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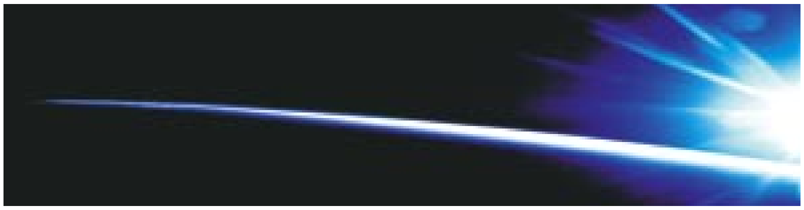
Manager of the Basic Research Investment for the Air Force



# Research HIGHLIGHTS

MAR APR MAY 03

## Research Leads to Lighter Weight UAV Nozzle

**Air Force Office of Scientific Research (AFOSR)-funded research has yielded computer-based models for fluid flows that are becoming key enablers for developing new capabilities for the Air Force.**

Thanks to advances in computational fluid dynamics (CFD), Lockheed Martin Aeronautics engineers are developing fluidic thrust control for aircraft that provide thrust vectoring with no moving nozzle parts. Many future unmanned aerial vehicles (UAVs) are tailless, and will depend on thrust vectoring for flight control. While conventional thrust vectoring may be achieved with a mechanical system using moving nozzle flaps, such as the F-119 nozzle, fluidic "fixed-geometry" thrust vectoring can result in substantial weight savings for aircraft. Lockheed Martin studies have shown that fluidic thrust control could boost control power for tailless UAVs, while slashing nozzle weight and cost by half.

Under AFOSR sponsorship, the University of Calgary and Lockheed Martin have collaborated on the development of CFD simulation methodologies which have been used to identify promising concepts for nozzle flow control. The simulations were used to study the effect of pulsed fluidic control jets on the nozzle flow. These fluidic injection techniques rely on the use of small control jets located in the nozzle wall to alter the flow direction of the nozzle stream by creating a "virtual" aerodynamic nozzle surface. The performance of this flow control technique depends on poorly understood relationships among numerous geometric and fluid properties. The challenge was to develop a concept that requires the minimum control jet airflow to achieve the largest thrust vector angle.

A systematic study of both steady and pulsed-injection jets blowing into a nozzle crossflow was undertaken using CFD methods. The CFD methodology involves dividing a flowfield into discrete volumes, or grid cells, and then applying a numerical algorithm with mathematical relationships governing fluid motion and a model of turbulent flow physics. Prior research from AFOSR grants with Princeton's George Mellor and Stanford's Parviz Moin have led to the development of physical models for turbulent flow that were used in these studies. The CFD tools allowed parameters such as injection momentum, frequency, and geometry, to be explored more rapidly and less expensively than would be possible in a purely experimental approach. The computational results were compared to experimental data taken at the University of Calgary. Those comparisons also guided the choice of computational methods, thus ensuring accurate predictions.

This work has already led to applied research efforts at the Air Force Research Laboratory (AFRL) to investigate thrust vectoring in structurally fixed nozzles. These tests have demonstrated thrust vector angles of greater than 10 degrees

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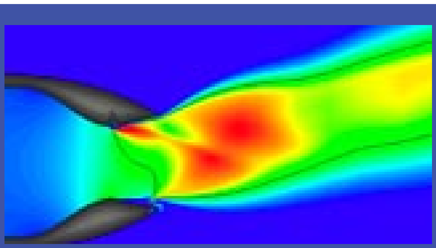

**ABOVE: Mach contours from a CFD solution of a fluidic thrust vectoring nozzle. By injecting a fraction (3-5%) of engine air from control jets inside the nozzle, a fluidic surface is created along the nozzle flap. This fluidic surface shape is actively controlled to steer the thrust without requiring moving surfaces.**

**BELOW: Future UAV designs often incorporate tailless configurations. These configurations will require thrust vectoring to provide adequate aerodynamic control authority for the aircraft. Fluidic control provides a lightweight, mechanically simple means of providing the required thrust vectoring.**

## Research Leads to Lighter Weight UAV Nozzle

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with good thrust efficiency. The predictive capability of CFD has been vital, since experimental evaluation of the many possible concepts would cost an estimated $1 million more in the preliminary design phase. Critical features of the control jet and nozzle design also have been transitioned to General Electric and Allison for an Integrated High Performance Turbine Engine Technology (IHPTET) effort to build large-scale hardware for an engine demonstration of fluidic thrust control. The Air Vehicles Directorate estimated a 30-50 percent nozzle weight reduction using fixed nozzles with this technology.

These basic research efforts on simulation and flow control techniques have already had a direct impact on the development of nozzle flow control technologies for Air Force Research Laboratory Programs. Future aircraft will benefit from the reduction of engine bleed air required for flow control, cooling flows and fluidic thrust vectoring. Unmanned aerial vehicles will enjoy improved engine performance and flight control.

**Dr. Thomas Beutner, AFOSR/NA**
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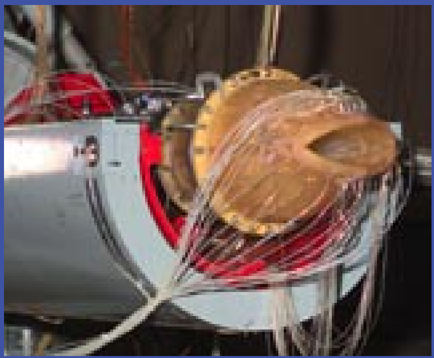
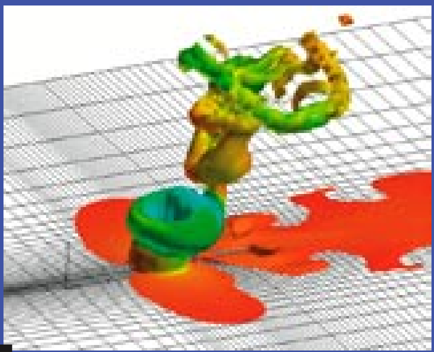
**Mr. Daniel Miller, Lockheed Martin Aeronautics Company**





# World Record for Silicon Light

**The world's third largest semiconductor manufacturer has discovered ground-breaking technology that allows silicon-based light emitters to match the efficiency of traditional light-emitting compound semiconductor materials such as gallium arsenide (GaAs).**

STMicroelectronic's new silicon-based, light emitting technology, which sets a world record for efficiency, can trace its creative origins back to important research conducted jointly in 1993 by the Air Force Research Laboratory at Hanscom and the Massachusetts Institute of Technology. The team's work in rare-earth doped light-emitting diodes lead the nation and inspired the STM's innovation, based on structure in which ions of rare-earth metals, such as erbium or cerium, are implanted in a layer of silicon-rich oxide.

The new technology opens up many potential applications in which optical and electrical functions are combined on a single silicon chip. Although silicon is ideal for building memories, microprocessors and other complex circuits, it could not be made to act as an efficient light emitter.

"The ability to combine optical and electronic processing on the same chip presents enormous opportunities," said GianGuido Rizzotto, STMicroelectronic's director of corporate technology R&D. "We have already identified a number of promising applications and key manufacturing issues have already been solved so that the technology can be rapidly moved into production."

One of the first applications of the new technology will be to build power control devices in which the control circuitry is electrically isolated from the power switching transistors. Currently, electrical isolation, mandatory in many applications for safety reasons, can only be achieved by using external devices such as relays, transformers or discrete optocouplers.

STM also has patented a novel structure in which two circuits, built on the same chip, but electrically separated from each other by insulating silicon dioxide, communicate via optical signals using integrated silicon light emitters and detectors. These devices will have numerous important applications, including motor control, power supplies, solid-state relays, and similar applications where the power circuit needs to handle much higher voltages than the control circuit.

Many of these innovations are possible because of the research funded by AFOSR over a decade ago.

**Dr. Gernot Pomrenke, AFOSR/NE**
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**TOP LEFT: Test hardware from AFRL and Lockheed Martin scale model tests utilizing the fluidic injection concept for thrust vectoring. Computational simulations were able to reduce test costs by examining many of the design variable tradeoffs prior to testing.**

**BOTTOM: A computational simulation of pulsed injection into a cross flow. A vortex ring is visualized just above the surface injection port using a constant vorticity surface with superimposed temperature contours. A weaker vortex ring from the previous pulsed injection cycle can be seen above this, and the vortex rings have begun entraining the surrounding fluid. Computational simulations not only provide a means of examining the design variables for pulsed injection concepts, they also provide researchers detailed insights into the mechanisms by which these actuators influence the primary flow field. The background grid shows how the flow field is partitioned into cells for the CFD simulation technique.**

# Aero-Propulsion Combusters

**Rolls Royce Corporation in Indianapolis, Ind. is incorporating new modeling capability developed from research supported by the Air Force Office of Scientific Research (AFOSR) to design combustors for future aircraft propulsion.**

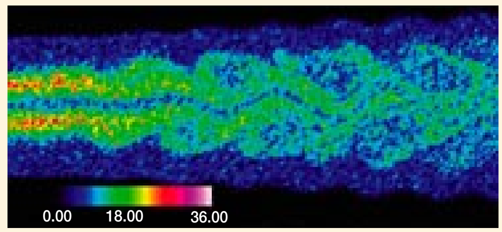
By taking fundamental aspects of a Large Eddy Simulation (LES) model for turbulent combustion formulated under the sponsorship of AFOSR by Dr. Peyman Givi at the State University of New York at Buffalo, Dr. Sunil James has created a LES-based combustor design model that many regard as the next major step in computational tools for aero-propulsion system design. The model is currently being applied and tested at the Rolls-Royce Corporation. Givi was James's professor at the university.

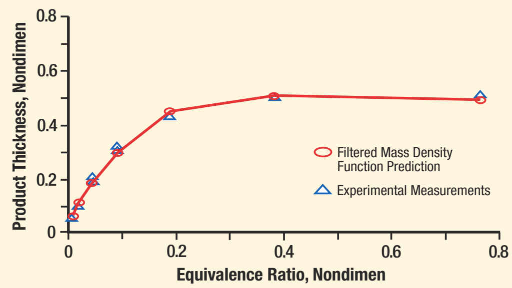
LES represents the next generation of models that offer the promise of delivering quantitatively accurate assessments of combustor behavior in a computationally-tractable manner. In the past twenty years, computational modeling has become an essential methodology for gas turbine combustor design, as well as for the design of combustors used in other chemical propulsion systems, including ramjets, scramjets and chemical rockets. Previous design approaches were based on trial-and-error testing that had proven to be costly, time consuming, and incapable of achieving optimum performance. Current computational modeling approaches use variations of the Reynolds-averaged Navier Stokes (RANS) approach to predict temporally-averaged parameters associated with combustor performance. While RANS models have been very useful for qualitative analysis of an engine's performance, they do not allow for a true quantitative predictive capability. Using the LES approach, future propulsion systems will offer stable performance over a wide range of flight conditions, while meeting the stringent requirements for fuel economy and emissions for both military and civilian communities.

LES models for turbulent combustion are being pursued actively in the combustion research community. LES solves the conservation equations for mass, momentum, energy, and chemical species at the largest physical scales of the combustor. It predicts the behavior of these parameters at the smaller scales of the flows below the resolution limits of the computational grid with approximate models — subgrid-scale (SGS) models. Dr. Givi has contributed a unique approach for SGS by a statistical treatment of the mass-weighted, small-scale properties of combustion in a scalar filtered mass density function (SFMDF). He has demonstrated both the accuracy and computational efficiency of this approach by comparing his prediction with experimental measurements for a turbulent mixing layer. Currently Dr. Givi is calculating the behavior of a turbulent jet flame as part of an international turbulent nonpremixed flame study.

Rolls Royce Corporation has produced aero propulsion system designs used on several items in the Air Force's inventory. Among those are the AE 2100D3 turboprop used in the C130J transport, the AE3007H turbofan on the Global Hawk surveillance aircraft and the F136 turbofan to be used on the F-35 Joint Strike Fighter. While large eddy simulations are not yet capable of application for complete combustor design, the interest shown in Dr. Givi's modeling effort by Rolls Royce reflects the growing industrial recognition of the need for and the viability of LES modeling as the next major advance in design methodology for Air Force aero propulsion combustors.

**Dr. Julian Tishkoff, AFOSR/NA, (703) 696-8478**

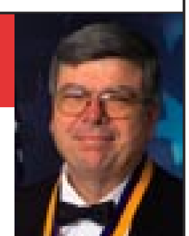



**LEFT, TOP:** Contours of fluid particle number density predicted by the LES-SFMDF model.

**LEFT, BOTTOM:** LES models show excellent agreement between theory and experiment.

# AWARDS: Dr. Bruce W. Suter



Dr. Bruce W. Suter

## ARTHUR FLEMING AWARD

**Dr. Bruce W. Suter was recognized as one of twelve outstanding public servants working in the federal government recently after receiving the 2002 Arthur S. Fleming Award.**

Sponsored by the Air Force Office of Scientific Research, Suter was honored for his achievements in both technical and managerial issues.

As a principal researcher at the Air Force Research Laboratory's Information directorate in information signal processing technology, he epitomized the best in scientific achievement through extensive personal study and collaboration with his peer group including professionals at the National Research Council, the Dayton Area Graduate Studies Institute, and many nationally recognized researchers in academia. These arrangements resulted in formal publication of advanced concepts in Hankel and Tchebyshev transforms and their application to a broad spectrum of scientific applications for improved information signal processing.

The Fleming Award was established in 1948 by the Downtown Jaycees to educate the public about the contributions young civil servants make to America. To date, only 400 people have had the honor bestowed upon them. Past Fleming honorees include Senator Daniel Patrick Moynihan (1965); Elizabeth Hanford Dole (1971); and Dr. Anthony Fauci, director of the National Institute for Allergies and Infectious Diseases (1979).

# AWARDS: Dr. Edmond M. Dewan

## DEWAN WINS BROWN AWARD

**Forecasting is something Dr. Edmond M. Dewan's knows about. However, its unlikely the man who created the template used to determine atmospheric weather conditions could have predicted his selection for the prestigious Harold Brown Award.**

Dr. Dewan, a member of the Air Force Research Laboratory's spacecraft technology division, was honored for creating an optical turbulence model that converts vertical profiles of atmospheric winds and temperature into vertical profiles of the optical turbulence parameter. Called by many, "the Dewan Model," it has been chosen to be incorporated into the Atmospheric Decision Aid to operate with the Airborne Laser Missile Defense System.

Dewan's model is especially significant to the Air Force because of its impact on the Airborne Laser (ABL) theatre missile defense system, scheduled to be deployed this decade. The effectiveness of this system will be strongly dependent upon atmospheric optical turbulence in the upper troposphere and lower stratosphere. For this reason there is a requirement for an optical turbulence forecaster. The ABL system is designed to destroy a theatre missile in the boost phase by means of a high-energy laser; but turbulence can diffuse, distort and deflect the laser beam. Thus, the ABL will be positioned relative to the target in a manner that will avoid as much turbulence as possible. To do this, it will make use of an Atmospheric Decision Aid (ADA). For this reason, and for use with future tactical high-energy systems, it is imperative to have a method to relate atmospheric weather parameters (like temperature, pressure, and wind profiles) to atmospheric turbulence.


Dr. Edmond M. Dewan

Dewan's model has already been used by the Air Force in conjunction with meteorological balloon observations in the Persian Gulf and Korean Peninsula, where it revealed a peak of optical turbulence associated with the subtropical jets there. His model, and its future improved versions, promise to be of crucial value for future Air Force optical turbulence prediction systems for many years into the future as new high energy laser systems are developed.

A recipient of the Guenter Loeser Memorial Award for lifetime achievement, Dr. Dewan has published 111 scientific papers and given more than 145 presentations.

His most recent honor is named for Dr. Harold Brown, the former Secretary of Defense under President Jimmy Carter.


## Research Highlights

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AFOSR would like to thank Drs. Thomas Beutner, Gernot Pomrenke, Julian Tishkoff, and Arje Nachman and Mr. Daniel Miller of Lockheed Martin Aeronautics Company for their assistance in making this issue possible.

*Research Highlights* is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

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