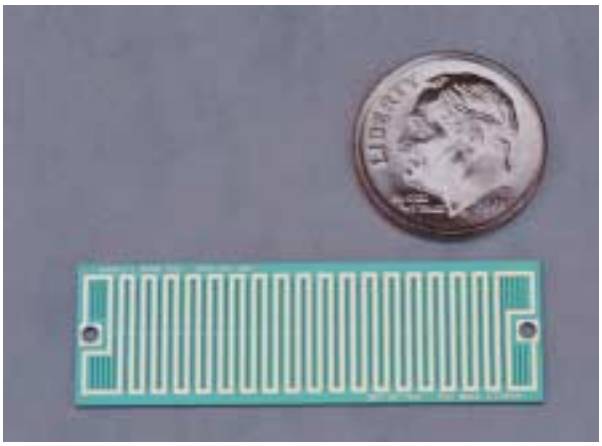
PROPULSION DIRECTORATE

Monthly Accomplishment Report
August 2001

Contents ***Page***

MICROPROPULSION SYSTEM DELIVERED TO ASU: In late July 2001, two flight versions of the MEMS fabricated heating element for the Free Molecule Micro-Resistojet (FMMR) were delivered to Arizona State University (ASU) for integration into two nanospacecraft. The FMMR is a micropropulsion system that addresses the need for low-mass, low-power, efficient, simple, and robust thrusters for microsatellites. This concept was developed collaboratively by the Propulsion Directorate, NASA's Jet Propulsion Laboratory (JPL), and the University of Southern California. Prior to delivery of the flight-heating elements to ASU, they underwent final vacuum tests to assess heat transfer characteristics and the actual power profile for the mission. ASU will next integrate the FMMR into two nanospacecraft that will be part of the 3-Corner Satellite Constellation. ASU's nanospacecraft has the unique goal of demonstrating a safe and simple micropropulsion system in a space flight experiment. Since the heating mechanism is the major component of the FMMR system, testing of these MEMS heating elements in space is a critical step in the future development of an operational FMMR and other MEMS fabricated thrusters. Other goals of the Constellation include demonstrating stereo imaging, virtual formation operations, cellular-phone communications, and innovative command and data handling. Actual in-space testing of the FMMR component is scheduled to occur by the end of 2003, when the Constellation is carried into space aboard NASA's Space Shuttle. (A. Ketsdever, AFRL/PRSA, (661) 275-6242)


MEMS fabricated FMMR heater element


FMMR flight structure delivered to ASU

NASA ADOPTS +100 FUEL ADDITIVE: Three NASA installations are in the process of implementing the +100 Thermal Stability Improver Additive in their fuel distribution systems. The three NASA locations are Kennedy Space Center (KSC) in Florida, Johnson Space Center (JSC) in Texas, and Johnson Space Center-West, which is located at the El Paso International Airport. The +100 additive was originally developed under a program sponsored by the Propulsion Directorate's Fuels Branch (AFRL/PRTG). The goal of this program was to extend the useful operating temperature of JP-8 fuel by 100°F (thus the +100 name) through the addition of a low-cost additive package. Since it was first fielded in 1994, JP-8+100 has been successfully used by thousands of Air Force aircraft as well as numerous aircraft of allied nations. NASA's adoption of JP-8+100 further expands the user base. All NASA aircraft at KSC, JSC, and JSC-West will be converted to operation on JP-8+100. The list of NASA aircraft at these locations includes T-38s, Gulfstream G2s and G3s, a Boeing 747, and the modified KC-135 zero gravity



NASA refuellers equipped to dispense JP-8+100

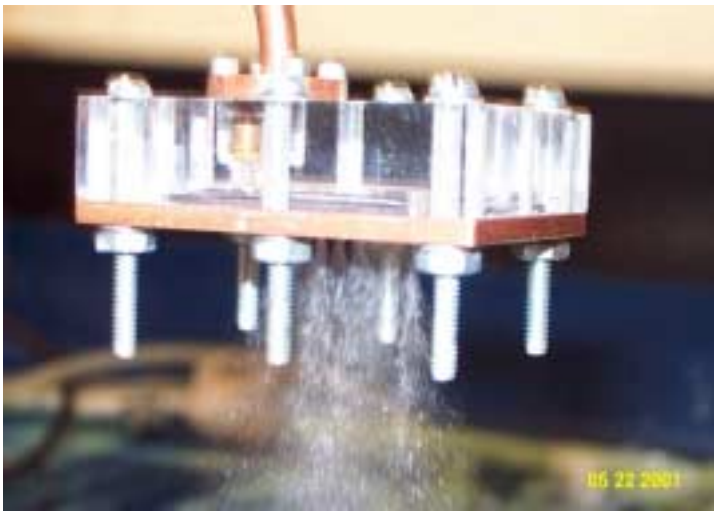
trainer known as the "Vomit Comet." The three locations currently undergoing conversion to JP-8+100 are scheduled to be up and flying by the end of August. (E. Strobel, AFRL/PRTG, (937) 255-4027)

HUISVELD HONORED FOR INVESTIGATION OF MISSILE FAILURES: Mr. Peter Huisveld III was approved for the Exemplary Civilian Service Award in July 2001. This is in recognition of his distinguished service as a Senior Aerospace Engineer in the Propulsion Directorate's Space and Missile Propulsion Division (AFRL/PRS). He served as the principal investigator for the MK-58 rocket motor Integrated Product Team (IPT) investigation into AIM-7 Sparrow missile failures. The Sparrow is used in an air-to-air role (designated AIM-7) by the Air Force, Navy, Marine Corps, and foreign customers. It is also used in a surface-to-air role (designated RIM-7) by the Navy and numerous foreign customers. Due to the Sparrow's wide usage, the Air Force, Navy, and industry were represented on the IPT. AIM-7 missiles had been operated for over 20 years without a catastrophic rocket motor failure before the Air Force experienced four failures (two catastrophic) between June 1997 and April 1999. In his capacity as principal investigator, Mr. Huisveld conducted extensive analyses of these failures and prepared a report documenting the findings. Due largely to his efforts, the problem with the MK-58 motors was identified and a workable inspection method developed. This has prevented the grounding of the Sparrow fleet and the scrapping of thousands of rocket motors. More importantly, a potential loss of DoD pilots and fighter aircraft has been averted as a result of Mr. Huisveld's outstanding efforts. (P. Huisveld, AFRL/PRS, (661) 275-5230)


Mr. Peter Huisveld

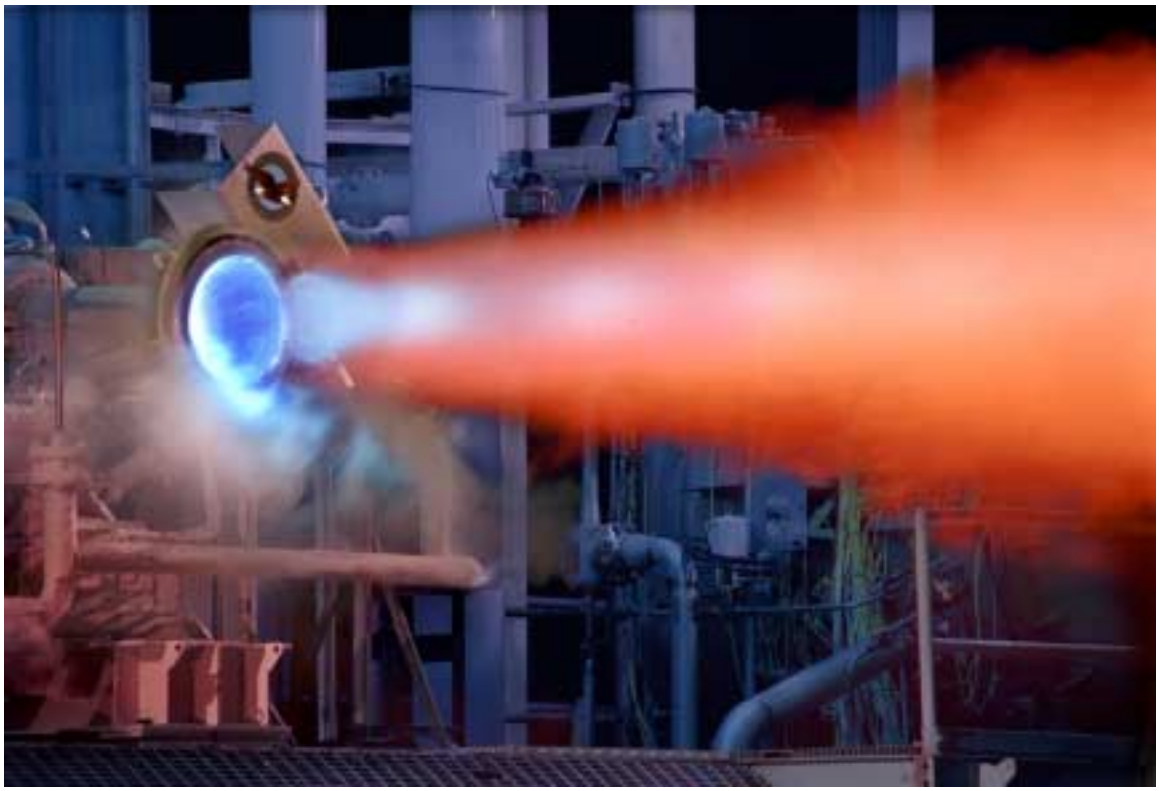

An AIM-7 Sparrow is fired from an F-15

UNIQUE SPRAY COOLING SYSTEM DEMONSTRATED: Spray cooling concepts are among the latest thermal management techniques being explored for potential use in high heat flux applications in aerospace systems. The Propulsion Directorate's Energy Storage & Thermal Sciences Branch's (AFRL/PRPS) in-house research team, in association with Universal Energy Systems, Inc and University of Dayton Research Institute engineers and technicians, have developed and fabricated a unique closed loop spray system. This new spray system employs an array of the tiniest spray atomizers ever built. It is capable of creating swirling flow necessary to generate a full cone spray and uniform cooling. Eight miniature atomizers are embedded in a multi-orifice plate capable of generating a uniform spray over a sample area of 1 cm by 2 cm simulating the target cooling of high heat flux laser diodes. This miniature multi-atomizer array is not available in the commercial market. A closed loop spray cooling experimental setup consisting of an evaporator heater, atomizer housing, pump, filter, and condenser was established in order to evaluate the performance characteristics of the spray system. The performance test exhibited that the multi-atomizer array was capable of generating full cone spray patterns with spray cone angles larger than 35° at pressure differentials greater than 20 psi between the supply and spray chambers. The critical heat flux (CHF) of the closed loop spray cooler, with the fluorocarbon fluids FC-72 and FC-87 as working fluids, were investigated at various supply liquid temperatures and atomizer pressure drops from 10 psi to 55 psi. The controllability of the target surface temperature was within 1.5°C in the range of 15°C to 80°C. It was demonstrated that the new spray cooler with the fluorocarbon fluids was capable of removing heat at a heat flux level of 90 W/cm^2, which is triple the CHF in the case of pool-boiling heat transfer. Other appropriate working fluids can be selected depending on specific application requirements. The present cooling technique is scaleable to larger areas as required for solid-state laser and high power microwave applications. (R. Ponnappan, AFRL/PRPS, (937) 255-2922)



Multi-atomizer spray pattern

COPPER TUBULAR COMBUSTION CHAMBER TESTED: A hot-fire testing of the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Upper Stage Demonstrator (USD) Advanced Expander Combustor (AEC) Chamber was conducted on 12 July 2001. The test was conducted at Pratt & Whitney's Test Stand E-08 in West Palm Beach, Florida. The USD Program contributes to the IHPRPT Phase I Orbit Transfer goals of a 1% increase in Specific Impulse (I_{sp}) and a 30% increase in Thrust-to-Weight (T/W). The purpose of the test was to obtain data confirming the increased heat transfer capability of copper tubes as part of a liquid rocket combustion chamber. (E. Spero, AFRL/PRSE, (661) 275-5972)



The Advanced Expander Combustor (AEC) Chamber is tested at Pratt & Whitney

HISTORY-MAKING SCRAMJET GOES ON TOUR: A scramjet (supersonic combustion ramjet) engine developed by Pratt & Whitney under the Propulsion Directorate's Hypersonic Technology (HyTech) Program is currently touring the country. This engine, known as the Performance Test Engine (PTE), is a heat-sink, hydrocarbon-fueled scramjet engine demonstrator. In January 2001, the PTE made history when it became the first integrated scramjet engine to successfully operate at hypersonic speeds using conventional hydrocarbon fuels without the use of energetic additives. During the history-making test program, performance and operability of the engine were verified in the Mach 4.5 to 6.5 flight regime. In July 2001, the PTE embarked on a tour of the country beginning with a stop at the 37th AIAA/ASME/SAE/ASEE Joint Propulsion Conference in Salt Lake City, Utah. The PTE then traveled to Oshkosh, Wisconsin, where it was displayed at EAA AirVenture Oshkosh 2001. The engine then returned home to be displayed in the Propulsion Directorate's lobby at Wright-

The Performance Test Engine on display at Oshkosh

Patterson AFB in August 2001. Wherever it has been displayed, the PTE has generated a great deal of interest and served as a striking symbol of coming advances in high-speed propulsion technology. (A. Boudreau, AFRL/PRA, (937) 255-1237)

PR PARTNERS WITH NIST TO COLLECT SOOT SAMPLES: National Institute of Standards and Technology (NIST) researchers collected particulates samples during their visit to the Propulsion Directorate's Well-Stirred Reactor (WSR) Facility during the week of 11 June 2001. Particulates emissions from aircraft are a major concern due to the increased visibility of combat aircraft due to the smoke plume, the health risks associated with small particulates in the atmosphere, and the combustion inefficiency related to unburned carbon particles in the exhaust. Understanding particulate formation mechanisms in gas turbine combustion systems is an important step in mitigating these pollutants. The WSR Facility recently came on-line in Test Cell 153, Building 490, at Wright-Patterson AFB, Ohio. In a SERDP effort to develop a sooting model using polycyclic aromatic hydrocarbon (PAH) build-up, NIST is partnered with the Combustion Science Branch (AFRL/PRTS) to develop particle/PAH-sampling techniques for the WSR. The reactor is currently operated using methane fuel, and there are plans to expand fuel capability to include higher-weight hydrocarbon fuels up to JP-8. NIST collected soot samples at several conditions, the most notable being a sample that was obtained over a 10-minute duration where a filter temperature of 500°C was achieved while the reactor was near rich blowout at 1200°C. The soot will be analyzed for PAH content at NIST facilities. On-site University of Dayton Research Institute (UDRI) researchers also collected smoke samples. Several filter stains were identified with reactor operating conditions near the onset of sooting at an equivalence ratio (Φ) of 1.70 and trending towards rich flame blowout, near Φ = 1.90. The samples compared well to the tolerance of ±3 smoke numbers generally accepted for the technique. Future collaborative efforts with NIST will involve developing a PAH injection system and testing candidate PAH mitigation additives for liquid fuels. (C. W. Frayne, AFRL/PRTS, (937) 255-6250 and J. Zelina, AFRL/PRTS, (937) 255-7487)

Well-Stirred Reactor (WSR) rig

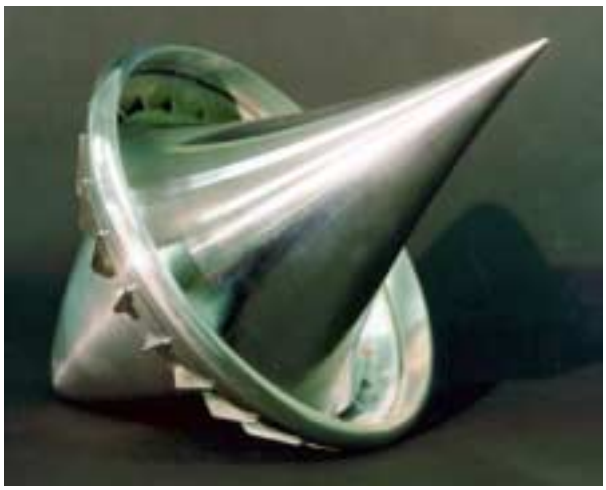
WSR smoke samples at various reactor operating conditions

DICK HILL RECOGNIZED FOR LEADERSHIP ROLE IN TURBINE ENGINE DEVELOPMENT: Richard J. Hill was approved for the Meritorious Civilian Service Award in July 2001 for his distinguished performance as both Chief of Technology and Chief of the Propulsion Directorate's Turbine Engine Division from 1 August 1992 to 31 March 2001. Dick demonstrated outstanding leadership, management capability, and technical expertise in the Integrated High Performance Turbine Engine Technology (IHPTET) Program. This is a joint undertaking among the turbine engine technology organizations of the DoD, NASA, DARPA, and the US gas turbine industry. The program is nearing completion and is demonstrating its goal of doubling propulsion capability while providing modernization to US front-line aircraft. His exceptional efforts have helped to make IHPTET one of DoD's premier programs. (F. Oliver, AFRL/PR, (937) 255-5334)


Mr. Richard J. Hill

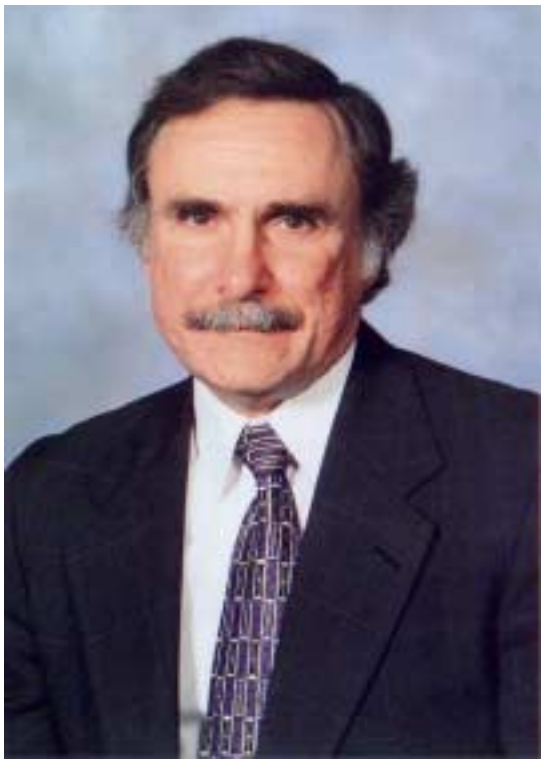
LIGHTCRAFT RESEARCHER HONORED BY AIAA: Dr. Franklin Mead, Jr. of the Propulsion Directorate's Propellants Branch (AFRL/PRSP) received a Certificate of Merit at the 37th AIAA/ASME/SAE/ASEE Joint Propulsion Conference Awards Luncheon held in July 2001 in Salt Lake City, Utah. Dr. Mead received this Certificate of Merit for the technical paper entitled "Laser Initiated Blast Wave For Launch Vehicle Propulsion" (AIAA Paper No. 2000-3848), which was named the 2000 AIAA Best Paper by the AIAA Nuclear and Future Flight Propulsion Technical Committee. This paper describes experiments conducted at the High Energy Laser Systems Test Facility, White Sands Missile Range, New Mexico, to investigate the behavior of a laser initiated blast wave. This blast wave provides the propulsive force for the Lightcraft, which is a launch vehicle propelled by a high-power, ground-based laser. Studies indicate that if this concept can be realized, it has the potential to reduce launch costs (cost per pound of payload) by an order of


Dr. Franklin Mead, Jr.


A Lightcraft model

magnitude or more. This paper was jointly authored with Dr. Don Messitt of Aerojet and Dr. Leik Myrabo of Rensselaer Polytechnic Institute. (F. Mead, AFRL/PRSP, (661) 275-5929)

McNALLY RECOGNIZED FOR SPEARHEADING IHPTET DEMOS: In July 2001, Mr. Richard G. McNally was approved for the Exemplary Civilian Service Award in recognition of his distinguished service as Chief of the Propulsion Directorate's Propulsion Branch (AFRL/PRTP) from 3 January 2000 to 31 May 2001. During this period, Mr. McNally provided superior engineering leadership to twelve senior engineers and one management assistant. He considers the welfare of his subordinates to be his highest priority, and they have thrived under his leadership as evidenced by a long list of awards and promotions they have received. The Propulsion Branch is charged with executing a $60 million annual budget to conduct all demonstrator engine testing in support of the Integrated High Performance Turbine Engine Technology (IHPTET) Program. The IHPTET Program, which is one of DoD's premier programs, has a goal to double propulsion system capability by the year 2005. Under IHPTET, demonstrator engine testing is conducted for three classes of aircraft turbine engines: turbofan/turbojet (fighters/ bombers/large transports), turboprop/turboshaft (trainers/helicopters/small transports), and expendable (missiles/unmanned air vehicles). Over the past year, demonstrator engine testing was conducted in support of both the turboprop/turboshaft and the expendable classes of engines. Additionally, design, hardware fabrication, instrumentation, and assembly activity was conducted in support of six demonstrator engine tests planned in all three-engine classes for the following year. It is a great credit to Mr. McNally that he executed his responsibilities flawlessly during this extremely active period. (R. Hill, AFRL/PRT, (937) 255-4100)


Mr. Richard G. McNally

NATIONAL HOVER TEST FACILITY DIRECTOR RECOGNIZED: Mr. Christopher Cass was approved for the Exemplary Civilian Service Award in July 2001 in recognition of his distinguished service as Director of the National Hover Test Facility (NHTF) and group leader of Chemical Spacecraft Propulsion from August 1998 to May 2001. As Director of the National Hover Test Facility, Mr. Cass was responsible for the daily direction and management of operations and maintenance of the NHTF. Throughout his tenure, Mr. Cass has been very diligent in ensuring that there was continuous funding for present and future kinetic kill vehicle testing. He also spearheaded efforts to support the Ballistic Missile Defense Organization (BMDO) Technology Roadmap Master Plan at the Propulsion Directorate's Edwards Site. This consisted of evaluating programs for BMDO applications and leveraging opportunities that developed. During his tenure as NHTF Director, Mr. Cass oversaw the successful test of the

XSS-10 propulsion system, which was a key demonstration of the AFRL/VSDD's and NHTF's ability to deliver on schedule and on budget for their respective customers. Mr. Cass has also been responsible for coordinating propellant loading operations for the XSS-10 flight experiment, which will be conducted by NHTF personnel for the vehicle at Cape Canaveral. Furthermore, he conducted the free-flight hover test of the Raytheon Exo-atmospheric Kill Vehicle, the National Missile Defense Interceptor, during which he orchestrated the solution of a major facility failure in less than 24 hours. As Test Director for the Navy Theater Wide tests, Mr. Cass ensured that all test facility preparations for the kinetic warhead static and free flight-test were accomplished well ahead of schedule. Thanks in part to his outstanding efforts, this test program is now under way at the NHTF. (C. Cass, AFRL/PRTE, (937) 255-6802)


Mr. Christopher Cass

GRUBER NAMED JUNE EMPLOYEE OF THE MONTH: Dr. Mark Gruber of the Propulsion Directorate's Aerospace Propulsion Office (AFRL/PRA) has been named PR's Employee of the Month for June 2001 in the Scientist, Engineer, or Supervisor category. Dr. Gruber was recognized for initiating and leading the most significant change to PRA's primary scramjet combustion test cell (Test Cell 22) since the facility was first brought on-line more than 3 years ago. Test Cell 22 is already a world-class facility for combustion research and development in the area of hydrocarbon-fueled scramjet propulsion systems; however, Dr. Gruber recognized that there were limitations in Test Cell 22 that would make it difficult, if not impossible, to achieve broader Air Force objectives. Three major upgrades to the capabilities of Test Cell 22 are under way, the centerpiece of which is the replacement of the "heat-sink" scramjet flow path with a fully water-cooled unit. This first upgrade has been completed with minimal disruption to scramjet development efforts. This new system will greatly increase research quality and output by allowing longer run-times (important for laser diagnostics) and shorter cycle times between runs. The other two upgrades, which involve installing a clean air heater (or vitiator) and a fuel heater/cracker, will be completed in the coming months. The new vitiator will provide cleaner, high temperature, combustion air to the scramjet, and is


Dr. Mark Gruber

designed to operate at lower cost than the previous system. The fuel heater/cracker will provide fuel to the scramjet combustor at the composition and temperature associated with fuel cooling a scramjet engine at hypersonic flight speeds. Careful planning will enable the phasing in of these two remaining upgrades while maintaining an active test program with both NASA (alternative scramjet fuels) and AFRL/VS (plasma ignition). The scramjet development effort is a highly integrated program between Pratt & Whitney and the experimental and computational groups of PRA's in-house team. The research conducted in Test Cell 22 is crucial to reduce technical risk in subsequent ground testing of the flight-type HyTech engine. Dr. Gruber's outstanding efforts to upgrade Test Cell 22 will greatly further scramjet development efforts within the Air Force. (P. Buckley, AFRL/PRA, (937) 255-5221)

DIODE DEVELOPED IN DUAL-USE PROGRAM FOR SPACE BASED RADAR: In May 2001, Cree Lighting, under a subcontract to Raytheon, announced the development of an aluminum-gallium-nitride (AlGaN-GaN) tunnel diode as part of a Propulsion Directorate Dual-Use Science & Technology Program. Tunneling is the quantum-mechanical effect where an electron can penetrate a potential barrier at a lower energy level than would normally be required. The tunneling effect was an unexpected discovery made while Cree Lighting was investigating gallium-nitride Schottky diodes. The effect was noticed with variations in AlGaN layer thickness, in that the forward voltage drop became a function of the AlGaN thickness and was lower than expected. Changing the doping level of the GaN independently varies the reverse blockage voltage. The resulting diode has a lower voltage drop with a nearly ideal reverse blocking characteristic. Cree Lighting has applied for a patent for the new device. (R. Thibodeaux, AFRL/PRPE, (937) 255-6016)