PROPULSION DIRECTORATE

Monthly Accomplishment Report
August 2002

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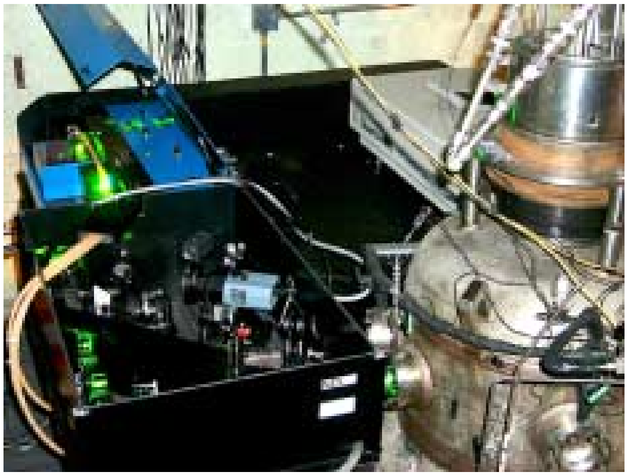
POTENTIAL TRANSITION OF COMPOSITE BEARING CAGES TO CRUISE MISSILE ENGINE: Carbon-carbon (C-C) composite cages continue to show great payoff in high performance, marginally-lubricated bearing applications. The most recent success involves their use in fuel lubricated bearings being evaluated by Williams International (WI) for the F107 turbofan engine, which powers the Tomahawk cruise missile. Full-scale, fuel-lubricated bearing tests conducted by WI under an Independent Research and Development (IRAD) effort demonstrated significant performance advantages over cageless and steel-cage bearing designs in over 1,000 hours of accumulated test time. This technology is scheduled for transition into a low-cost, fuel lubricated version of the F107 engine being considered by Lockheed and the Air Force for the Extended Range Joint Air-to-Surface Standoff Missile (JASSM-ER). This will be the first full-production application of C-C cages if the engine is selected by the Lockheed/Air Force team. C-C cages have already transitioned into the Allison Advanced Development Company (AADC) XTL-16 Joint Expendable Turbine Engine Concept (JETEC) technology demonstrator engine in December 1998 and are planned for transition into the AADC XTL-17 and AADC/General Electric Aircraft Engines (GEAE) XTC-77/1 demo engines. GEAE and Pratt & Whitney are considering the technology for large fighter class turbine engines (i.e., IHPTET/VAATE demos and the Joint Strike Fighter) and Hamilton-Sundstrand is also considering this technology for the Miniature Air Launched Decoy TJ50 production engine. C-C cages were jointly developed by Propulsion Directorate engineers Drs. Nelson Forster and Lewis Rosado and Mr. Wei Shih of Allcomp Inc (Patent No. 5,752,773, May 1998). PR's Mr. Matthew Wagner assisted in the technology transition effort with WI. In 2000, Allcomp Inc entered a Cooperative Research and Development Agreement (CRADA) with PR to further develop C-C cage technology and was granted an exclusive patent license from the Air Force to manufacture C-C cages for military and commercial applications. (L. Rosado, AFRL/PRTM, (937) 255-6519)

Carbon-Carbon bearing cages

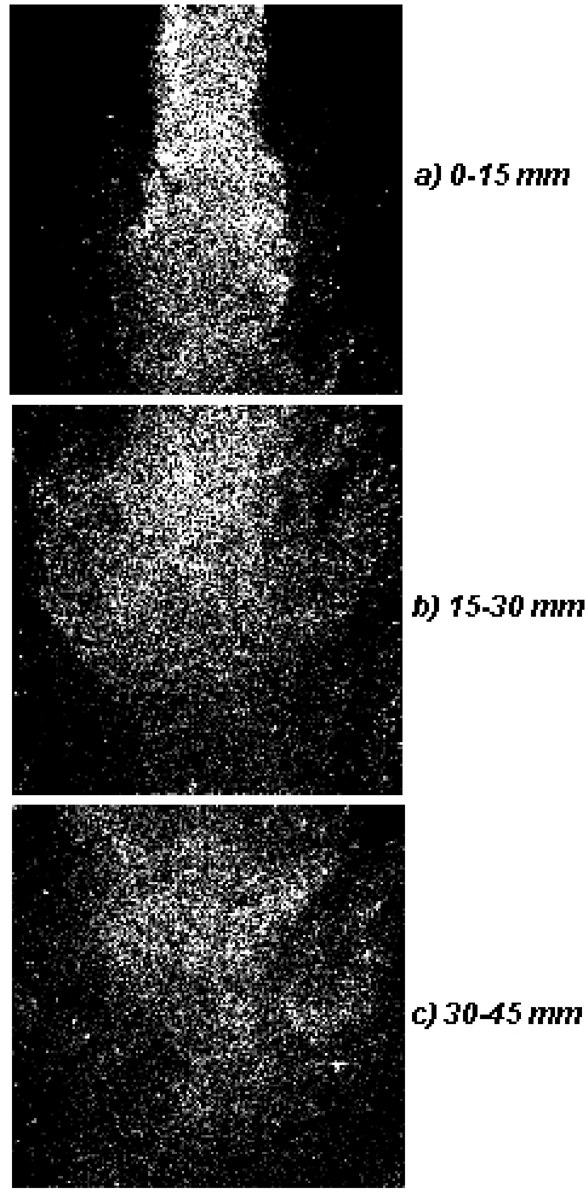
F107 turbofan engine

SBIR PROGRAM YIELDS OUTSTANDING IMAGES OF DENSE SPRAY: The first ever single-shot coherence gated images of a dense high pressure spray were recently achieved in the Propulsion Directorate's high pressure spray facility at Edwards AFB, California. This work was performed under a Phase II Small Business Innovation Research (SBIR) program with



Imaging system

North Dancer Labs, Inc of Burlington, Vermont. It is noteworthy that this program will finish on time and within cost with no contract extensions. Spatially and temporally resolved visualizations of the intact core length of a Space Shuttle Main Engine (SSME) preburner injector were easily obtained through a cloud of drops so dense as to frustrate all previous visualization attempts. Based on short coherence length laser interferometry imaging, the technique used is a variant of approaches originally developed to image medical objects such as tumors behind highly scattering media such as flesh. This is a rare case where combustion and spray applications actually tend to be less challenging to a technique than the application for which it was originally developed. A brainstorming session was held which identified numerous other strong potential applications in combustion and sprays. Charlie Lysogorski, Jr. was the principal investigator at North Dancer Labs, and he worked with Pete Strakey of AFRL/PR to produce these highly promising results. (P. Strakey, AFRL/PRSA, (661) 275-5673)



Composite of several images obtained during testing. This is a SSME preburner injector operating at cold-flow conditions designed to simulate the SSME preburner hot-fire conditions. The images represent a temporally resolved (10 ns) view of the cross-section of the spray at three axial stations downstream of the injection point. Each image is at a different point in time, so they are just representative of what the spray typically looks like.

<u>BLASIUS RECOGNIZED FOR OUTSTANDING CONTRACTING LEADERSHIP</u>: On 17 July 2002, Mr. David W. Blasius received the Exemplary Civilian Service Award in recognition of his distinguished service as Chief of the Propulsion Directorate's Contracting Division (AFRL/PRK) from 1 January 2001 to 31 March 2002. Mr. Blasius was recognized for providing outstanding

leadership to AFRL/PRK, invaluable support to the technology divisions of PR, and topnotch support as chief business advisor to the director. During this period, his organization administered 550 contracts, grants, and other assistance instruments with a combined face value of $1.65 billion. Among these was the $750 million Integrated High Performance Turbine Engine Technology (IHPTET) Program, without doubt PR's all-time largest, most complex, and highest priority program and an oft-cited model for the DoD. Among his achievements, Mr. Blasius is credited with improving relations with other directorate organizations. This has had a positive impact, as it has provided a means to identify and resolve potential roadblocks to successful award and contract performance. Mr. Blasius also established innovative procedures to reduce the award time of Small Business Innovation Research (SBIR) contracts. His efforts allowed for the award of 19 SBIR new starts in an average of just 8 days each, compared to the 22 days required the previous year. He is also a leader of people, with a strong, cohesive contracting team of more than 20 acquisition professionals under his supervision. He organized and implemented numerous divisional off-sites and team building activities that resulted in better morale and working relationships among division personnel. Consequently, AFRL/PRK has been molded into a fine cadre of contracting professionals whose primary goal is meeting customer needs. Mr. Blasius is a most deserving recipient of this honor. (Col A. Janiszewski, AFRL/PR, (937) 255-2520)

Mr. David W. Blasius

CANADA MOVES AHEAD WITH PLAN TO IMPLEMENT +100 FUEL ADDITIVE: The Canadian Forces recently announced their intentions to move ahead with a plan to convert ground-based air operations from F-40 (aka JP-4) to F-37 (aka JP-8+100) fuel.* This shift will make Canada the third NATO member to adopt the +100 thermal stability fuel additive following the lead of the US and Denmark. Current plans call for the transition from F-40 to F-37 to occur during the period of February to April 2003. At the end of the transition period, current F-40 suppliers in Canada, which include Shell, IOL, and Petro-Canada, will stop producing F-40/Jet B type fuel. Canada is currently putting the infrastructure in place to supply fuel with the +100 additive to aircraft. Their planning provides for various means of injecting the additive into the fuel, including injection at the loading rack, on refueling vehicles, or with a portable unit. However, no +100 additive will be put into storage tanks. Canadian Forces will retain the flexibility to provide F-34 (aka JP-8) without the +100 additive to non-program or transient aircraft. Furthermore, F-44 (aka JP-5) fuel will be retained for shipboard operations. The +100

* Note: The "F-##" designations are NATO codes for fuels, where F-34 is JP-8, F-40 is JP-4, and F-44 is JP-5. The +100 additive is assigned a separate NATO code of S-1749. F-34 fuel with the +100 additive, or JP-8+100, has a separate NATO code of F-37.

additive was developed by the Propulsion Directorate's Fuels Branch (AFRL/PRTG) in an effort to minimize maintenance associated with fuel degradation in aircraft engines and fuel systems. The +100 additive has been a major success, and it has significantly reduced fuel-related maintenance costs for a wide range of military and commercial systems. (P. Pearce, AFRL/PRTG, (937) 255-6918)


The Challenger (left) and the F-18 (right) are among the many aircraft that will soon operate on F-37 fuel.

Trailer mounted injection on a US F-16

HLVW Refueller

<u>AFOSR STAR TEAMS RENEWED FOR 3-YEAR TERMS</u>: The Air Force Office of Scientific Research (AFOSR) recently renewed two of the Propulsion Directorate's AFOSR STAR Teams for three-year terms. The two STAR Teams renewed were (1) the "Advanced Supercritical Fuels/Supercritical Combustion" team led by Dr. Tim Edwards, and (2) the "High Temperature Superconductor (HTS) Materials for Advanced Power Systems" team led by Dr. Paul Barnes. Both of these STAR Teams were initially established in 2000, an honor which recognized them as being among the finest basic research groups in the Air Force. The "Advanced Supercritical Fuels/Supercritical Combustion" STAR Team is performing basic research to better understanding fuel behavior as aerospace fuels are heated to 750°F (critical temperature) and beyond, through their use as coolants. A key aspect of this work is understanding and controlling deposition ("coking"). Members of this team include Drs. Chris Bunker, Don Phelps, and Jim Gord from AFRL/PR; Prof. Jamie Ervin, Drs. Steven Zabarnick and Matthew DeWitt, and Mr. Rich Striebich of the University of Dayton Research Institute; and graduate students Messrs.

Tom Ward, Nick Kuprowicz, and Thammarat Doungthip. The "High Temperature Superconductor (HTS) Materials for Advanced Power Systems" STAR Team addresses the basic scientific issues related to the development of the second generation high temperature superconducting coated conductor and incorporation of that conductor into magnet and generator coil windings for power generation. Members of this team include Dr. Charles Oberly, 2Lt Justin Tolliver, and 1Lt C. Brent Cobb of AFRL/PR; and Mr. Tim Peterson and Dr. Rand Biggers of the Materials Directorate (AFRL/ML). (T. Edwards, AFRL/PRTG, (937) 255-3524 and P. Barnes, AFRL/PRPG, (937) 255-4410)

Dr. Tim Edwards

Dr. Paul Barnes

BOEING BRIEFED ON POWER SYSTEM VOLTAGE ISSUES FOR NEXT-GENERATION TRANSPORT AIRCRAFT: On 10 July 2002, at the request of Boeing Commercial management personnel, members of the Propulsion Directorate's Power Generation Branch (AFRL/PRPG) met with representatives from the Boeing Commercial Aircraft Division to answer specific questions about power system voltages and sub-atmospheric interactions as related to their next-generation transport aircraft. The meeting began with PRPG personnel essentially conducting an impromptu tutorial on voltage breakdown and insulation issues in high altitude environments for the Boeing personnel. This led into a detailed discussion of each of the following items (and their relevance) on Boeing's "strawman" agenda: 1) updates on High Voltage Design Guide revision efforts; 2) recent program experience with 270 Vdc and 230 Vac in high altitude (> 45-50,000 ft.) aircraft; 3) requirements and testing experience for Corona; 4) familiarity/contacts with any related work in European defense community (EFA/JSF, etc.); 5) power systems, and components lessons learned (generators, motors, contactors, power distribution units, etc.);

6) insulation materials and processing; 7) test equipment/facilities such as voltage levels, altitude chambers, and corona measurement equipment; 8) best practices guidelines; and 9) discussion on how the USAF and DoD certify systems operating in or near the Corona environment on high altitude aircraft. A tour of the PRPG Applied Electromagnetics Laboratories (High Power Lab) and observation of experiments helped enhance the technical discussions. This exchange brought out technical needs related to qualification testing for power system components that could potentially result in updated industry standards. The discussions elucidated the technical need for baseline technology questions that need further research before sensible qualification tests and procedures can be developed. Discussions also included the possibility of setting up a collaborative government-industry technical working group under the auspices of the appropriate technical society to coordinate these efforts. As a start, Boeing will follow up with a draft system requirements document which is to be later reviewed by PRPG personnel. (D. Schweickart, AFRL/PRPG, (937) 255-9189)

TECH TRANSFER EFFORTS EARN PRAISE FOR SCHARIO: On 17 July 2002, Ms. Kristen Schario was presented with the Exemplary Civilian Service Award in recognition of her distinguished service as the Propulsion Directorate's Lead for Technology Transfer from 3 April 2000 to 19 April 2002. In this position, Ms. Schario provided expert and effective leadership in the successful transfer of a multitude of propulsion and power technologies to the commercial sector. Due to her wide-ranging activities and vast network of contacts in the Federal Laboratory Consortium (FLC), she acquired and maintained a significant volume of up-to-date knowledge of ongoing research in other federal agencies. This knowledge proved to be invaluable as she worked with directorate personnel to identify collaboration opportunities with other federal agencies. She further refined and improved the technology assessment process to such a high degree of effectiveness that her process was adopted at the national level. Ms. Schario's outstanding contributions earned her FLC's Representative of the Year Award for 2000 and also a 2001 Award from the Greene County Board of Commissioners. Her selection for these awards is due to her many contributions to and expert management of PR's Technology Transfer program, her leadership recognition within AFRL, and her volunteer contributions at the national level. Ms. Schario is well deserving of this award. (C. Reeves, AFRL/PROP, (937) 255-8209)


Ms. Kristen Schario

SIMULATED COOLING SYSTEM CHECKED OUT FOR TURBINE RESEARCH FACILITY: The Propulsion Directorate's Turbine Research Facility (TRF) is used to evaluate the external aerodynamics and heat transfer behavior of advanced turbine designs to achieve the technology goals of the Integrated High Performance Turbine Engine Technology (IHPTET) and Versatile Affordable Advanced Turbine Engines (VAATE) Programs. Modern jet engine turbines operate at temperatures that exceed the maximum allowable turbine blade metal temperatures and hence require cooling. The TRF is designed to simulate the proper aerothermal conditions to evaluate aerodynamic and heat transfer performance of innovative turbine designs while holding the metal temperature at ambient conditions. This is done by maintaining proper non-dimensional parameters including the gas-to-metal temperature ratio. The precise effect of the cooling flows on the performance of the turbine is a matter of great importance in meeting technology goals. The focus of recent work was to provide scaled cooling flows in the TRF in order to study and characterize their effect. This required maintaining the proper temperature for the cooling flow near -150°F, thus a cryogenic cooling system had to be designed. The cryogenic hardware consists of an 11,000-liter liquid nitrogen tank that supplies liquid nitrogen to two smaller run tanks for stator and rotor cooling flows. The pressure and temperature need to be controlled and uniform in these runs to provide constant coolant conditions to the test turbine. A standard controller was obtained for the pressure control, but special items had to be designed to control the temperature and maintain temperature uniformity. A cryogenic heater was designed and fabricated to allow heat to be added to the tanks as needed to modify the gas temperature to meet the test requirements. Maintaining a uniform cooling temperature proved to be challenging. Initial testing showed a 175°F stratification from top to the bottom in the run tanks. Therefore, a cryogenic mixing system was critical to meeting the uniformity requirements. With the new mixing system, temperature uniformity within less than 3°F was achieved. This new test capability will now be used to evaluate the effectiveness of film cooling on turbine design. (T. Gillaugh, AFRL/PRTE, (937) 255-6802)


Liquid nitrogen tank that is a component of the TRF cryogenic cooling system

BARGA HONORED FOR ATEGG LEADERSHIP: Mr. Michael A. Barga of the Propulsion Directorate's Propulsion Branch (AFRL/PRTP) was recently presented with the Exemplary Civilian Service Award in recognition of his distinguished service as the Advanced Turbine Engine Gas Generator (ATEGG) Group Leader and as the technical lead for the Joint Strike Fighter (JSF) F136 Advanced Technology Demonstration (ATD) Program from 3 January 2001 to 31 March 2002. Under the ATEGG Program, the most advanced turbine engine technology in the world is demonstrated in a core engine environment, for the first time ever, at temperatures and pressures far in excess of today's capabilities. As Group Leader for the ATEGG Program,

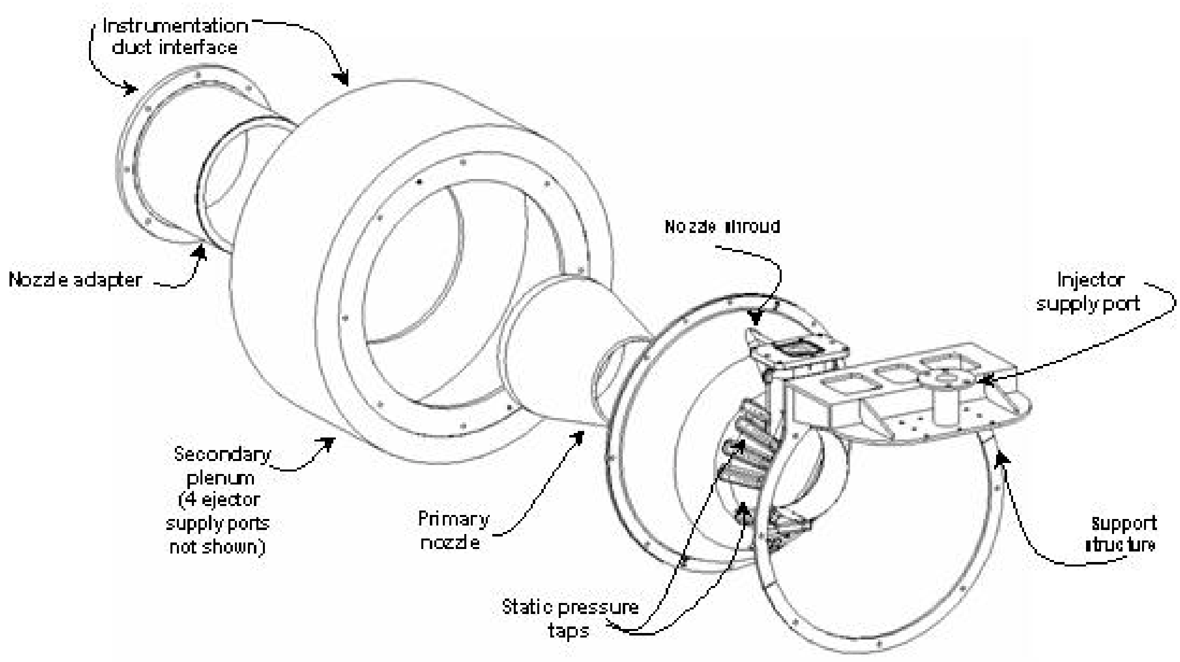
Mr. Michael A. Barga

Mr. Barga is responsible for all demonstrator engine core testing for the turbofan/turbojet class of engines in support of the national DoD and NASA Integrated High Performance Turbine Engine Technology (IHPTET) Program. Over the past year, two core engines have been in the preliminary design phase, a third was in the assembly and instrumentation phase, and a fourth was on test. Despite this high level of activity, Mr. Barga flawlessly executed his responsibilities. In addition to his duties as the ATEGG Group Leader, Mr. Barga is the technical leader of the JSF F136 ATD Program, one of the largest ATDs in AFRL. This ATD will transition technology to the JSF F136 engine. The program will provide the technology to allow the JSF F136 engine to meet performance requirements, reduce weight by 78 pounds, and decrease life-cycle cost by $1.3 billion. Mr. Barga's dedicated service as the ATEGG Group Leader makes him a worthy recipient of this award. (R. McNally, AFRL/PRTP, (937) 255-2278)

NOZZLE TECHNOLOGY LINER PROGRAM: The Pratt & Whitney (P&W) PRDA VI Nozzle Technology Program was a one-phase, two-part program designed to enhance nozzle technology in areas that mitigate risk and mature the critical nozzle technologies necessary to achieve the Integrated High Performance Turbine Engine Technology (IHPTET) Phase III goals of reduced cost, weight, durability, cooling, and leakage. The first part of this program was devoted to a third generation Advanced Metallic Liner (AML) cooling liner task. The design concepts developed under this part of the program were specifically directed toward the IHPTET Phase III goals. The second part was the Integrated Fixed Aperture Nozzle (IFAN) aerodynamic verification test. This test was designed to determine the nozzle aerodynamic thrust performance, fluidic thrust vectoring capability, and nozzle flow field characterization of an advanced thrust vectoring axisymmetric exhaust system. Both the metallic

Shroud hardware used during testing

and the CMC liners show significant potential to reduce overall system cost. Significant drivers to this liner selection are the manufacturing costs and the trade factors chosen. It is recommended that additional life cycle cost analysis be done on the system of choice to verify the ranking of the designs. Within the design accuracy of this study, many options were similar in merit. The performance verification testing of the IFAN nozzle concept highlighted several key aspects of the design that will require additional study and potential design adjustments to enhance the overall performance of the nozzle. The test results showed that increasing the shroud divergent angle improves ejector pumping, but thrust performance is degraded if the length of the shroud is not shortened accordingly. The details of this tradeoff need to be better understood to evaluate the impact to the overall nozzle performance. Due to an uncoupling of the primary flow with the injected flow, the intermediate power thrust vectoring was found to not measure as high as originally predicted. This reduces the magnitude and surface area of pressurization caused by the injected flow. At the maximum augmentation simulation condition (small ejector slots), the pretest predictions agreed well with the models, suggesting that some aspect of the flow physics changes as the ejector slot increases in size. This phenomenon needs to be studied to develop improved design tools and models to support robust nozzle design activities. The P&W Nozzle Technology Program has achieved its purpose by advancing the technology foundation for advanced liner designs and cooling schemes, as well as identifying through testing and analysis critical gap areas in the understanding of fixed-aperture, fluidic vectoring nozzle aerodynamics. These results provide firm foundation for continued development of fixed-aperture, fluidic vectoring nozzles with advanced liner systems that will play important roles in IHPTET and the Versatile Affordable Advanced Turbine Engines (VAATE) Programs. (S. Panzardi, AFRL/PRTA, (937) 255-4867)



Exploded view of test hardware

COMPACT PULSED POWER MURI ANNUAL REVIEW: The second part of the Multidisciplinary University Research Initiative (MURI) annual program review on compact, portable, pulsed power was held in Hollywood, California, on 1 and 2 July 2002. This review was collocated with the Institute of Electrical and Electronics Engineers (IEEE) International Power Modulator Conference. The two-day review agenda included presentations from the government review panel members, US industries, and two contractor consortiums. The presentation by the DoD laboratory representatives outlined the requirements for compact pulsers in their programs, with several common goals and pulsed power requirements identified which could be met by MURI objectives. Although the switch speed (2-10 ns rise time) and the switch voltage requirements were relatively closely bracketed in the 30 kV-100 kV range, the repetition rate requirements varied widely from hundreds Hz frequency up to several kHz. Similarly, the peak power requirements varied from 1 MW to several GW, and average power (energy) from a few joules to tens of kilojoules. It is not clear if this MURI Program can meet all of these requirements ranges, although an excellent opportunity exists to develop compact pulsers for improving plasma-assisted ignition and flame holding in very high altitude and high speed combustors (e.g., SCRAM) by leveraging MURI funding with 6.2 and SBIR/STTR contracts. (B. Ganguly, AFRL/PRPE, (937) 255-2923)

COMMITTEE MEETING FOR GASEOUS ELECTRONICS CONFERENCE: The semi-annual executive committee meeting of the Gaseous Electronics Conference (GEC) of the American Physical Society (APS) was held in Minneapolis, Minnesota, on 28 and 29 June 2002. The meeting agenda included conference abstract sorting, conference session organization, past and present year budget approval, and the selection of future conference sites. The change of conference date from October to September was also discussed. The 2004 meeting will probably be held in September of that year. A total of 271 abstracts were submitted to the 55th GEC, and approximately 35% of the abstracts are from overseas research institutions. Besides the normal business meeting agenda, an additional discussion item included potential alignment of the GEC with the Division of Atomic, Molecular, and Optical Physics (DAMOP), other APS divisions, or to create an independently run multidisciplinary conference. The executive committee unanimously recommended aligning the GEC conference with the DAMOP. The final approval will be determined by a simple majority vote of the GEC members, not all of whom are APS members. (B. Ganguly, AFRL/PRPE, (937) 255-2923)