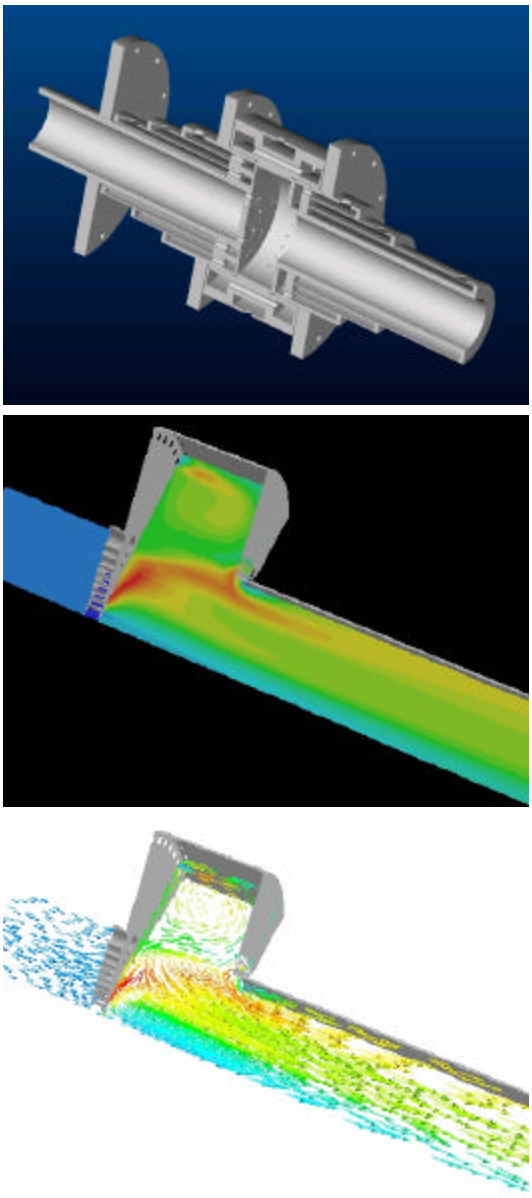
ACCOMPLISHMENT REPORT

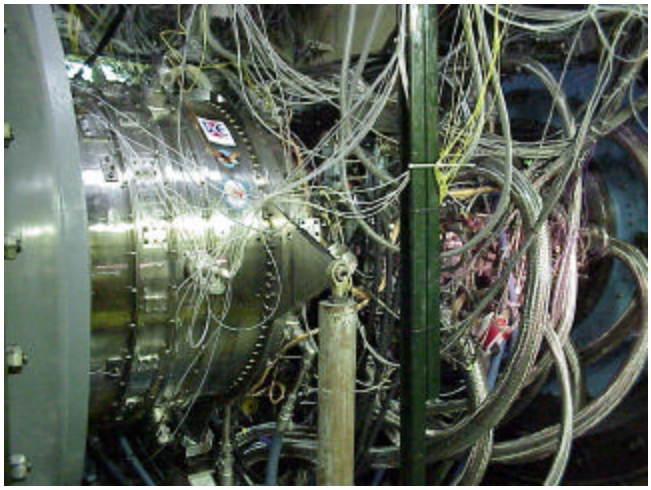
PROPULSION DIRECTORATE
July 2000

COMBUSTOR CONCEPT DEMONSTRATES LOWER EMISSIONS: Researchers from the Propulsion Directorate's Combustion and High Speed Systems Branch (AFRL/PRSC) and the Department of Energy's National Energy Technology Laboratory in Morgantown, West Virginia, are collaborating to test a novel low emissions combustor. On 15 and 16 June 2000, the team conducted Rich-Burn, Quick-Quench, Lean-Burn (RQL) tests of the Trapped Vortex Combustor (TVC) in PRSC's atmospheric combustion test cell at Wright-Patterson AFB. In these tests, pyridine (C_5H_5N) was added to fuel to simulate fuel-bound nitrogen. The data from these recent double cavity tests have been analyzed and compared with previous single cavity data. The results are very promising, with the double cavity TVC converting 12 percent less fuel-bound nitrogen to NO_x than the single cavity TVC. With the single cavity TVC, 27 percent of the fuel-bound nitrogen was converted to NO_x; however, with the double cavity TVC, only 15 percent of the fuel-bound nitrogen was converted to NO_x. This is a significant reduction in the level of NO_x, and this work will continue with an ultimate goal of converting less than 5 percent of the fuel-bound nitrogen to NO_x. Reducing NO_x is important because it is a key participant in ozone-depletion, acid-rain formation, and the creation of photochemical smog. Furthermore, environmental legislation limits allowable NO_x emissions, and these limits are expected to become more restrictive in the future. (Capt I. Vihinen, AFRL/PRSC, (937) 255-8623 and V. M. Belovich, AFRL/PRSC, (937) 255-4229)



RQL TVC schematic (top), temperature profiles (center), and velocity vectors (bottom)

PRATT & WHITNEY FOUR-STAGE COMPRESSOR TEST UNDERWAY: Testing of Pratt and Whitney's four-stage core compressor began on 16 May 2000 in the Propulsion Directorate's Compressor Research Facility (CRF). This compressor is designed to meet Integrated High Performance



Four-stage compressor installed in the CRF

Turbine Engine Technology (IHPTET) Phase III goals by performing the same work of a five-stage compressor in only four stages. The combined team of CRF, Pratt & Whitney, and Dynamic Engineering, Inc personnel accomplished the unprecedented turnaround time from test compressor arrival at the CRF to testing in just two weeks. This is 50 percent of the time that has been required in the past to install a test compressor. The initial test phase, including mechanical check-out to 102 percent speed and vane optimization, was completed by 1 June 2000 to meet program goals. Results to date demonstrate that IHPTET Phase III goals can be met. The next phase of testing will require fixing the variable stator vanes in their optimized settings. To accomplish this, CRF personnel will remove the rig casing and seal the end gaps of the three variable stators. It is expected that this procedure will increase compressor efficiency and flow to meet the design intent. If this is successful, IHPTET Phase III performance goals will be demonstrated in a full-scale compressor. (M. Reitz, AFRL/PRTE, (937) 255-6802)

FRIES CARR WINS FLC TECH TRANSFER AWARD: Sandra Fries Carr of the Propulsion Directorate's Electrical Technology Branch (AFRL/PRPE) and Dr. Robert Monter of the Wright Technology Network have won a 2000 Federal Laboratory Consortium (FLC) Award for Excellence in Technology Transfer. They were recognized for their efforts to develop a new high temperature, high performance dielectric film for use in aircraft capacitors. The new film, called Fluorene Poly Ester (FPE), fills a critical need in state-of-the-art aircraft capacitors. These capacitors are considered to be the weakest link in power electronic systems due to their limited operating temperatures; however, FPE films overcome this limitation as they function over a temperature range of -55ºC to 227ºC (-67°F to 440°F). The initial beneficiaries of this technology will be the military and other government agencies such as NASA. However, FPE has the potential to be successfully applied in commercial settings such as oil well drilling, automotive, commercial aircraft ignition systems, and medical defibrillators. The transfer of this technology from AFRL to the commercial sector has resulted in numerous companies establishing business opportunities and new alliances. (S. Fries Carr, AFRL/PRPE, (937) 255-6016)

Sandra Fries Carr

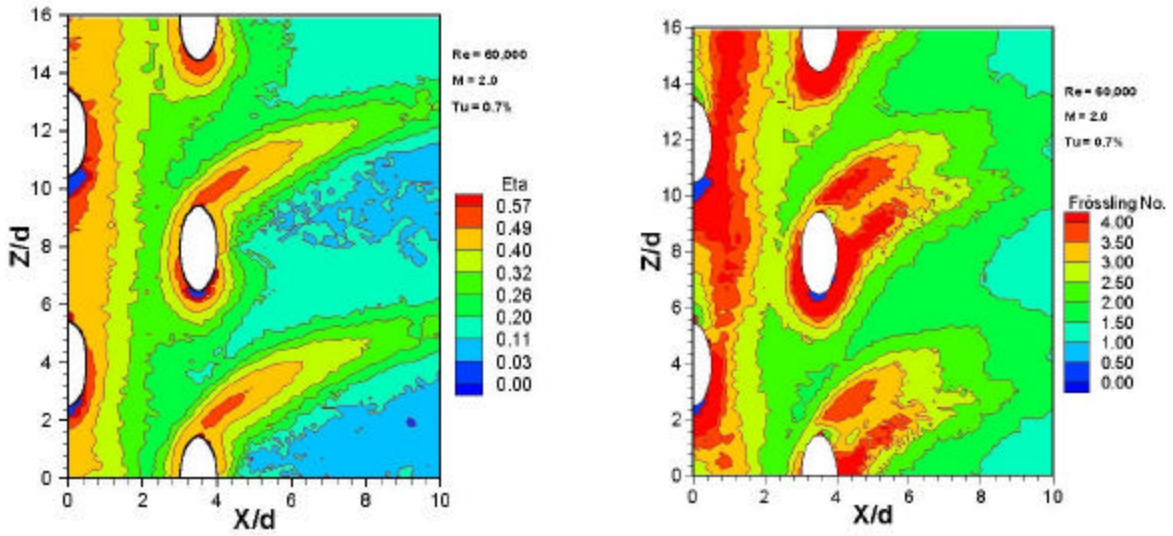
SOLAR PROPULSION CONCEPTS EXAMINED: In response to an Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Steering Group action item, the Propulsion Directorate's Rocket Propulsion Division (AFRL/PRR) has initiated an effort to compare solar propulsion system concepts. A modeling effort is now under way to compare solar thermal propulsion (STP) to solar electric propulsion (SEP). For STP, sunlight is concentrated to heat a propellant that is expanded through a nozzle to generate thrust. In SEP systems, electrical power is obtained by solar illumination of solar cells, and this electrical power can be used to power a propulsion system. These are both low-thrust, high efficiency concepts suitable for orbital transfer maneuvers. A parametric model of the payload to orbit versus the IHPRPT goals has been formulated. Results of this study will be reported in a paper at the American Institute of Aeronautics and Astronautics (AIAA) Joint Propulsion Conference in July 2000. (L. Quinn, AFRL/PRR, (661) 275-5630)

CANADA TO ADOPT +100 ADDITIVE: Canada has announced that it will be the third NATO country to use the +100 thermal stability fuel additive. The +100 additive was developed by the Propulsion Directorate's Fuels Branch (AFRL/PRSF) in an effort to minimize maintenance associated with fuel degradation in aircraft fuel systems. The additive is now in use in a wide range of systems, and its performance in the field has been outstanding. The Canadian Forces recently completed a study that recommended the conversion of all Canadian military aviation fuel from F-40 to F-34+100 with the exception that F-44 will be retained for shipboard operations. [Note: F-40, F-34, and F-44 are the NATO designations for JP-4, JP-8, and JP-5, respectively.] The recommendation to convert to F-34+100 fuel has been approved by the Canadian Forces Chief of Staff, and funds have been budgeted over the next three years to implement this conversion. The goal is to have all Canadian bases and wings converted to F-34+100 by December 2002. Canadian Forces use approximately 375 million liters (or approximately 100 million gallons) of aviation fuel per year. Canada will join the United States and Denmark as the other NATO countries using the +100 additive. (P. Liberio, AFRL/PRSF, (937) 255-6918)

A Canadian Forces F-18 (left) and C-130 (right)

RESEARCHERS STRIVE TO IMPROVE TURBINE COOLING: Current material technologies require film cooling to protect turbine airfoils from hot gas streams. The airfoil leading edges are a region of particular concern because they are exposed to the highest temperatures. In the past, most of the

leading edge film cooling studies used film holes with large injection angles (usually 30º-35º) and small film hole pitch (the distance between two hole centers at the same row). The use of large injection angle tends to cause coolant lift-off from the turbine airfoil surface at lower blowing ratio, which is accompanied by a decrease in film effectiveness. The use of small hole pitch results in an increase in the number of required film holes which in turn increases the required coolant flow and could weaken the structure of turbine airfoil. In order to address these shortcomings, Propulsion Directorate researchers recently performed experiments on leading edge film hole configurations with a smaller injection angle and larger film hole pitch. This study investigates the film effectiveness and heat transfer coefficient distributions on a large-scale symmetric circular leading edge. A transient liquid crystal image technique was used to obtain the film effectiveness and the heat transfer coefficient in the experiment. The distributions of film effectiveness and heat transfer coefficient in the measurement domain were obtained with high spatial resolutions owing to the liquid crystal image method, which is superior to the conventional method of arrays of thermocouples. The results from this study will be used to design and analyze the cooling of advanced turbines. (S. Ou, AFRL/PRTT, (937) 255-6043)



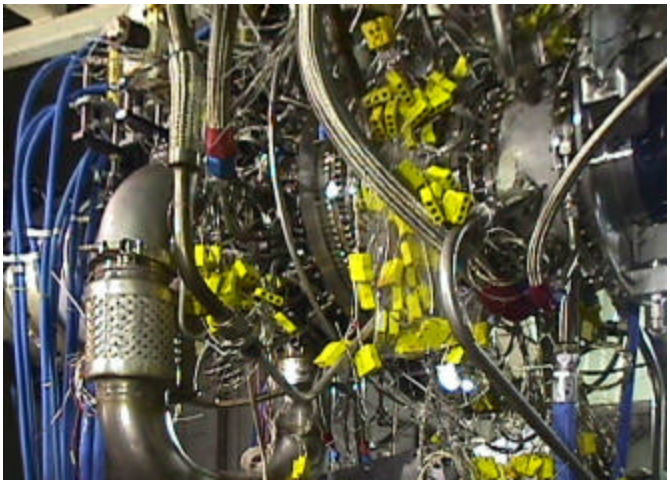
Measured film effectiveness distribution (left) and heat transfer distribution (right)

RESEARCHERS GARNER AIAA BEST PAPER AWARD: Dr. John E. Leland and Dr. R. "Pon" Ponnappan of the Propulsion Directorate's Power Generation Branch (AFRL/PRPG) and K. S. Klasing of General Electric Aircraft Engines (GEAE) were recently honored for their technical excellence. On 20 June 2000, the American Institute of Aeronautics and Astronautics (AIAA) presented this team with the Thermophysics Best Paper Award. A committee of their peers judged their paper, "Experimental Investigation of an Air Micro-Jet Array Impingement Cooling Device," to be the best paper presented at all the AIAA Thermophysics Technical Committee sponsored sessions in 1999. This paper was selected as the best of more than 150 papers presented. The award winning paper describes a research effort to examine the effectiveness of a technique for cooling high power electronic devices. This work supports efforts to develop electronics cooling technologies for the More Electric Aircraft (MEA), Space Based Laser, and Space Based Radar Programs. The award was presented at

a luncheon held in conjunction with the 34th AIAA Thermophysics Conference held in Denver, Colorado. (J. Pearce, AFRL/PRO, (937) 255-5451)

Dr. John E. Leland (left) and Dr. R. "Pon" Ponnappan (right)

HONEYWELL IHPTET PHASE II JTAGG TESTING INITIATED: Testing of the Integrated High Performance Turbine Engine Technology (IHPTET) Phase II Joint Turbine Advanced Gas Generator (JTAGG) was initiated in May 2000. The purpose of this initial Phase II JTAGG core test was to demonstrate the mechanical integrity of the components in the gas generator, to establish a performance baseline, and to conduct diagnostic testing. The total estimated run time should not exceed 15 hours. The following components are being evaluated during the test: (1) single-stage splittered low-pressure (LP) compressor; (2) a two stage axial-centrifugal high-pressure (HP) compressor; (3) a single stage cooled HP turbine; and (4) a single stage LP turbine preceded by uncooled Niobium nozzle vanes. The JTAGG II core test performance will be evaluated in comparison with a pretest analytical model prediction. This model



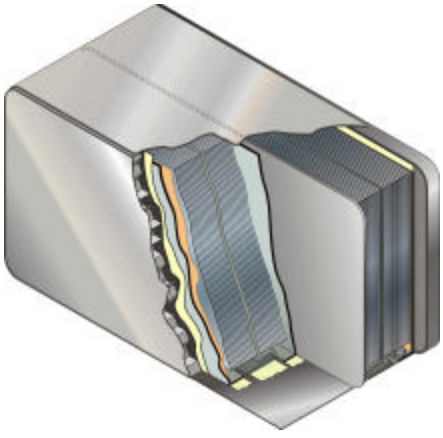
Honeywell's Phase II JTAGG demonstrator

will incorporate measured results from previous component rig tests. Testing to date included several successful lightoffs at 40 percent and 60 percent HP rotor speeds. While attempting to reach idle, the engine experienced a mild rub of the splittered rotor. Upon examination it was discovered that one of the splittered blades was bent very slightly. The blade and shroud are currently being repaired, and additional instrumentation will be installed to monitor movement of the LP shaft and the splittered blades. The JTAGG test will result in the demonstration of a 27 percent reduction in Specific Fuel Consumption (SFC) versus an IHPTET Phase II goal of 30 percent and a 70 percent increase in power-to-weight ratio versus a goal of 80 percent for IHPTET Phase II. (M. Huffman, AFRL/PRTP, (937) 255-2278)

Dr. Shawn Phillips

PHILLIPS RECEIVES NASA TECH BRIEF AWARD: The work of Dr. Shawn Phillips of the Propulsion Directorate's Propulsion Materials Applications Branch (AFRL/PRSM) was recently recognized by NASA. Dr. Phillips was presented with a NASA Tech Brief Award for his work on POSS (polyhedral oligomeric silsesquioxanes) nanotechnology. Over the past two years, collaboration was developed between NASA's Jet Propulsion Laboratory (JPL) and PRSM's Polymer Working Group. This collaboration focused on developing space-survivable polymers using POSS nanotechnology. The results of this collaborative effort are presented in the NASA Tech Brief titled "High Performance POSS-Modified Polymeric Composites." This NASA Tech Brief, which is the basis for the award, was submitted by Dr. Witold Sokolowski from JPL. (S. Phillips, AFRL/PRSM, (661) 275-5416)

AIR FORCE AND NAVY COLLABORATE ON F-16/F-18 REPLACEMENT BATTERY: Representatives of the Propulsion Directorate and the Naval Air Systems Command (NAVAIR) met on 27-28 June 2000 to kickoff a joint Dual Use Science & Technology (DUS&T) agreement with Electro Energy Inc (EEI). The objective of this joint DUS&T program is to develop a 17-Ah main aircraft battery using bipolar nickel metal hydride (Ni-MH) technology. The new battery is to meet performance requirements of Air Force F-16 (Blocks 25/30/32) and Navy F/A-18 A-D aircraft and using the 7.5-Ah battery box from the F-18. In addition, the capability of Ni-MH technology to function off the aircraft bus will be evaluated to possibly eliminate the charger requirement or replace it with a lower cost transformer/rectifier unit. Successful completion of this effort would give the Air Force and Navy a common battery for over 30 percent of the DoD aircraft fleet. This would reduce manufacturing costs by as

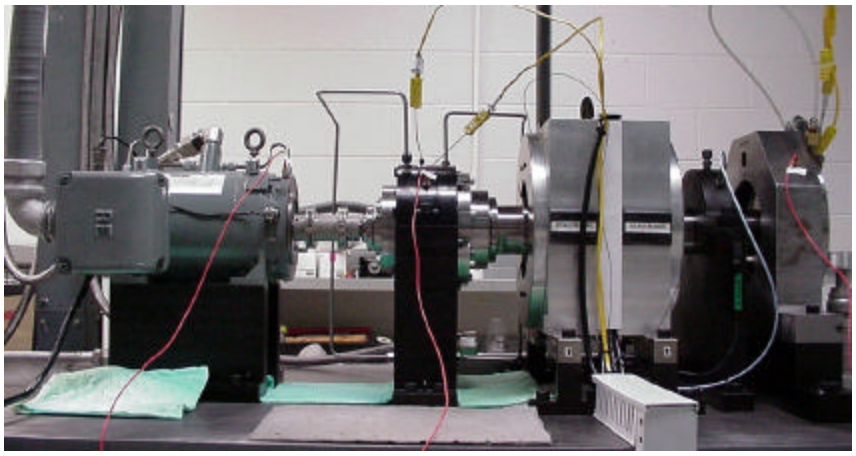


Bipolar cell design

much as 25 percent and eliminate HAZMAT disposal of both vented nickel cadmium (Ni-Cd) and Sealed Lead Acid batteries from the two services. (J. Erbacher, AFRL/PRPB, (937) 255-7770)

UPPER STAGE EXPANDER CYCLE REVIEW: The Propulsion Directorate's Rocket Propulsion Division (AFRL/PRR) has completed the design review for the next build of the Upper Stage Expander Cycle Liquid Rocket Engine Demonstration Program. The review included hardware recovery, minor modifications to improve the turbopump operation, and the inclusion of additional instrumentation to better understand transient turbine performance and axial loads. Repair of the damaged liquid hydrogen turbopump is also progressing well. The objective of this effort is to integrate the fuel turbopump and thrust chamber assembly hardware to feed a high-pressure expander cycle testbed engine. Generating high chamber pressure is the engine's primary factor to increasing its performance. Advanced cooling design and manufacturing techniques are being developed, and high thermal conductivity alloys are being used. (L. Quinn, AFRL/PRR, (661) 275-5630)

NEW BEARING RIG COMMENCES OPERATION: The Propulsion Directorate's Lubrication Branch (AFRL/PRSL) recently commenced operation of a new in-house magnetic/auxiliary bearing test rig at Wright-Patterson AFB. Initial testing in the rig began with the first high temperature auxiliary bearing concept to be tested for the Integrated High Performance Turbine Engine Technology (IHPTET) Program. This bearing concept, the Zero Clearance Auxiliary Bearing (ZCAB), closes down on the rotor with ball bearing supported rollers if shaft eccentricity threatens touch down on the magnetic bearing elements. Mohawk Innovative Technology, Inc supplied the ZCAB to the Air Force following their own test and evaluation program. The PRSL in-house auxiliary bearing test rig has now been successfully run with the ZCAB. The rig shaft can be magnetically levitated and has been rotated at speeds up to 6000 rpm with magnetic levitation. Upon initial check-out in the auxiliary bearing rig, one of the ZCAB bearings failed. PRSL was able to procure the replacement bearings required to rebuild the ZCAB and continue auxiliary bearing testing. The ZCAB is the first of several auxiliary-bearing concepts that will be evaluated with the PRSL auxiliary-bearing rig. (G. Givan, AFRL/PRSL, (937) 255-1286)



New in-house magnetic/auxiliary bearing test rig

NEW FUEL VALVE CONCEPTS DEVELOPED AND EVALUATED IN SBIR EFFORTS: Under a Phase I SBIR Program sponsored by the Propulsion Directorate's Turbine Engine Division (AFRL/PRT), Scientific Monitoring, Inc (SMI) completed development and testing of a high response fuel valve. This is the first high frequency (650Hz) device developed for active combustion control, and its unique design combines state-of-the-art piezoelectric actuation with an innovative mechanical lever system which drives the valve. Recently, SMI returned the valve to AFRL for further evaluation with the goal of obtaining additional performance characteristics to verify and extend the contractor's work. Phase I efforts centered on developing a valve capable of meeting Pratt & Whitney's specifications for flow rate, modulation, and operating frequency. During Phase II, SMI will develop a flight weight valve, triple the modulation capability, and deliver a set of valves to the Air Force for evaluation on an active combustion control rig. A significant technical challenge in Phase II is improving the modulation capability. Proportionally controlling a significant percentage of fuel flow at high frequencies requires a large displacement actuator or a novel flow control strategy. SMI's concept depends upon the use of piezoelectric actuation, which is an inherently small displacement device. However, SMI has developed and analytically evaluated a unique elliptical flowbody design which can potentially control up to 30 percent of the fuel flow. This would meet all active combustion control actuation requirements, including size and weight. Three sets of hardware are to be supplied to the Air Force by the first quarter of 2001 for evaluation on an active combustion control rig. (K. Semega, AFRL/PRTA, (937) 255-6690)

High response fuel valve

PROJECT INITIATED TO STUDY PIPELINE DRAG REDUCERS: The Propulsion Directorate's Fuels Branch (AFRL/PRSF) has entered into a CRDA with Conoco to test new pipeline drag reducing additives. The primary purpose of these drag reducing additives is to increase fuel flow in existing pipeline systems. A secondary benefit of these additives is a reduction of indirect emissions from oil pipelines, since less energy is needed to pump fuel through the pipelines. Though the benefits of these additives are clear, their use with aviation fuels raises the question of whether they will have any detrimental effect on the fuel. Therefore, Fuels Branch personnel will conduct tests to determine if Conoco's drag reducing additive will have

A fuel pipeline

any adverse effects on aviation fuels. Impetus for this project comes from a successful CRDA with Buckeye Pipeline Company that showed that drag reducing additives produced by Baker Petrolite may be usable in jet fuels. Conoco has a drag reducer with a different chemistry than the Baker product that they would like to use in their pipelines. (1Lt K. Wohlwend, AFRL/PRSF, (937) 255-3190)

REVAMPED FUELS TECHNOLOGY WEBSITE UNVEILED: For several years, the Propulsion Directorate's Fuels Branch (AFRL/PRSF) has maintained a website on the science and technology of aviation turbine fuels. This site represents the largest presentation of fuel technology-related data and information in the world, and PRSF has recently unveiled a major revision to the popular website. With a new "look and feel" including improved navigational tools and a new organizational structure, the site has improved usability while maintaining an extremely high level of data security. Although the newly organized site has not been fully converted, informational integrity is being maintained by giving authorized users access to the old version of the website as well as the new version. The site features extensive search capabilities as well as access to various forums (often called bulletin boards) on fuel-related technologies where users can post questions and get answers from fuels experts. These questions and answers are visible to other forum users thereby improving transition of technical knowledge to the user in the field. Access to this site is limited to DoD elements and authorized DoD Contractors only. To request access to this site, contact Bob Morris at robert.morris@wpafb.af.mil or visit the web site at https://posfbbs.appl.wpafb.af.mil and go to the Request Access section. (R. Morris, AFRL/PRSF, (937) 255-3527)