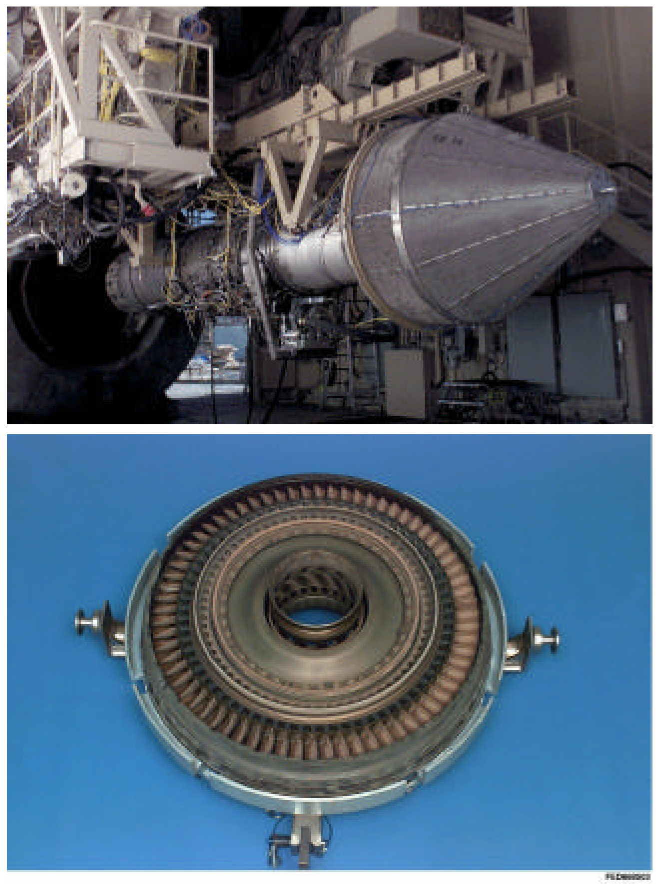
ACCOMPLISHMENT REPORT

PROPULSION DIRECTORATE
February 2000

SUPERCOOLING TECHNOLOGY READY FOR TRANSITION: The F100-229 Supercooled Advanced Technology Demonstrator (ATD) engine achieved a significant milestone in December when it was approved as a technology ready for transition by the joint ASC and AFRL Advanced Technology Transition Council (ATTC). The objective of this ATD Program was to provide significant improvement in turbine life and maintainability by addressing field durability issues for turbine components. The goal was achieved through a technology advancement in cooling design known as "supercooling." Supercooling was applied to components designed to be retrofit into the F100-229 engine; specifically, the first turbine rotor (superblade) and blade outer air seal (super BOAS) of the high-pressure turbine. Metal temperatures were mapped and 1,060 total accumulated cycles (TACs) of durability testing were accomplished. Lower metal temperatures were obtained and a "productionized" fabrication process was demonstrated that offers the potential for increasing TACs in the current F100-229 engine. In this joint effort, the Propulsion Directorate's Turbine Engine Division (AFRL/PRT) managed the design, fabrication, instrumentation, and engine test; the Propulsion Development Systems Office (ASC/LPP) provided the F100-229 test engine; and the Joint Strike Fighter (JSF) Propulsion Technology Maturation Team (ASC/LPL) provided funding for the engine durability test. The supercooled BOAS was successfully transitioned early in the program through the Falcon 229 Component Improvement Program (CIP) to solve an oxidation problem in the turbine shroud. The hardware and technology are now available for further CIP testing if future requirements dictate a need for increased durability beyond current needs. Technology from this program is also being used in the JSF119 and PW4000 engines. (C. Norden, AFRL/PRTA, (937) 255-2121)



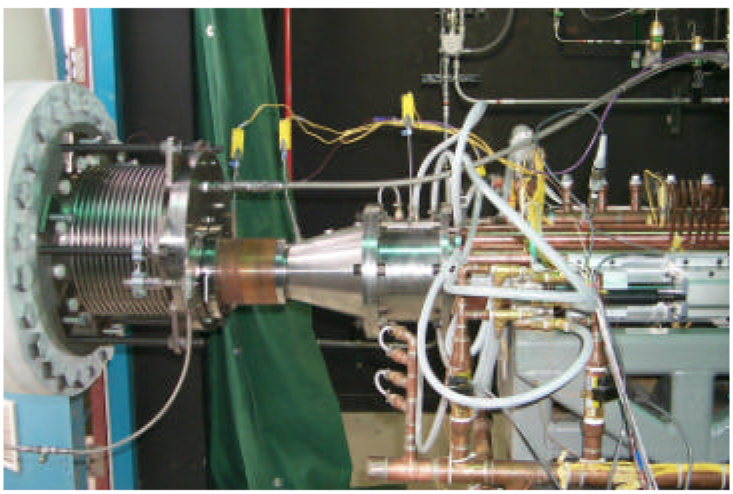
F100-229 engine (top) and the F100-229 superblade rotor (bottom)

DANES COMMENCE OPERATION WITH JP-8+100: At the April 1999 North Atlantic Treaty Organization (NATO) Aviation Fuels & Lubricants Meeting, the Royal Danish Air Force (RDAF) declared their intention to convert to JP-8+100 fuel. The conversion is now under way, and the RDAF has been flying F-16s on JP-8+100 for over two months at their Skrydstrup airbase. The +100 additive was developed by the Propulsion Directorate's Fuels Branch (AFRL/PRSF) in an effort to minimize maintenance costs associated with fuel degradation in aircraft fuel systems. The efficacy of the additive has already been proven in a number of military and commercial engine demonstrations, and despite having used the additive for only a short time, the RDAF is impressed with the results. Though no engines operating on +100 have been overhauled yet, comparisons of engines using the +100 additive and those using additive-free JP-8 are striking. The exhaust region of aircraft using the additive appears to be clean and relatively free of residue, while aircraft not using the additive appear black and sooty. In order to expand the conversion process in Denmark, the RDAF is working with the manufacturer of the additive injector pumps to obtain adequate equipment. As this equipment arrives, the RDAF plans to eventually convert all of their bases to JP-8+100. The transition of the +100 additive to one of our NATO allies is an enormous step towards ensuring the interoperability of NATO forces. (P. Liberio, AFRL/PRSF, (937) 255-6918)


A Danish F-16 being refueled by a USAF tanker (left) and an F-16 at a Danish airbase (right)

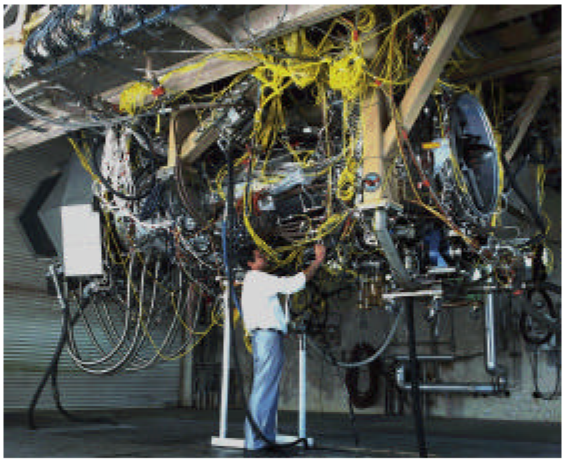
MAINSTREAM WINS REGIONAL SMALL BUSINESS AWARD: Based on a nomination from the Propulsion Directorate, Mainstream Engineering Inc was recently named a regional winner of the Small Business Administration's (SBA) Small Business of the Year Award. The nomination of Mainstream for this award was based on a record spanning more than 12 years of outstanding contract performance under the auspices of the SBIR Program. During this relationship, Mainstream has never had an unsuccessful program or a cost overrun requiring additional Government funds. This achievement is quite remarkable when considering the high-risk type efforts that are typical in the SBIR arena. Mainstream has also demonstrated a unique ability to commercialize their products having commercialized products from all of their Phase II and several of their Phase I SBIR Programs with the Propulsion Directorate. Mainstream has an overall DoD commercialization index of 80 percent, one of the highest in the nation. Due to this record of success, Mainstream has established itself as a world leader in thermal control, heat pumps, vapor compression, and cryocooling. Mainstream will be among the 10 regional winners in attendance at the 33rd Annual Joint Industry/SBA Procurement Conference in Washington DC in June 2000 where the national Small Business of the Year Award winner will be announced. (J. Gottschlich, AFRL/PRPG, (937) 255-6241)

PULSED DETONATION ROCKET ENGINE MILESTONE ACHIEVED: On 20 January 2000, Adroit Systems, Inc (ASI) and Propulsion Directorate engineers at Edwards AFB, California, achieved a major milestone in the development of Pulsed Detonation Rocket Engines (PDREs). The team successfully demonstrated, for the first time, that a PDRE could be started under simulated altitude conditions of 100,000 to 200,000 feet. This test addressed the issue of whether propellants would exhaust into a vacuum faster than they could be detonated. A six-tube PDRE was coupled to a vacuum tank to simulate altitude. It was demonstrated that the nozzle could be made to choke within only the first few cycles, and a back pressure in the combustion chamber could then be readily built-up and sustained once the nozzle choked. ASI is developing the PDRE under joint funding from the Propulsion Directorate and NASA. It is estimated that a PDRE would allow a 10-15 percent increase in engine specific impulse in all engine sizes from boost phase to orbit maneuvering applications when compared to conventional chemical rockets using the same propellants. In addition, the PDRE would allow a reduction in pump discharge pressure requirements. In general, pulsed detonation engines are attractive because of their high fuel efficiency, high thrust-to-weight, and their relative mechanical simplicity. (E. Coy & R. Cohn, AFRL/PRSA, (661) 275-5219)



Adroit System Inc's Pulsed Detonation Rocket Engine

DEMONSTRATOR ENGINE PROVIDES TECHNOLOGIES FOR JSF: Testing of the Pratt & Whitney (P&W) Phase II Integrated High Performance Turbine Engine Technology (IHPTET) Joint Technology Demonstrator Engine (JTDE) has been completed. The JTDE accumulated over 71 hours of engine testing between 19 January and 7 September 1999 at P&W's West Palm Beach, Florida, facility. Testing consisted of initial start/shakedown, structural clearance, vaneless Low Pressure Turbine (LPT) performance assessment, Turbine Exhaust Case (TEC) performance evaluation, LPT thermal assessment, Spherical Convergent Flap Nozzle (SCFN) thermal evaluation, and dry maximum thrust demonstrations. Posttest inspections have found the majority of the hardware in good condition. P&W presented the following Phase II goal achievements at the December 1999 posttest review: a thrust-to-weight increase of 46 percent, a production cost reduction of 25 percent, and a maintenance cost reduction of 33 percent relative to the 1987 IHPTET baseline state-of-the-art engine. The Government team is in the process of evaluating the proposed goal achievements. A number of technologies tested in the JTDE will transition to the Joint Strike Fighter (JSF) Program. These include advanced thermal barrier coatings, a gamma TiAl LPT coverplate, and a lightweight LPT damper. These technologies will reduce JSF engine weight by 30 pounds and reduce Life Cycle Cost (LCC) by approximately $280 million. There are no current plans to rebuild the JTDE; however, there may be future opportunities to test additional technologies in this demonstrator engine. (Capt T. Cerminaro, AFRL/PRTP, (937) 255-2767)



Pratt & Whitney's JTDE (left) and the recipient of many of its technologies, the Joint Strike Fighter (right)

BREAKTHROUGH IN FUEL FILTER TECHNOLOGY: Introduction of the +100 thermal stability additive into aviation turbine fuel has sparked a technology breakthrough in the filter/coalescer systems used to remove dirt and water from fuel. The +100 additive, developed by the Propulsion Directorate's Fuels Branch (AFRL/PRSF) to minimize maintenance costs associated with fuel degradation, disarms the currently fielded filter/coalescer systems. Consequently, the additive must be injected into the fuel downstream of the filter/coalescer units. AFRL/PRSF and the San Antonio Air Logistics Center (SA-ALC) have been working with filter companies and the commercial fuels community to remedy this problem by updating filter/coalescer technology. The Air Force has adopted a commercial specification (API 1581) for filter testing. The new specification has three categories: "C" for commercial aviation fuel, "M" for military aviation fuel including all mandatory additives, and "M100" for military fuel with all mandatory additives and the +100 additive. M100 is the toughest on the filter/coalescer system because it addresses the challenge presented by the +100 additive. Facet International, a filter company based in Tulsa, Oklahoma, recently made an advance in filter/coalescer technology that meets the M100 challenge. In December 1999, Facet's coalescer and separator

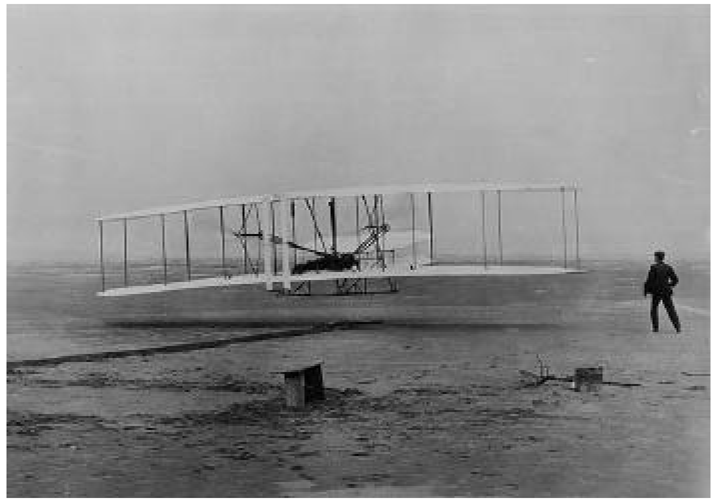
New filter elements compatible with JP-8+100 elements were tested against the new API 1581 M100 protocol and successfully passed all test criteria. The Facet filter element is a drop-in system that requires no modification to existing Air Force fuel handling hardware. SA-ALC personnel are working to transition the new filter to the field. The new filter elements will aid in the transition of the +100 additive to all military and commercial aircraft as well as providing cleaner fuel for all aviation fuel users. (P. Liberio, AFRL/PRSF, (937) 255-6918)

Work being performed on new heated inlet system for the CRF

NEW CAPABILITY ENHANCES COMPRESSOR TESTING: Researchers at the Propulsion Directorate have designed a new heated inlet system for the Compressor Research Facility (CRF) at Wright-Patterson AFB, Ohio. The function of the heated inlet system is to increase the inlet temperature. By recirculating compressed exhaust gas from the experimental compressor and mixing it with the incoming atmospheric air, inlet temperatures up to 750°F can be achieved. These elevated temperatures allow researchers to test compressors at actual "engine" mechanical speeds. The heated inlet system will provide the CRF with an advanced capability to support the Integrated High Performance Turbine Engine Technology (IHPTET) Phase III goals and Turbine Engine Affordability initiatives such as High Cycle Fatigue. Installation of the heated inlet system is scheduled to be completed on 15 March 2000. (D. Rabe, AFRL/PRTE, (937) 255-6802, x231)

IHPTET PHASE II JTAGG READIES FOR TEST: Testing of the Honeywell/General Electric Integrated High Performance Turbine Engine Technology (IHPTET) Phase II Joint Turbine Advanced Gas Generator (JTAGG) is scheduled to begin in late February 2000. The purpose of this initial Phase II JTAGG core test is 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 will be 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 will incorporate measured results from previous component rig tests. The JTAGG test will result in the demonstration of a 28 percent reduction in Specific Fuel Consumption (SFC) versus an IHPTET Phase II goal of 30 percent and a 102 percent increase in power-to-weight ratio versus an IHPTET Phase II goal of 80 percent. (M. Huffman, AFRL/PRTP, (937) 255-2278)

PR TAKES LEADERSHIP ROLE IN "EVOLUTION OF FLIGHT" CELEBRATION: The 100th anniversary of the Wright Brothers' historic first powered flight on 17 December 1903 is fast approaching. In celebration of this momentous event, the American Institute for Aeronautics & Astronautics (AIAA) is planning a series of events under the theme of "Evolution of Flight." As the hometown of the Wright Brothers, Dayton has been chosen as the location for one of the major events in the overall celebration. This event, the "International Symposium and Exposition in Celebration of 100 Years of Powered Flight," is being organized by AIAA and the International Council of the Aeronautical Sciences (ICAS). Dr. Lourdes Maurice, on temporary assignment from PR to SAF/AQ, is the AIAA Co-Chair for the symposium. In addition, Ms. Cindy Obringer of the Fuels Branch (AFRL/PRSF) is serving as the Vice Chair and Capt Ralph Anthenien of the Combustion and High Speed Systems Branch (AFRL/PRSC) is serving as the Executive Secretary. The symposium will showcase four faces of the aerospace community: commercial, military, general aviation, and space. In the spirit of the celebration, an active social program and cultural exhibits are also planned for Dayton under the Inventing Flight umbrella. The symposium will be held in Dayton from 14-17 July 2003. (C. Obringer, AFRL/PRSF, (937) 255-6390)



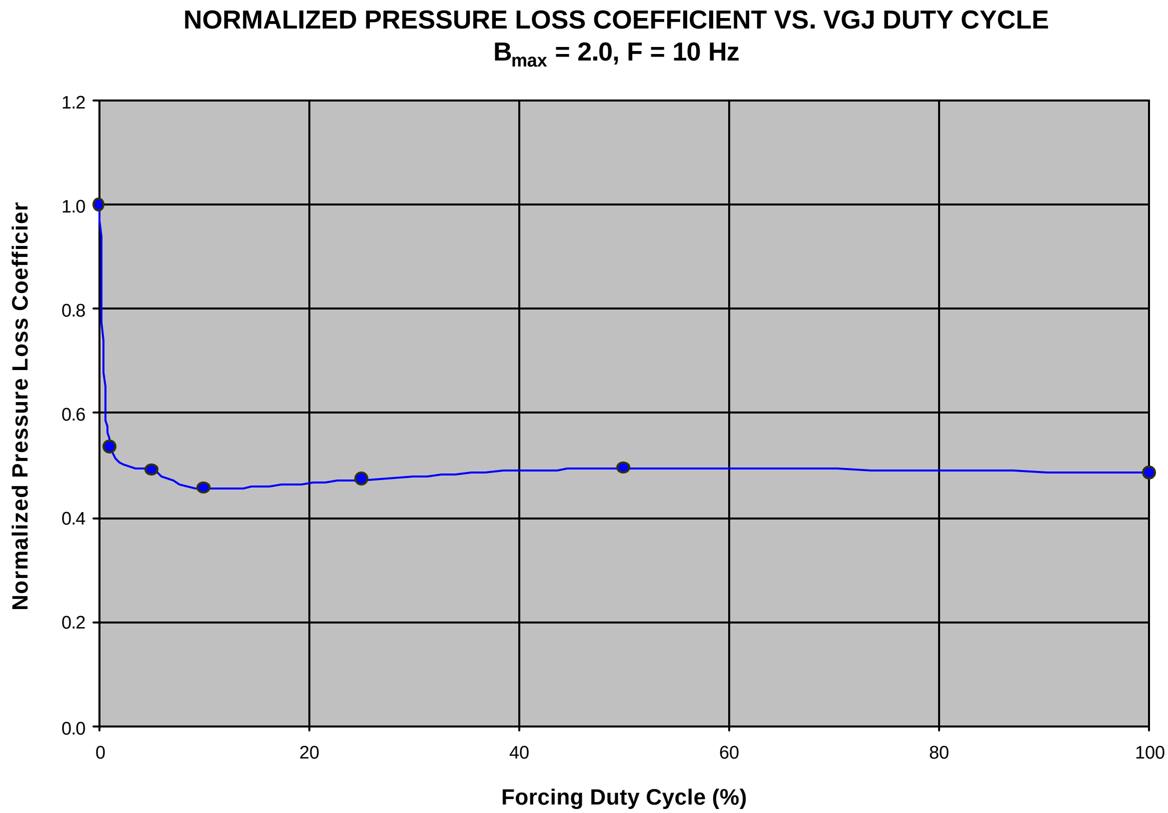
The first successful powered flight of the Wright Flyer

[For more information on the symposium and other 2003 AIAA events visit the AIAA web site at http://www.flight100.org/events.html.]

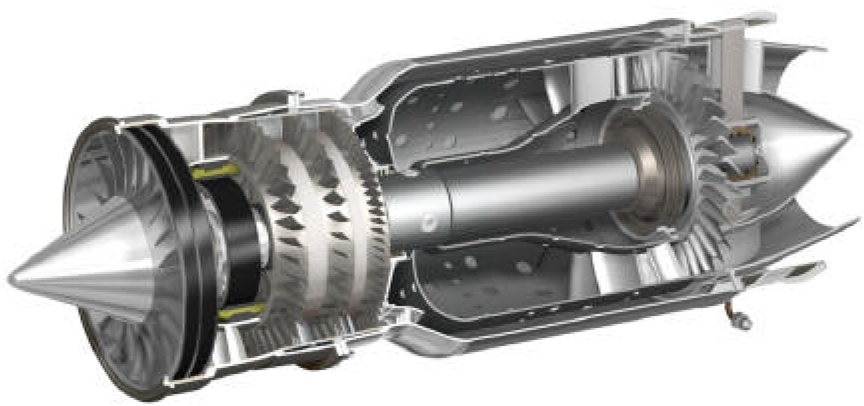
[More details on the Inventing Flight program can be found at http://www.activedayton.com/community/groups/2003/.]

NEW METHOD TO SUPPRESS TURBINE BLADE SEPARATION: Operation at high altitude results in a significant drop in the flow density found inside a turbine engine that can have a profound effect on the operation of the low pressure turbine (LPT). As a result of the low density, the Reynolds (*Re*) number of the flow around the turbine blades and vanes is often reduced to a level significantly below the design point of the airfoils. Consequently, the airfoils become sensitive to flow perturbations and are highly prone to flow separation, which degrades component efficiency and increases localized heat transfer to the blades. Researchers in the Propulsion Directorate's Turbine Branch (AFRL/PRTT) have been experimentally and numerically studying the low *Re* number behavior of a typical LPT blade shape. Current experimental work is focused on techniques for reducing low *Re* number blade losses. A promising technique is the use of Vortex Generator Jets (VGJs), which are small jets in the blade surface similar in size and flow rate to film cooling jets. Previously reported studies using continuous flow

VGJs showed a more than 50 percent reduction in total pressure loss coefficient, which is a direct measure of the aerodynamic losses of the airfoil. Current studies are focusing on a variation of the VGJ technique in which the flow from the VGJs is pulsed. Results indicate that pulsed VGJs can give the same benefit as continuous flow VGJs while using 1 percent or less of the mass flow required by continuous flow VGJs. Therefore, significant aerodynamic efficiency gains can be made with very minimal cycle impact since control flows can be made to be only a tiny fraction of the mass flow already used for turbine cooling. (R. Sondergaard, AFRL/PRTT, (937) 255-6768)



WILLIAMS JETEC ENGINE POISED TO CONTINUE TESTING: Testing of Williams International's Integrated High Performance Turbine Engine Technology (IHPTET) Phase II Joint Expendable Turbine Engine Concept (JETEC) demonstrator engine was initiated in January 1999. To date, the JETEC engine has successfully completed over 24.5 hours of testing, but Williams has been waiting for a test window at NASA Glenn Research Center (GRC) to complete the final phase of testing. In the interim, Williams has repaired the abradable layers over the second, third, and fourth stages of the drum compressor to ensure the predicted engine performance during the next test. An acceptable test window at NASA GRC could not be secured so it was decided to conduct the test at Arnold Engineering Development Center (AEDC) in March 2000. Testing will initiate with a facility/demonstrator engine check-out during the week of 6 March 2000 with the all metal hot section utilized in all testing to date. The demonstrator engine will then be reconfigured and tested with a ceramic hot section approximately 2 weeks later. This final test will include a demonstration at simulated transonic and low supersonic flight conditions, as well as the demonstration of the IHPTET Phase II supersonic expendable goals of a 70 percent increase in Fn/Wa and 45 percent reduction in production cost. (L. Chrisinger, AFRL/PRTP, (937) 255-2767)



Williams International's JETEC demonstrator

IHPTET PHASE II JETEC TESTING UNDER WAY: The Allison Advanced Development Company (AADC) recently initiated testing of their Phase II Integrated High Performance Turbine Engine Technology (IHPTET) Joint Expendable Turbine Engine Concept (JETEC) demonstrator engine. The objective of the performance test is to demonstrate the Phase II supersonic JETEC specific thrust goal. The supersonic engine was designed to demonstrate such technologies as lamilloy turbine vanes, single crystal turbine blades, a high temperature exhaust nozzle, a high-pressure turbine structural rod, and a high temperature bearing with impact damper. During a start-to-idle run, the engine lit and accelerated to idle speed (25,000 rpm) where transient and steady-state data were collected for several minutes. Engine temperatures and vibrations were within or below anticipated ranges. Metal temperatures of the Durad-620B vapor lubricated, hybrid ceramic bearing were also within acceptable limits as were the bearing cavity pressures. Following this test, the engine was restarted to conduct the high-speed calibration. At 88 percent corrected rotor speed, a pronounced change in engine vibration was observed. While the magnitude of the vibration was only marginally higher than the anticipated steady-state limit, the rate of change of the vibration was of concern. A review of the data showed no obvious cause for the vibration, and the test was repeated. Again at 88 percent corrected speed, vibration sensor levels exceeded the transient limits, and the engine was decelerated to idle. During deceleration the vibration levels continued to exceed acceptable levels, and the engine was shutdown. Inspection indicated that a rub had occurred with distress to the turbine rotor blades, blade track, and the number two bearing. Total run time was 4 hours, 31 minutes with 37 minutes of hot time. An engine disassembly and investigation as to the cause of the vibration is ongoing. (R. Newman, AFRL/PRTP, (937) 255-2767)