI), J. Rudd, D. Zimdars, M. Warmuth (Picometrix), and James Gord (AFRL/PRTS), "Terahertz Radiation Measurements in Combustion Environments."

in "Survivability/Vulnerability"
Vincent Belovich (AFRL/PRTS), Fumi Takahashi, and W. Schmoll (University of Dayton Research Institute), "Suppression of Non-Premixed Flames Stabilized by an Obstruction."

In addition, a sixth award winning presentation had a Propulsion Directorate co-author, as indicated below:

in "Future Vehicle Technology"
Max Blair, William Baron (AFRL/VASD), and Sandra Fries-Carr (AFRL/PRPE), "Structurally Integrated Textile Capacitor."

Congratulations to all of the winners. (J. Pearce, AFRL/PRO (UTC), (937) 255-5451)

Want more information?

- More detail on these Best Presentation Awards is available in the May 2001 AIAA Dayton-Cincinnati Section newsletter available on-line by clicking here.

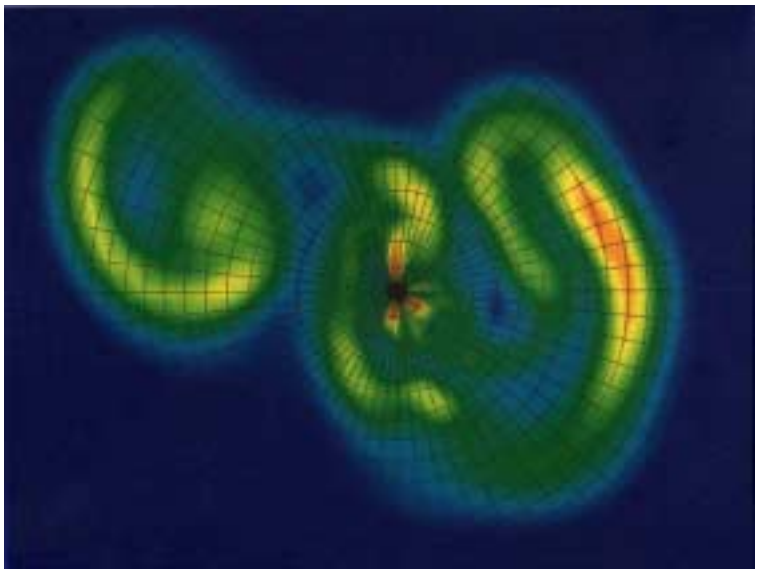
COLLABORATIVE RESEARCH ON CAPACITOR FILMS FOR MEMS DEVICES: The Propulsion Directorate's Capacitor R&D Team (AFRL/PRPE) is collaborating with the Sensors Directorate's RF Components and MEMS Teams (AFRL/SNDD) to develop novel dielectric materials for microwave applications. Spearheaded by Dr. Tony Quach (SNDD) and Dr. Susan Heidger (PRPE), this collaboration leverages each lab's strengths in the area of dielectric materials, material deposition, fabrication, design, and characterization. Non-traditional materials will be explored to dramatically improve micro electro-mechanical system (MEMS) device/circuit performance while reducing the overall size and cost. The Capacitor R&D Team is using its expertise in the deposition of high performance dielectric materials to cooperatively develop new MEMS RF switches and MIM capacitors for MMICs. Barium strontium titanate (BST), polycrystalline diamond (PCD), and diamond-like carbon (DLC) dielectrics will be investigated for use in MEMS RF devices as potentially superior alternatives to silicon nitride dielectrics. The BST material has extremely high dielectric constant (as-deposited ~ 30, annealed ~ 700) and $1x10^6$ V/cm breakdown strength as compared to silicon nitride, which has a dielectric constant of 5.6 and essentially the same breakdown strength. The PCD material in turn has a dielectric constant of 5.7 and breakdown strength of $1x10^7$ V/cm, while DLC has a dielectric constant of 3.0 and breakdown strength of $3x10^6$ V/cm. Recent test substrates were deposited BST dielectric films, and one BST sample was annealed at 250^oC to produce a film with microcrystalline grain structure and high dielectric constant (k ~ 700). A series of wet etching experiments were performed on the as-deposited and annealed BST film, from which a high etch rate solution was determined. Additional etching experiments will be conducted to refine the etching solution and demonstrate controlled reproducibility. Wet and dry etching techniques will be investigated for PCD and DLC as well. MIM capacitors will be fabricated using BST, PCD, and DLC dielectrics by standard photolithographic techniques and characterized for operation at X-band frequencies (8-12 GHz). MEMS RF switches will be fabricated and tested, and applications of dielectric layers for passivation and electrical isolation for MEMS will be examined. These devices have many military and commercial applications such as in phase shifters, phased-array radar, circuit tuning, band switching, and filters. MEMS RF switches have many advantages over present solid state switches such as low switching power (< 1μW), extremely low off-capacitance and extremely low insertion losses at microwave frequencies (< 0.1dB). (S. Heidger, AFRL/PRPE, (937) 255-6016)

PR-WEST SECURITY TEAM HONORED: The PR-West Security Team has been named the Propulsion Directorate Team of the Month for May 2001. This team, led by James (T. J.) Turner, also includes Darrell Rhoden, Chet Zisk, Kriss Vander Hyde, and Huy (Tony) Nguyen. The team was recognized for their exceptional efforts in preparing the entire Edwards Site for the AFRL "Full Spectrum Security Staff Assistance Visit (SAV)" which was conducted 3-5 April 2001. The 7-person SAV team inspected and reviewed the PR-West security program in the following areas: Information Security, Industrial Security, Foreign Disclosure, Physical Security, Resource Protection, Personnel Security, Special Access, Operation Security (OPSEC), Information

The PR-West Security Team was honored for their outstanding preparation for the SAV team visit

Assurance, and Emissions Security. In preparation for this visit, the Security Team conducted a 5-month preparation effort to ensure all DoD, Air Force, and AFRL security policies and procedures were being followed. All 790 government and contractor personnel at the Edwards Site were given security "refresher" training at Director's Calls, in computer based training exercises, and in office visits by the security team. As a result of these efforts, the overall assessment by the SAV team was excellent. According to the SAV team, the Edwards Site has an "effective security program" with "excellent procedural handbooks." The computer security program was deemed "noteworthy," and the SAV team remarked that computer users at the site are well informed on policies and procedures. The PR-West Security Team will next lend their expertise and experience to PR-East as they prepare for a SAV Team visit in July 2001. (A. Kuphal, AFRL/PRO, (661) 275-5343)

PR ON-SITE CONTRACTORS CAPTURE AIAA AWARDS: Propulsion Directorate on-site contractors were recently honored by the American Institute of Aeronautics and Astronautics (AIAA) at the AIAA Dayton-Cincinnati Section Annual Awards Banquet held in Dayton, Ohio, on 22 May 2001. Dr. Jamie Ervin of the University of Dayton was presented the section's Special Service Award for 2000. He was recognized for his efforts to increase student interest in aerospace careers through his service as the faculty advisor to the Student Section of AIAA. Dr. Ervin supports the PR mission by leading an on-site research team that is developing advanced fuel additives for the Fuels Branch (AFRL/PRTG). Dr. Rob Baurle of Taitech, Inc was also honored at this ceremony. He was presented with the Art-in-the-Science "Critic's Choice" award for his image depicting an instantaneous snapshot of vorticity in the developing wake of Mach 2.5 flow



This image, depicting an instantaneous snapshot of vorticity in the developing wake of Mach 2.5 flow past the blunt base of a sting, won the Art-in-the-Science "Critic's Choice" award

past the blunt base of a sting. Dr. Baurle supports the PR mission by performing computational fluid dynamic (CFD) analyses for the Aerospace Propulsion Office (AFRL/PRA). These awards highlight the key role that on-site contractors play in accomplishing the Propulsion Directorate's mission. (J. Pearce, AFRL/PRO (UTC), (937) 255-5451)