Air Force Research Laboratory

SUCCESS *Stories*

A Review of

2003

100th ANNIVERSARY OF FLIGHT

To receive more information about any of the success stories in this book or on the CD-ROM, or for other technical activities in the Air Force Research Laboratory, contact TECH CONNECT at (800) 203-6451.

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AFRL Success Story Program

Helping to maintain the Air Force's strong Science and Technology foundation one success at a time.

This year marks the 100th anniversary of powered flight and reminds us of the important role that science and technology has always played in our Armed Forces—and especially in our Air Force. Science and Technology represents the foundation upon which our former leaders built the Air Force more than 55 years ago, and it continues to lead the way into the 21st century.

Innovation and technology are key components of the Air Force's strong foundation. The imagination of the world's best and brightest minds—in government, industry, and academia—are what provides the best equipment, weapon systems, and ideas driving our organization. These success stories showcase some of the work accomplished within the Air Force Research Laboratory (AFRL) to turn science fiction into fact.

AFRL, headquartered at Wright-Patterson Air Force Base, Ohio, is the Air Force's largest employer of scientists and engineers—about 3,000, of which more than 800 have doctorate degrees in science and engineering disciplines. These highly skilled and motivated personnel are critical to our success in leading our government/industry/university team and in making technology breakthroughs. Our scientists and engineers push the limits of air and space, bringing critical technologies to new heights in their scientific disciplines.

You will find in these pages some of our most noteworthy success stories for 2003. These stories are just a sample of AFRL technologies currently under development. This year we have also added a CD-ROM that provides a link to the same information showcased in this book as well as other AFRL technology areas.

If you want to know more about a success story, please contact our technology clearinghouse, TECH CONNECT, at (800) 203-6451, and they will direct you to the appropriate laboratory expert. Visit our Web site at *www.afrl.af.mil*.

Introduction

The Air Force Science and Technology Success Stories herein often represent the combined effort of several scientists and engineers working as a team. The basic and applied research, plus the follow-on technology development described, are essential to the continued success of the Air Force mission.

Success Stories were selected from one or more of the following categories:

Support to the Warfighter

Technology that has potential for or has achieved application on a Department of Defense system in development or operation or that has provided "quick-reaction" response to problems or needs of field organizations.

Emerging Technologies

Major innovative technological advancements that offer significant potential for existing and future Air Force systems.

Technology Transfer

Technology that has transferred from the laboratory to the private sector, to include industry, academia, and state and local governments.

Awards/Recognition

Awards or recognition by the scientific community at large, concerning technology advancements in the areas of technology transition, technology transfer, or technical achievement.

Support to the Warfighter

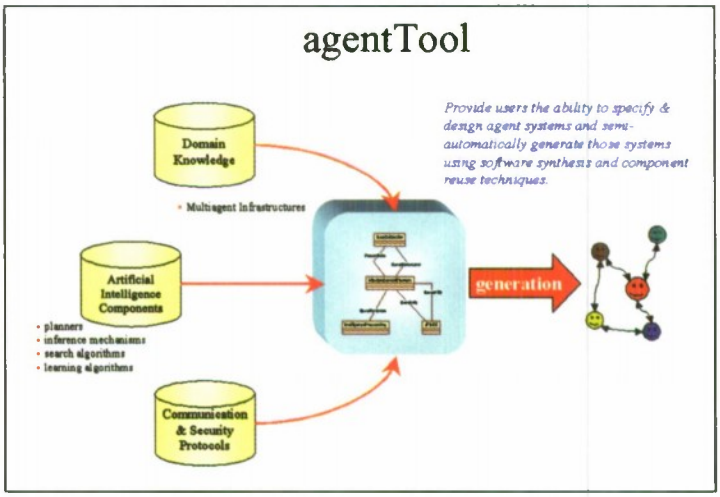
Continued on next page

Support to the Warfighter

Multi-Agent Distributed Goal Satisfaction Device

Payoff The Multi-Agent Distributed Goal Satisfaction (MADGS) device, a JAVA™-based, mobile-agent system, could help ease the burden of planning and executing large-scale missions. MADGS is a sophisticated system that fully understands how to retrieve, analyze, synthesize, and disseminate information to commanders on and off the battlefield. MADGS also factors in incomplete or uncertain information and addresses working with a large number of people, limited resources, external influences, and nearly every other conceivable obstacle.

Accomplishment Dr. Eugene Santos, an Air Force Office of Scientific Research (AFOSR)-funded professor of computer science and engineering at the University of Connecticut, developed a field-savvy, Palm Pilot-like device, called MADGS, loaded with advanced logistics system software. Armed with MADGS, leaders no longer have to worry about items sent to the wrong location—a factor in determining the success or failure of a mission.



Background AFOSR's Mathematics and Space Sciences Directorate sponsors Dr. Santos' team of scientists. This team includes Drs. Alexander Shvartsman and Steven Demurjian, at the University of Connecticut; Dr. Scott Deloach, at Kansas State University; and Dr. Michael Cox, at Wright State University in Ohio.

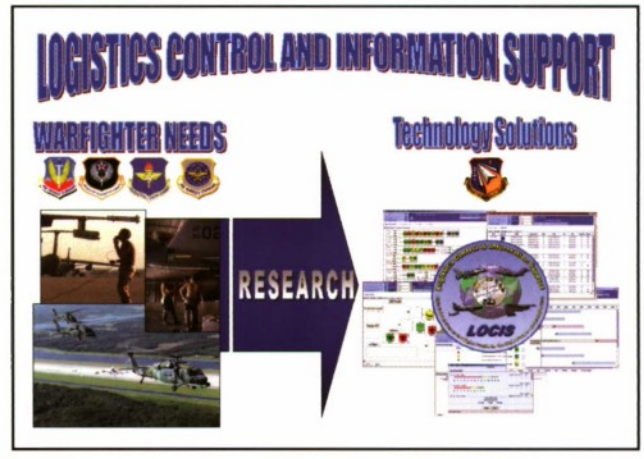
Dr. Santos' team developed software versatile enough for a general in battle or a mayor responding to a terrorist attack by forming a union of five components: Agent-Server (Carolina), mobile-agents, Distributed Goal Satisfaction (DGS), agentTool, and PRODIGY®. To make it work, Dr. Santos' team injected mobile-agents into the system through the agentTool to help the user analyze missions that require complex planning and execution. The DGS module provides users with resource alternatives to the PRODIGY-constructed master plan.

AFRL Technology Enhances Logistics Situation Awareness

Payoff The Human Effectiveness Directorate's Deployment and Sustainment Division recently conducted a field evaluation of Logistics Control and Information Support (LOCIS) Spiral 1 and Spiral 2 technologies with the 16th Special Operations Wing at Hurlburt Field, Florida. This evaluation demonstrated dramatically increased situation awareness of mission resources through advanced visualization techniques, data fusion, customizable user interfaces, and threshold monitoring and reporting.

Accomplishment The directorate's LOCIS research team conducted three preliminary field evaluations and a final evaluation, analyzed the data, and reported their findings. Personnel at Hurlburt Field widely accepted the LOCIS capabilities and used them daily to support deployment and sustainment of Operation ENDURING FREEDOM.

The LOCIS informational views provide a quick look of wing capability to senior decision makers and are used in lieu of briefing charts for maintenance stand-up meetings. This saves time searching for and assembling data into stand-up reports.



Background LOCIS is a 4-year proof of concept. The directorate's Logistics Readiness Branch developed the program, and the Agile Combat Support Division of the Air Force Command and Control Intelligence, Surveillance, and Reconnaissance Center at Langley Air Force Base, Virginia, officially sponsored the program.

LOCIS focuses on wing-level command and control for logistics. The program is researching and developing information technologies that will enhance the ability of the logistics community to effectively manage mission resources and assimilate logistics information for decision making in an Expeditionary Air Force/Agile Combat Support Command and Control environment.

The LOCIS effort consists of three yearly spirals, culminating in annual demonstrations where the team collects user feedback for the next spiral. The LOCIS field evaluation provided valuable warfighter feedback for improving LOCIS tools and created strong program advocates that are leading technology transition activities.

Crew Fatigue Quantified During ENDURING FREEDOM Airlift Missions

Payoff Human Effectiveness Directorate scientists and engineers (S&Es), in conjunction with Air Force Operational Test and Evaluation Center (AFOTEC) personnel, conducted an objective wartime aircrew fatigue assessment during C-17 missions to Afghanistan. Directorate S&Es expect the results of this assessment to lead to decreases in the approximately $54M in personnel, aircraft, and property lost each year in Air Force Class A mishaps related to warfighter fatigue.

Accomplishment As an integral part of the Air Mobility Command's (AMC) Counter Fatigue program, S&Es from the directorate's Warfighter Fatigue Countermeasures program, at Brooks City-Base, Texas, and AFOTEC, Det. 1, at Kirtland Air Force Base, New Mexico, conducted an objective wartime aircrew fatigue assessment during the round-trip C-17 missions supporting Operation ENDURING FREEDOM. These extended 22+ hour missions, with crews deployed from the continental United States, included multiple aerial refuelings.

This effort will provide a baseline for development of the AMC fatigue management policy. Data will also support the ongoing operational validation of the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE®) model that quantitatively predicts fatigue effects on human performance.

Background Data collection during the C-17 flights included the use of psychomotor tests, activity monitors, activity logbooks, and subjective fatigue self-assessments. Part of the analysis will include a comparison of actual aircrew work and sleep performance with predicted cognitive effectiveness ratings generated by the Fatigue Avoidance Scheduling Tool (FAST™).

The FAST software interface generates cognitive effectiveness predictions over time based on the SAFTE model. The SAFTE model is a homeostatic representation of the three-process, biological mechanisms that affect cognitive and physiological capability in humans. The model is the product of more than 12 years of extensive model development and comparisons of the model's algorithms to laboratory data collected during the past 20 years.

Problems associated with human fatigue are not limited to military operations. Air Force fatigue countermeasures research products also have direct application to more than 20 million Americans who perform shift work and to millions who experience the adverse effects of jet lag or even a night of disrupted sleep.

Spatial Audio Technology Reduces Risk for AWACS Transition

Payoff The Human Effectiveness Directorate developed and transitioned its spatial audio knowledge and software, which dramatically improves an operator's ability to discriminate among multiple communication channels. This software directly reduces risk for the Airborne Warning and Control System (AWACS) Block 40/45 fleet upgrade by demonstrating a communications system with many of the same attributes as those desired for the airborne platform. Among those who will use the system at Nellis Air Force Base (AFB), Nevada, are operators from the United States Air Force (USAF) Weapons School and the Combined Air Operations Center supporting the Joint Expeditionary Force Experiment.

Accomplishment The directorate collaborated with Compunetix, Inc., the Pittsburgh, Pennsylvania vendor selected to upgrade the communication system at the USAF Weapons School, to transition the spatial audio capability into Compunetix's hardware and software architecture. The 98th Operation Support Squadron at Nellis AFB, Nevada, selected Compunetix to provide a system nearly identical to the system previously installed at the Pacific Missile Range Facility, Barking Sands, Kauai, Hawaii.

The USAF Weapons School Command and Control Operations Division at Nellis AFB is the premier site for air battle management tactics instruction. This location will be optimal for showcasing the new capability to the entire command and control (C2) community.

Background AWACS controllers typically communicate in noisy acoustic environments during mission operations that exceed 20 hrs in duration. Battle managers routinely monitor up to five external and four internal communications ports (radios and intercom channels), discriminating which port is active by a combination of voice recognition and volume setting. The spatial audio technology gives the listener the impression that the voices on the different channels are coming from different directions with respect to his/her location.

With a spatial audio addition, operators experience intelligibility increases of 15-30% when azimuth separates the audio channels, as well as the ability to discriminate between multiple simultaneous radio/intercom communications. The directorate initiated the Virtual Air Commanders program to transition technologies that specifically benefit the airborne C2 operator's system interface. Spatial audio is one of the technologies specifically examined and tailored to that interface.

IPNVGS Increase View, Situational Awareness, and Protection

Payoff The Human Effectiveness Directorate's Integrated Panoramic Night Vision Goggle (IPNVG) system provides aircrew members with increased viewing and unsurpassed situational awareness at night, offers protection from lasers, and causes less neck fatigue during long missions. General Michael Ryan, former Air Force Chief of Staff, stated the Air Force needs panoramic night vision goggles (PNVGs) in the field...fast! This declaration prompted the recent transition of this technology to the Aeronautical Systems Center for system development, demonstration, and eventual production.

Accomplishment Night Vision Goggles (NVGs) offer tactical advantages in both air and ground arenas, but the currently fielded system—the AN/AVS-9—provides only a limited 40° circular field-of-view (FOV). The IPNVG, however, generates an intensified FOV that is one and one-half times larger than the AN/AVS-9.

The IPNVG achieves increased FOV by using four smaller (16 mm format) image intensifier (I2) tubes rather than the two traditional (18 mm format) I2 tubes. The IPNVG's ultrawide, 95° FOV significantly improves night navigation, targeting, weapons delivery, and search and rescue by allowing advanced tactics during night missions.

The IPNVG integrates laser-hardening technology, accommodates prescription and laser eyewear, and has a highly producible straight-through optical design in all four channels. The IPNVG eliminates some current maintenance requirements, such as purging with nitrogen every 90 days, and also incorporates numerous maintenance-friendly elements including separate but interchangeable parts for solder-free repairs.

Background Warfighters are evaluating the operational usefulness of the new IPNVG design on various Air Force platforms including the A-10, F-15, F-16, and HH-60. An extensive field survey showed that most pilots desire an increased FOV, but not at the expense of reduced resolution.

Previous day and night visual studies indicate the optimal FOV should be between 80° and 100°. To meet this requirement, the directorate initiated a Small Business Innovation Research (SBIR) program and produced a PNVG concept demonstrator.

The follow-on Phase II SBIR produced seven low-profile prototypes (PNVG Model I) designed for ejection-seat aircraft. The Phase II SBIR also provided five more prototypes (PNVG Model II), whose traditional NVG design complements existing NVG mounts.

Warfighters evaluated these systems on transport and rotary-wing aircraft as well as for ground personnel use. Directorate researchers collected performance data and obtained invaluable pilot design inputs after evaluating operational utility for Air Force warriors aboard multiple aircraft. These inputs provided the basis for the IPNVG program.

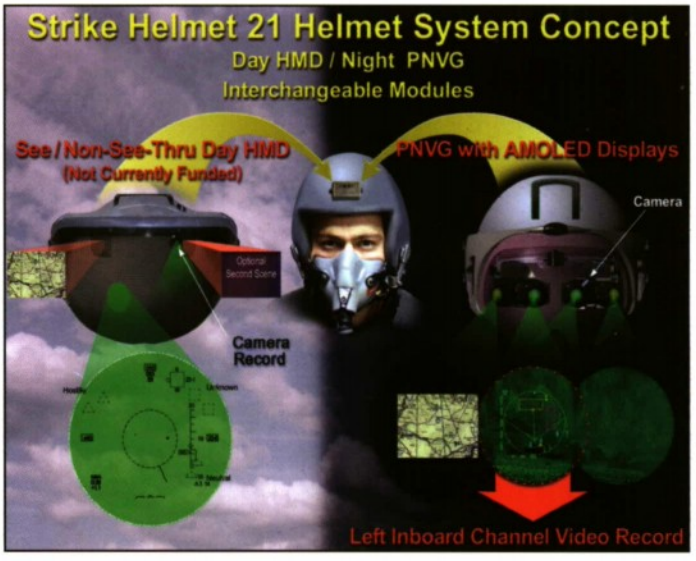
New Microdisplay Transitions to USAF and Industry

Payoff The Human Effectiveness Directorate transitioned a new type of microdisplay, ideally suited for use in helmet-mounted displays (HMDs), into the United States Air Force (USAF) Strike Helmet 21, Panoramic Night-Vision Goggle (PNVG), and Digital Knee Board programs as well as industry.

Accomplishment Current airborne military HMDs use miniature cathode-ray tubes (CRTs) to produce the images the pilot sees. However, these CRTs have drawbacks. They are bulky, do not emit light efficiently, cannot easily produce color, and require potentially hazardous high voltages.

The directorate created a microdisplay technology that overcomes these issues. Termed active-matrix organic light-emitting diodes (AMOLEDs), these new displays are small, thin, lightweight, low voltage, low power, and completely self-contained with their own video controller.

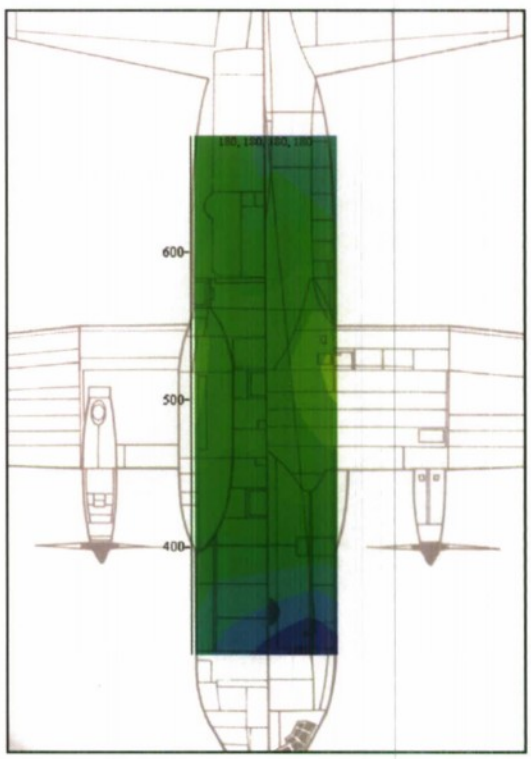
AMOLED manufacturers use the same techniques as those used to make semiconductors, so they produce displays in one continuous, economical process. AMOLEDs occupy minimal space and can run on battery power, maintain visibility in bright environments, and emit the same range of colors as a desktop CRT.



Background The directorate produced AMOLEDs through Phase III Small Business Innovation Research and Dual-Use Science and Technology programs. According to one estimate, more than 100 companies are pursuing this technology. Since the transition of AMOLED technology to the USAF, the US Army, and commercial contractors, far-reaching benefits are possible such as wide field-of-view PNVGs, high-definition television, three-dimensional game systems, and digital video disc players.

Active Synchrophaser Lowers C-130 Interior Noise Levels

Payoff The Human Effectiveness Directorate's Crew System Interface Division completed flight tests and analyses of the C-130 Active Synchrophaser System, which showed reduced interior noise levels by as much as 22 decibels (dB). Now for the first time, the directorate demonstrated reduced noise levels in four-engine propeller aircraft using a propeller synchronization technique.



Accomplishment Using four-engine C-130s, directorate engineers demonstrated that noise from one propeller could cancel out the noise from another propeller when properly synchronized. The decrease in sound is significant in reducing pilot and crew fatigue, in mitigating exposure to prolonged noise and elevated noise levels, and in retaining the ability to hear.

Background The propellers of C-130 aircraft emit a low, resonating tone, precipitating the need to reduce the acoustic signature. The directorate's bioacoustics expertise was key in that effort.

The directorate conducted in-flight and ground noise measurements of the advanced synchrophaser control unit to determine if controlling the propeller phase angles of C-130 type aircraft could reduce the noise. During the flight test, aircrew noted test points where cockpit noise levels were so low, they had to remove their hearing protection to be assured that the engines were operating. In fact, the directorate identified a 22 dB reduction in cockpit noise levels during that particular phase of the testing.

The directorate demonstrated a basic synchrophaser system for twin-engine aircraft in 1992, based on a manually tuned system with no phase control. Two years later, the directorate produced the first digital synchrophaser that controlled the propeller phase by regulating the fuel flow to obtain a 10-15 dB interior noise reduction in an OV-10 twin-engine propeller aircraft.

However, the C-130 Active Synchrophaser System uses acoustic feedback from microphones specifically arranged and mounted to the fuselage or by a personal computer-based controller to find the correct phase for reducing noise levels. The C-130 Active Synchrophaser System demonstrated that significant noise-level reductions can be accomplished for turboprop aircraft without affecting the basic aircraft performance.

Non-Distributed Flight Reference Off-Boresight Symbology Advances Warfighting Capability

Payoff Off-boresight attitude symbology improves the warfighter's situation awareness of aircraft attitude when performing off-boresight tasks such as air-to-air or air-to-ground maneuvers.

Accomplishment The Human Effectiveness Directorate's Visual Display Systems Branch developed a small footprint off-boresight attitude symbology called Non-Distributed Flight Reference (NDFR). The NDFR allows pilots to keep their attention out of the cockpit during tactical engagements and still maintain situation awareness of their attitude, thus yielding tactical and safety advantages. The directorate demonstrated the capabilities of the NDFR to a group of pilots at a technical information meeting and adopted it as the off-boresight attitude symbology for the Strike Helmet 21 program.

Background The development of off-boresight attitude symbology was an ongoing project within the directorate's Visual Display Systems Branch. Researchers modified NDFR by a series of in-house experiments. Each of these experiments compared NDFR to other off-boresight displays in various operationally representative tasks. In all cases, NDFR proved to give pilots the best situation awareness of their aircraft state.

Directorate engineers performed operational testing to assess the utility of NDFR in a variety of tasks including unusual attitude recovery, and air-to-air and air-to-ground maneuvers. In all three cases, NDFR proved most effective for giving pilots attitude awareness, allowing them to spend more time outside the cockpit to perform their given tasks.

Cockpit Accommodation Research Changes USAF Pilot Assignment Policy

Payoff The United States Air Force (USAF) utilized data from all USAF aircraft to assign pilot candidates of extreme body size to particular aircraft. This process avoids potential safety problems associated with aircraft/body size accommodation mismatches and expands flight opportunities for candidates who might otherwise have limited opportunities.

Accomplishment The Human Effectiveness Directorate measured approximately 30 test subjects of extreme body size in 24 USAF aircraft types to determine each aircraft's accommodation levels. Directorate researchers used these survey results, along with extensive anthropometric measures on all subjects, to predict the ability of people of extreme size to accomplish performance requirements as established by each USAF command.

The prediction equations developed from this research are quite good—accommodation levels in most high-performance aircraft are very close to original design specifications, people outside current entrance requirements for size should not be assigned to these aircraft, and some heavy aircraft can accommodate pilots of extreme size. The USAF Surgeon General's (SG) office uses these results to match pilot candidates of extreme size with specific classes or tracks of aircraft defined by their accommodation limits.

Background Air Force medical standards (AFI-48-123) require USAF pilot candidates to be between 64 and 77 inches in stature and 34 and 40 inches in sitting height. Directorate researchers use this population to set design parameters for most USAF aircraft cockpit layouts.

However, in the mid 1990s, the Joint Primary Aircraft Training System (JPATS) program set body size design limits for the T-6 at 58 through 77 inches for stature and 31 to 40 inches for sitting height. Initially, the USAF considered relaxing entrance requirements to make flight training more accessible to both larger and smaller candidates.

The directorate was involved in developing cockpit design and evaluation methods for many years, typically working with program offices on specific platform requirements and testing. The current study applied those techniques to an evaluation of all USAF fleet aircraft with the goal of setting new pilot selection criteria.

The directorate briefed the results to the Chief of Staff of the Air Force, the commander of the Air Force Materiel Command, the commander of the Air Education and Training Command, USAF/SG, and CORONA. The directorate also presented the results at several conferences and published those results as a USAF technical report.

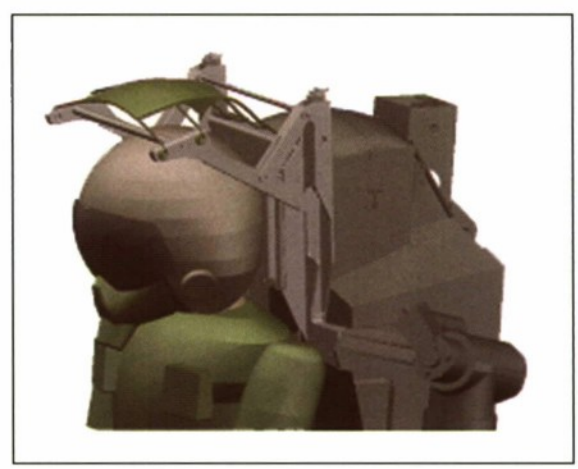
Passive Head/Neck Protection System Reduces Neck Injuries During Emergency Ejections

Payoff A new passive head/neck protection system should decrease major injuries and fatalities caused by aerodynamic-induced lift forces in the head/neck area for crewmembers ejecting at airspeeds to 600 knots equivalent air speed (KEAS).

Accomplishment The Human Effectiveness Directorate successfully led the development and demonstration of a passive head/neck protection system that deploys during emergency ejection and reduces injurious lift loads acting on the ejection seat occupant's head and neck.

Background Directorate researchers and contractors developed and demonstrated a seat-mounted flow stagnation design that effectively controls the lift forces on the neck and impact of the head with the headrest during emergency ejections to 600 KEAS. The system is stowed on the ejection seat during normal flight operations and deploys during emergency escape.

Directorate researchers and contractors placed emphasis on seat-mounted concepts to avoid crew encumbrance with the addition of aircrew-mounted restraint straps or helmet modifications. The effort has the potential to decrease neck lift forces to non-injurious levels during high-speed ejections for the expanded size and weight range of crewmembers from the small-frame female to the large-frame male.

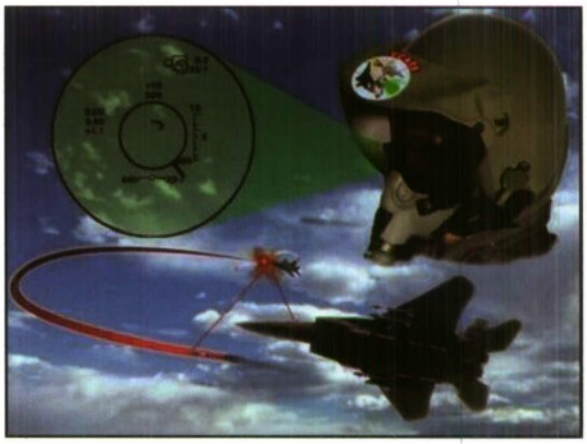


HMD Visor Transmissivity Modeling Promotes Target Recognition

Payoff Study of the transmissivity or see-through performance of helmet-mounted displays (HMDs) helps researchers to identify the key parameters that affect pilot target recognition range in a combat environment.

Accomplishment The Human Effectiveness Directorate's Crew System Interface Division derived a unique equation that describes the interaction of key parameters on see-through helmet visors. The directorate modeled, tested, and verified the expected results in the laboratory and in field studies before transitioning them to HMD programs for use in HMD and visor designs. The directorate's HMD test results demonstrate a very strong correlation between the model's predictions and field trial results.

Background HMD testing in recent years shows that the reflective coatings used to enhance symbology contrast on HMDs interfere significantly with combat pilots' tactical situation awareness—the ability to maintain visual contact with low-contrast targets and with allied formation members to the maximum possible visual slant range. Luminance contrast requirements for legibility of symbology on see-through HMDs are fairly well established. However, the directorate has not thoroughly investigated the see-through performance for HMDs to identify key parameters and their interaction nor determined their effect, if any, in a combat environment.



Division researchers began a thorough investigation that presented numerous challenges, such as deriving an accurate, useful quantitative expression for the effect of coatings on see-through helmet visors, and established measurement procedures that would accurately determine if the physical quantities involved would behave as described mathematically. Additionally, after receiving pilot confirmation that the laboratory results correlated with field performance, the researchers applied the field test results with respect to a pilot's ability to find, fix, track, identify, and maintain target identification and location during combat air maneuvers.

Distributed Mission Operations Effectiveness

Payoff The Human Effectiveness Directorate Warfighter Training Research Division's Training Systems Technology Team is providing valuable data to Air Combat Command (ACC) relating to the design and application of Distributed Mission Operations (DMO) systems for aircrew training. These data substantially enhance the effectiveness of DMO systems for fighter pilots and air weapons controllers by identifying the tasks and missions best suited for DMO, defining the system capabilities required for effective distributed training and creating a strategy for developing future training programs using DMO.

Research using DMO for Flight Leader Upgrade, Instructor Pilot Upgrade, and Fighter Weapons Instructor Course training programs is demonstrating the return on investment realized through the effective integration of learning objectives-based DMO syllabi with existing operational academic and live-flight aircraft training.

Accomplishment Structured interviews with F-16 instructor pilots and unit commanders indicated that many mission-qualified pilots lacked recent experience in four-ship tactics due to high cost, scheduling difficulties, constrained airspace, and very limited availability and interactions with Airborne Warning and Control System (AWACS) controllers. The directorate's Training Systems Technology Team developed and tested DMO training syllabi and measurement methods that augment live-flight aircraft training with high-fidelity, multiplayer simulation.

The training research syllabi involve the four-ship, F-16 DMO test bed, located in Mesa, Arizona, integrated with the AWACS simulation facility, located at the directorate's site at Brooks City-Base, Texas, and the constructive integrated air defense system developed and operated by the Air Force Information Warfare Center, Kelly Air Force Base, Texas. With the support of ACC's DMO office, the directorate conducted training exercises for mission-qualified F-16 pilots, supported by an instructor pilot and AWACS controllers.

Results demonstrate that complementing aircraft training with DMO enhances warfighter proficiency and reduces the need for repeating training flights at the home unit. In addition, the Fighter Weapons School syllabus served as the initial test and validation for new F-16 weapons employment standards implemented in the school. Validation in the Mesa test bed resulted in significantly more rapid evaluation and adjustment of the standards than possible, using live flight alone.

Background The Air Force's DMO program is a major advance in ground-based training that allows pilots and other warfighters to train for complex, multiplayer combat operations using a network of flight simulators and other systems. DMO is a shared training environment comprised of live, virtual, and constructive simulations that allow warfighters to train individually or collectively at all levels of war.

DMO allows multiple players at multiple sites to engage in instructionally valid training scenarios designed to focus on individual, team, and intra-team competencies development and refresher training within a realistic combat-oriented environment. DMO allows participation, using almost any type of networkable training device, from each weapon system and mission area.

Improved Laser Eye Protection Receives Safe-to-Fly Recommendation

Payoff Newly developed laser eye protection (LEP) stops a second visible threat wavelength to operational aircrews in addition to the far red and wideband near-infrared laser protection provided by previously fielded LEP.

Accomplishment The Human Effectiveness Directorate Directed Energy Bioeffects Division's LEP Team rapidly responded to an immediate operational need from the Air Combat Command Vice Commander (ACC/CV) to provide time-critical data, data analysis, and conclusions critical to obtain an unrestricted safe-to-fly (STF) recommendation for new, more capable LEP devices for the warfighter. The LEP team's quick response resulted in a provisional STF recommendation within a month and an unrestricted STF within 4 months of an ACC/CV tasking.

Background In August 2002, ACC identified an immediate need to expedite laser protection for aircrew and sensors. After presenting various options, ACC asked the directorate to accelerate ACC and Air Mobility Command aircrew evaluations of an improved LEP designed, developed, and demonstrated by the directorate. The improved LEP provides protection from a second visible threat wavelength.

ACC selected two formats for accelerated evaluations: (1) conventional spectacles for aircrew not requiring vision correction, and (2) clip-on articles for wear over aircrew-issued spectacles for those who do require vision correction.

Within a month after receiving the go-ahead from ACC, the directorate's military and contractor team collated, analyzed, and delivered results of laboratory data on physical, optical, and human visual performance of "Block 0+" LEP, an enhanced version of the current Block 0 LEP, to the 311 Human Systems Wing (HSW) Program Office in support of a provisional STF recommendation. The scientific data was of such quality that the 311 HSW immediately issued a provisional STF recommendation for wear of Block 0+ LEP while they accomplished final aircrew in-flight evaluations.

The directorate's contractor and government team accomplished final simulator, ground, and in-flight evaluations of Block 0+ LEP with C-17 and F-15E aircrews and provided the final data package and analysis to the 311th HSW. The C-17 and F-15E aircrews of the 437th and 315th Airlift Wing and the 4th Fighter Wing most frequently rated Block 0+ LEP either "highly" or "very highly" acceptable and never "unsafe to fly."

Human Effectiveness Study Helps Improve USAF Information Warfare Flights

Payoff A recently completed baseline study of US Air Force information warfare flights (IWF) highlights IWF issues and requirements and provides input to improve existing IWF procedures and requirements.

Accomplishment The Human Effectiveness Directorate conducted a baseline study to gather data to help the Air Combat Command, Air Intelligence Agency, and directorate researchers gain an understanding of IWF's missions, roles, and personnel. The study helped capture critical decisions, position-specific requirements, and internal/external coordinating agencies, and it included step-by-step procedures for many of the IWF positions.

The directorate used the data to aid the development of information warfare (IW)-related technologies for refining IW training requirements, standardizing IWF procedures, and creating criteria for the Air Force Inspection Agency's management reviews and inspections. The IWF data collection effort, including the task checklists, also received general officer-level praise and recognition.

Background The data collection consisted of two phases conducted at five continental US and outside-continental US IWFs. Results of the study provided input to improve existing IW tactics, techniques, and procedures; operational requirements documents; and IW system requirements, specification, and design documents. Additionally, the task diagrams evolved into task checklists, providing focus and guidance and prompting action for information operations planners during contingencies and exercises.

New Visor Offers Clear Improvement

Payoff A newly developed visor for flight helmets permits aircrew members to vary the visor's tint from 15–65% simply by turning a knob. The visor can also adjust itself automatically as lighting conditions change and operate for many hours off of a small battery. This unprecedented capability will allow pilots to optimize their vision and enhance the visibility of helmet-mounted displays (HMDs).

Accomplishment Researchers and engineers within the Human Effectiveness Directorate's Visual Display Systems Branch conducted a Phase II Small Business Innovation Research project with AlphaMicron, Inc. of Kent, Ohio, and developed a visor for the HGU-55/P flight helmet that varies its tint electronically.

Although the visor's original purpose was to increase the contrast of HMD images under bright daytime viewing conditions, it is also useful as a stand-alone alternative to conventional, fixed-tint visors. Commercial applications of the technology include sunglasses, ski goggles, and visors for motorcycle helmets.

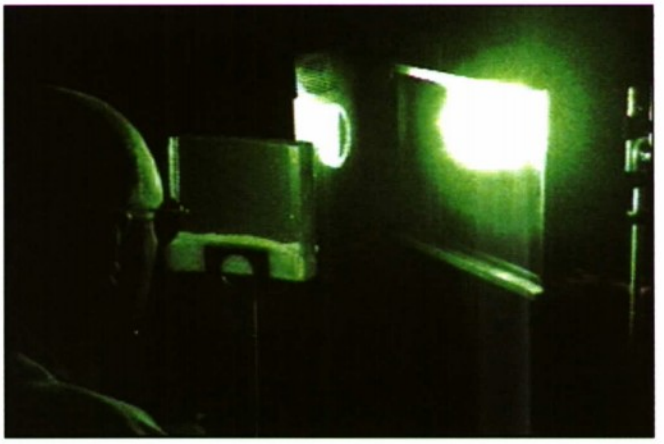
Background The new visor uses a thin layer of liquid crystals to control the orientation of dichroic dye molecules. This design provides fast switching speed, high optical quality, a wide array of available tints, and allows the visor to revert to its lightest tint state if power is lost.

Simulator Study Helps Validate Safety of PRK for Aircrew

Payoff The Air Force (AF) Surgeon General desired a test to determine whether photorefractive keratectomy (PRK) surgery could obtain refractive correction without impeding visual processing of static and dynamic stimuli in low-contrast and glare conditions. Since haze and glare effects may evolve over time, a meaningful test was needed to accommodate a longitudinal evaluation. Scientists at the Human Effectiveness Directorate employed a simulated cockpit to validate visual performance of aircrew after PRK laser eye surgery. Results of this study contributed to the AF Surgeon General's continued approval of PRK to correct myopia and astigmatism in aircrew.

Accomplishment Directorate researchers combined three visual performance experiments, using laser and broadband glare in the simulator, with other specialized tests measuring visual performance under aerospace conditions to answer the AF Surgeon General's question concerning aircrew safety after undergoing PRK. The simulator study helped validate the visual performance of aircrew under operational conditions after PRK.

Background The United States Air Force (USAF) has an ever-increasing number of aircrew requiring the use of spectacles for flying duties. Spectacle wear can create some significant compatibility issues with the unique life-support systems that are essential for survival in the aerospace environment.



For over a decade, the AF Surgeon General has approved soft contact lens for aircrew, but not all aircrew members can wear soft contact lenses. PRK is another alternative to spectacles and soft contact lenses and may offer some distinct advantages in operational situations.

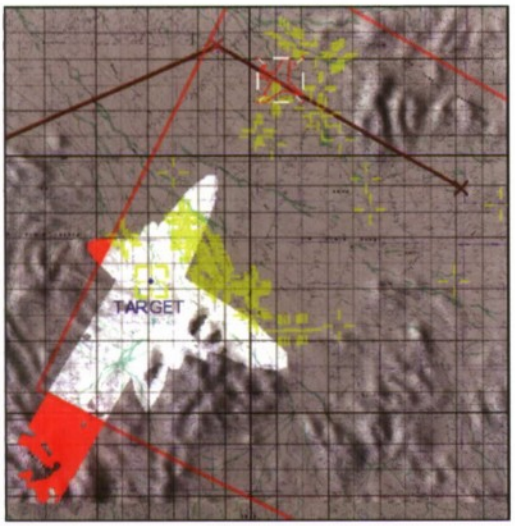
The USAF had concerns about the aeromedical and operational effects of laser surgery on the cornea. Other types of refractive surgery, including surgical keratoplasty procedures such as radial keratotomy, have resulted in corneal haze, diurnal refractive instability, excessive ocular glare, and change in prescription following prolonged exposure to altitude.

Standard visual acuity tests, which still comprise the primary basis for accession and retention in the military, may underestimate or completely overlook the potential threat from corneal haze and ocular glare. This indicated a need for new tests to evaluate the potential duty impact on the USAF.

Laser Range Management Software Fielded at Over 45 Ranges Worldwide

Payoff The Human Effectiveness Directorate's Optical Radiation Branch at Brooks City-Base, Texas, built a Laser Range Management Software (LRMS) system that allows for safe, realistic engagement with directed energy systems. LRMS combines technology and military combat tactics to identify laser surface danger zones on digital terrain range maps. The software provides operational planners the capability to develop missions that integrate the use of safe combat laser tactics.

Accomplishment The LRMS, running from a personal computer, calculates the laser surface danger zone (LSDZ), allowing aircrew to receive the most realistic laser delivery training. It provides visualization of LSDZs to avoid overlap of endangered species sanctuaries, manned positions, and/or uncontrolled land on a two-dimensional terrain map. Aircrew can effectively use laser designators and illuminators without fear of inadvertent injury to themselves or ground personnel. LRMS provides LSDZs for ground-to-ground and air-to-ground laser engagements so aircrews can also train with ground-forward air controllers who designate and illuminate targets. The software has also provided a basis for future research developments in advanced risk analysis.



LRMS is utilized at more than 45 Department of Defense ranges worldwide. The software is also used to perform more effective and efficient laser range safety surveys. LRMS reduces the size of old hand-drawn range LSDZs with greater accuracy and saves the range community $70K a year in laser range analysis time. Savings are increased with the continual creation of additional training ranges and drastic modifications to current ranges. During the past 10 years, the cost and time to complete a range survey has been reduced by about 40%.

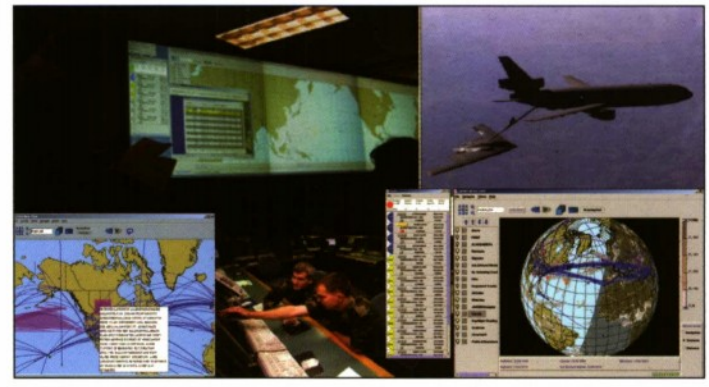
Background The use of military and commercial laser systems has grown rapidly during the last few years. Military lasers used by friendly forces provide a significant advantage in accomplishing military missions. Laser designators are a significant force multiplier that reduces the risk to aircrew and materiel. Laser illuminators and pointers allow aircrew, special operations, tactical ground personnel, and others to identify targets, enhance survivability, and reduce risk in combat. Effectiveness in combat requires realism in training.

A software solution was needed to help the range users train as they fight, using laser target designators for precision-guided weapons. In addition, the software must allow for the effective planning of range usage and quick-test mission safety planning as well as to act as a training tool for laser safety.

Visionary Technology Demonstration Supports Synchronized Air Force Operations

Payoff Demonstration of integrated information extraction, sharing, and presentation technologies provides vision for synchronized Combat Air Force (CAF) and Mobility Air Force (MAF) operations.

Accomplishment A joint Electronic Systems Center (ESC), AFRL, Air Mobility Command (AMC), and Air Combat Command (ACC) Team, with support from the Air Force Command and Control & Intelligence, Surveillance, and Reconnaissance Center (AFC2ISRC) and the Air Mobility Battle Lab (AMBL), conducted a demonstration that showed enhanced Air Force operations by providing command and control, and aircrew common situation awareness and proactive problem identification/resolution capabilities in accordance with the Global Strike and Global Mobility Concept of Operations (CONOPS). This effort was called the Global CONOPS Synchronization Demonstration.



The Human Effectiveness Directorate's Global Air Mobility Advanced Technologies, along with the Information Directorate's Integrated Flight Management/Advanced Technology Demonstration and Portable Interactive DataWall software and display technologies, played a central role in this demonstration. They provided new capabilities and efficiencies in information processing and flow, innovative visualization, common situation awareness, proactive problem identification, and support for rapid resolution to all command and control nodes and simulated aircraft.

Background Major General Craig Weston of ESC, tasked ESC to develop a visionary demonstration that would highlight the operational benefits of improved interoperability between MAF and CAF Command Centers and airborne aircraft. A joint ESC, AFRL, AMC, and ACC Team, with support from the AFC2ISRC and the AMBL, built and conducted a demonstration based on a Global Strike mission scenario involving a B-2 bomber mission launched from the continental United States.

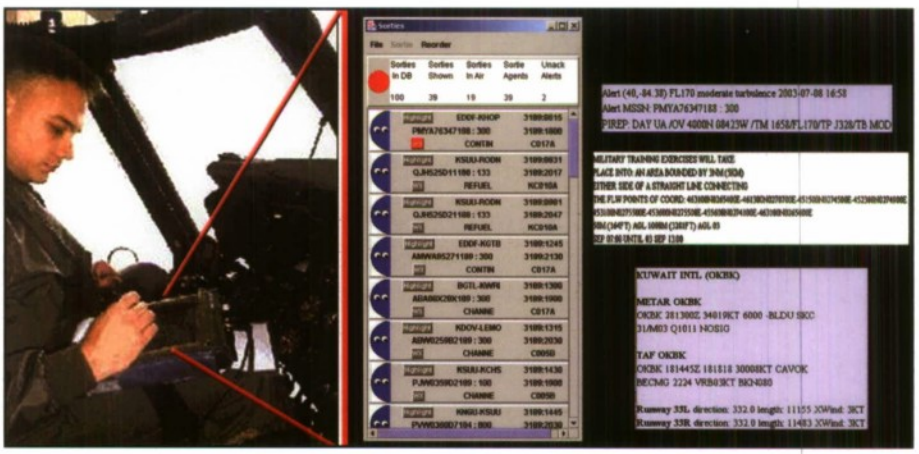
The B-2 bomber rendezvoused with multiple MAF tankers en route to the targets. Events en route (such as Notices to Airmen, changing weather, airspace restrictions, and retargeting) required rapid replanning and retasking capabilities. Communications and information presentation technologies enabled the synchronous coordination and retasking of both airborne assets and ground-based command and control elements.

Real-Time Weather Management Information Demonstrated

Payoff The Human Effectiveness Directorate and the Air Mobility Battle lab demonstrated the ability to proactively identify real-time problems due to changing weather conditions and provide that information directly to in-flight operators and aircrew. The directorate developed software called the Work-Centered Support System for Global Weather Management (WCSS-GWM), which was loaded onto an electronic kneeboard and used for the demonstration. The demonstration was provided to various Electronic Systems Center and Air Mobility Command (AMC) senior leaders.

Accomplishment The WCSS-GWM was developed under the Global Air Mobility Advanced Technologies program. The system was customized for an electronic kneeboard to demonstrate critically needed real-time weather management capabilities for in-flight aircrews.

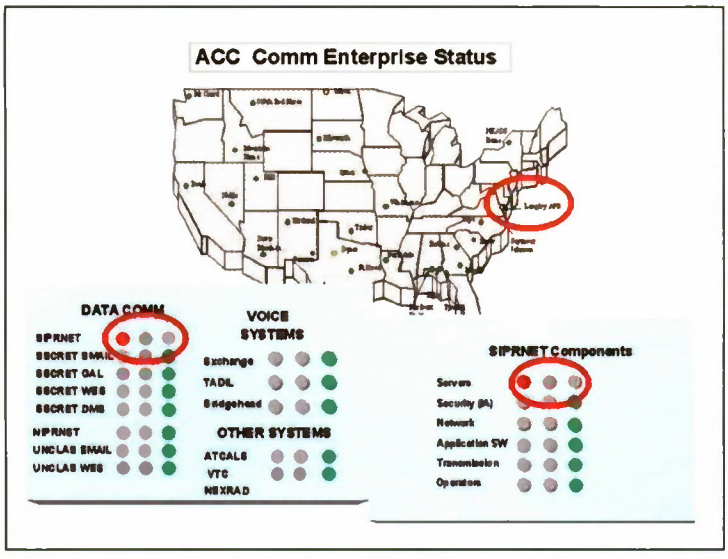
Background The WCSS-GWM software already provided AMC's ground-based command and control (C2) operators the ability to anticipate and resolve potential impacts on missions due to changing weather conditions. The electronic kneeboard was developed under the Air Mobility Battle Lab's Real-Time Information in the Cockpit initiative. An electronic kneeboard is a tablet-based computer that is envisioned to replace the paper-based kneeboard currently used by military pilots.



The demonstration used the WCSS-GWM software, electronic kneeboard hardware, and a simulated ground-to-air link, which reflect the typical communications link between ground-based C2 nodes and AMC aircraft. The demonstration illustrated how this combination could be used to proactively identify and simultaneously alert AMC's C2 personnel and aircrew of "pop-up" weather hazards. Additionally, airfield weather conditions and forecasts, as well as relevant Notices to Airmen information, were sent to the electronic kneeboard to enable C2 operators and aircrew to rapidly identify problems and jointly carry out necessary replanning actions.

Air Force Communications Enterprise Management System

Payoff The Information Directorate's Air Force Communications Enterprise Management (ACEM) system provides a tool to display high-level status of the entire communications enterprise, the overall status of a mission's communications enterprise, and the communications status for each of the mission's functional areas. The ACEM manages data networks (routers, servers, hosts) and communications systems that are not network-aware such as flight-line systems, transmission systems, and switching systems (voice/video switches, multiplexers, fiber and wireline systems, radios and radio nets, and satellite communication systems).



This Web-enabled software system provides visibility into the communications enterprise for any level of interest. The ACEM alleviates the current "stovepiping" of communications management and control tools by taking status information from these tools, consolidating and translating the information, and presenting overall communications status in an operational context, thus allowing personnel to know the operational impact of communications faults and attacks.

Accomplishment The ACEM builds comprehensive enterprise awareness by collecting information from existing tools as well as directly from information provider (IP) devices when needed and from non-IP devices. The ACEM's decision support function then allows the translation of this pool of technical data into relevant, mission-oriented views that are scalable from a Major Command perspective to a functional support concern (logistics) and even to an individual unit's area of interest.

The ACEM provides situational awareness of the entire communications enterprise and translates technical status information into a view of each organization's (Operations, Headquarters, Medical, and Support) communications health. This allows prioritized restoration of service and the best possible quality of service.

An ACEM server can obtain specific technical status information from each communications management tool and combine that with other ACEM status information to determine and present communications enterprise status in an operational, mission-oriented context. The ACEM objective is to allow anyone from the commander to the shift worker to access the communications status and the operational impact of faults and attacks.

Background The ACEM completed an operational demonstration at the Air Combat Command Network Operations Security Center, where it received and translated status information from the unclassified but sensitive Internet Protocol Router Network, the secret Internet Protocol Router Network, and non-IP devices. Currently, the directorate is integrating ACEM with the Multi-Domain Network Manager (MDNM), the Master Caution Panel (MCP), and the AF Enterprise Defense (AFED) to form the Command and Control Enterprise Management System (C2EMS).

The MDNM builds an integrated network management capability across multiple security domains (unclassified, secret, top secret, sensitive compartmented information, coalition). MCP provides situational awareness of command centers and application programs. The AFED provides intrusion detection and network defense. The C2EMS will provide situational awareness of the status of the entire C2 enterprise.

Flight Demonstration Showcases C2 Interoperability and Real-Time Collaboration

Payoff The Information Directorate, along with Boeing Phantom Works, recently concluded a successful flight demonstration of emerging information technologies that enable enhanced interoperability and real-time collaboration among command and control (C2) and strike platforms.

Accomplishment This new technology, developed under the Weapon System Open Architecture (WSOA) program (managed by the directorate), demonstrated advances in both C2 and strike platforms' ability to operate within a network-centric environment. Directorate engineers conducted the flight demonstration using Boeing's F-15E1 Advanced Demonstrator and a 737 Avionics Flying Laboratory.

The directorate's new technology transferred pictures of targets and updated threat locations within a minute from the 737 to the F-15E. A joint tactical terminal on the 737 provided satellite communication input for part of the simulated time-critical target scenario.

The WSOA program provides an open system architecture bridge across multiple legacy platforms to support timely, efficient transmission of situational-awareness information. The WSOA architecture leverages commercial middleware technologies and adaptive resource management technologies, developed by the Defense Advanced Research Projects Agency's (DARPA) Quorum program and the directorate, to increase interoperability over emerging tactical data links such as Link-16.

During the flight, Boeing illustrated both imagery support and the ability for C2 and fighter aircraft to share data in real time in order to retask en route strike forces in response to changes in mission priorities such as time-sensitive targets. Boeing also demonstrated full imagery downloads over Link-16 in less than a minute.

During the demonstration, Boeing passed target imagery, threat locations, and routing information to the F-15E. The F-15 weapon systems officer selected and downloaded target images and collaborated with the C2 operator by annotating over a common battlespace view to identify and attack the target.

Background The Air Force originally awarded the WSOA contract in 1999 to Boeing Phantom Works and its partners—Washington University of St. Louis, Missouri; BBN Technologies; and Honeywell. The directorate's Embedded Information Systems Engineering Branch manages the contract, sponsored by the Computer Resources Support Improvement program, DARPA, Open Systems Joint Task Force, and the Joint Tactical Terminal Program Office.

Information Directorate Helps Develop the WAVE of the Future for Exploitation of Weather Prediction Data

Payoff As any warfighter can tell you, weather can be your best friend or an absolute mission breaker. To address the weather issue, the Information Directorate helped develop a standardized Web-based interface between warfighter applications and a weather information service, using Internet hardware and software technologies. Weather Access for Visualization and Exploitation (WAVE) allows warfighters to incorporate weather forecasts directly within their computer-assisted, decision-making processes.

Accomplishment Decision-quality weather data is available, but not readily accessible, to decision-support applications. The process involves manual input, mental ingestion, translation, and exploitation, and it is cumbersome, slow, and error-prone.

Directorate personnel, working with the Command and Control Battlelab, Northrop Grumman Information Technology, and the Defense Information Systems Agency-chartered Joint Naval Meteorology and Oceanography Command (METOC) Data Standardization Working Group, facilitated the adoption of a Department of Defense Joint METOC Broker Language. This application programming interface (API) allows warfighter applications to automatically obtain numerical weather prediction data, produced and stored within the military weather weapon system.

WAVE is exploiting the new extensible markup language web service technology to provide warfighter applications with access to numerical weather prediction data available within the new Joint Weather Impacts System Environmental DataCube (EDC). The EDC is a by-product of the directorate's Joint Environment Exploitation Segment program.

Warfighter applications requiring numerical weather forecast data can request data from WAVE. WAVE parses the request, retrieves the desired data from the EDC, packages the results, and sends the reply to the requesting application.

Background The attributes and object structure of the API, designed by the WAVE program, were fully accepted. Prior to WAVE, there were no definitive plans to design or define a common API. Now, however, the Department of Defense is well on its way towards using a standard. As a result of implementing the standard and the attendant Web-service technologies, warfighters can visualize and exploit weather prediction data within their decision-support applications.

All-Purpose Remote Transport System Supports Force Protection and Active Range Clearance Activities

Payoff The All-purpose Remote Transport System (ARTS) provides the warfighter with a robust suite of tools to accomplish force protection and active range clearance activities. It allows the warfighter to stay out of harm's way since no human is onboard. All of the ARTS components are commercial off-the-shelf items designed to withstand intense conditions.

The vehicle's components allow technicians to make quick and inexpensive repairs when damage does occur and move the vehicle control computer and software package from one vehicle platform to the next, reducing duplication of effort while maximizing commonality across all platforms. The removal of the operator from the hazard area also reduces the requirement for expensive and bulky armor plating.

Accomplishment Engineers at the Materials and Manufacturing Directorate developed a low-cost, survivable platform capable of remote operations in a variety of mission profiles. ARTS, developed in cooperation with Headquarters Air Combat Command and the 99th Civil Engineering Group, Nevada Test Range, already established its value during range clearance operations and demonstrated great potential for success in force protection, fire fighting, natural disaster cleanup, inclimate weather operations, range remediation, and active range clearance.

Background Following the tragic incident at Khobar Towers in June 1996, Air Force officials identified a need for the ability to safely remove or disable terrorist bombs. Systems used at this time were too small to remove these improvised explosive devices or disable weapons of mass destruction in such incidents, so the directorate's Airbase Technologies Division began working on alternatives.

The division's Robotics Research Group, part of the Office of the Secretary of Defense Joint Robotics program, coordinates the Air Force effort to develop robotic technologies and systems that provide land forces with highly mobile, multi-mission, unmanned ground vehicles to achieve leap-ahead capabilities across a wide spectrum of mission challenges. With the support of a contract team, the directorate immediately sought to develop technology to respond to these critical real-world situations.

The ARTS is a modified version of a standard light construction tractor, the Posi-Track™ MD70, manufactured and distributed by All Season Vehicle, Inc., Grand Rapids, Minnesota. The platform has a four-cylinder, liquid-cooled diesel engine that delivers power to the 18-inch wide, Kevlar-reinforced rubber tracks through a dual hydrostatic transmission. The tracks have over 3,000 square inches of contact area, resulting in ground contact pressure of approximately 2 pounds-per-square-inch. This vehicle profile allows for a low center of gravity and light footprint, which makes the rugged and reliable vehicle the perfect candidate for range operations by minimizing forces that could detonate sensitive munitions.

The Air Force has seen significant success for ARTS, as explosive ordnance disposal specialists have used it for unexploded ordnance clearance and remediation. The Air Force currently operates several active bombing ranges where pilots train by dropping advanced and lethal anti-armor/antipersonnel weapons.

Materials and Manufacturing Directorate Engineers Brief American Air Forces

Payoff The logistics officers who attended weeklong logistics conference briefings are better informed and more adequately prepared to handle aging aircraft issues facing their nation's armed forces. They have a greater understanding of current and emerging technologies available from the US Air Force and AFRL. The knowledge and information imparted through the briefings will strengthen the defense of the Western Hemisphere, foster trust and respect for the Materials and Manufacturing Directorate, and help build strong professional relationships among the participating nations.

Accomplishment Directorate engineers briefed senior Air Force logistics officers from 18 North, Central, and South American countries, including the United States, Canada, and Mexico, on aging aircraft and available technologies to keep them flying. Directorate engineers translated their briefings from English into Spanish since most of the officers speak Spanish.

Background General Thomas D. White, the US Air Force chief of staff in 1961, conceived the idea to gather the commanders of the American Air Forces to strengthen friendly relationships and plan an effective professional cooperation system. The Air Force held the first conference in April 1961 at Randolph Air Force Base (AFB), Texas and in Washington DC under the heading Conference of the Chiefs of the American Air Forces, or CONJEFAMER, derived from Spanish—the conference's official language.

The commanders of the American Air Forces approved the acronym SICOFAA for the System of Cooperation among the American Air Forces in 1965 during the fifth CONJEFAMER gathering. Today, member nations know SICOFAA as the Constitutional Charter of the System of Cooperation among the American Air Forces. Membership in SICOFAA is voluntary, and there are currently 18 member Air Forces including the US Air Force.

CONJEFAMER, the annual decision-making conference that provides direction to the SICOFAA and implements the spirit of cooperation within the system, constitutes the ideal forum for the study of subjects of professional interest to the majority of its members. Because it brings together the highest military authorities from each of the member and observer American Air Forces, CONJEFAMER is the highest level meeting within the SICOFAA. The scope of the CONJEFAMER includes discussions and commander resolutions related to the organizational structure, missions, objectives, and functions of SICOFAA and its eight operational committees.

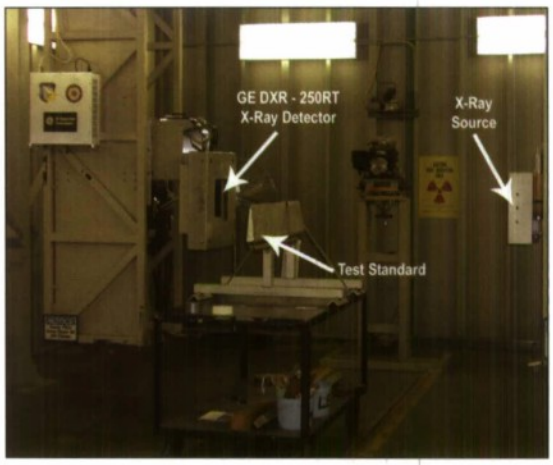
Mr. Bruce Rasmussen and Mr. Juan Calzada, of the directorate's Metals, Ceramics, and Nondestructive Evaluation Division; Mr. Steve Gerken, Mr. George Slenski, and Mr. Robert Ware, of the Systems Support Division; 2nd Lt Brian Smith and Mr. Mick Hitchcock, of the Manufacturing Technology Division; and Ms. Sally Chaney, of the directorate's Integration and Operations Division, played key roles in CONJEFAMER's first annual Logistics Committee Conference at Wright-Patterson AFB, Ohio.

Powerful Digital X-ray Flat-Panel Detector and Software Transitioned to OC-ALC for NDI Production Use

Payoff Digital X-ray flat-panel detector technology offers significant advantages over image intensifier systems because it exhibits higher resolution capability due to its enhanced software imaging tools and small size. This improves an inspector's ability to find anomalies in the captured image.

Accomplishment Engineers from the Materials and Manufacturing Directorate and the Aeronautical Enterprise Program Office (AEPO) transitioned a new high-resolution digital X-ray flat-panel detector system and its image processing software to Oklahoma City Air Logistics Center's (OC-ALC) Advanced Composite Repair Center Real-time X-ray Inspection facility. Funded by AEPO, OC-ALC non-destructive inspection (NDI) personnel will use this detector system for real-time and static radiographic production inspections of B-1, KC-135, E-3 horizontal and vertical flight control surfaces and B-1 structural control vanes. This system provides image archiving capability, enhanced performance, improved productivity, and best of all, higher resolution and sensitivity than previous digital detector systems.

Background NDI inspections are important because they eliminate the need for unnecessary maintenance and aircraft disassembly, which are time- intensive and can potentially create additional damage and problems in these Air Force systems. These inspections also pinpoint specific locations requiring maintenance actions. Therefore, better NDI systems can yield huge maintenance and cost savings for the Air Force.



X-ray radiography is an important NDI technique used to evaluate parts and assemblies for integrity during aircraft component manufacturing. Inspectors also use X-ray inspection in the maintenance of aging aircraft to inspect structures and honeycomb cores for damage, internal moisture, corrosion, and to evaluate intricate internal geometries in turbine engine components for cracking and inclusions.

Under a contract with AEPO and the directorate's Nondestructive Evaluation Branch, Marietta X-ray, Inc. (MXRI) evaluated and assessed the performance of various commercial off-the-shelf hardware and software systems from several X-ray detector platforms using aircraft components. MXRI evaluated the General Electric (GE) DXR-250RT flat-panel detector system and GE Radworks 5.1 imaging software and selected them to meet the inspection requirements of OC-ALC.

The system's transition also marks the completion of the third phase of the Digital Radiography Insertion Program (DRIP). The DRIP program focuses on transitioning digital radiography technology to address specific Air Force depot applications and improve NDI depot production capabilities and productivity.

Lean Value Chain Success Relieves Critical Part Shortage

Payoff At Oklahoma City Air Logistics Center (OC-ALC), the number of rotor overhauls the center could accomplish increased from 84 per month to 156 per month, while the average critical part resolution time decreased from 143 days to 61 days. At the Corpus Christi Army Depot (CCAD), helicopter engine overhauls increased from 10 per month up to 40 per month, while the engine cycle time through the shop decreased from an average of 326 days to just 176 days.

Management can now immediately identify inventory shortages with greater flexibility in scheduling subsystem overhauls. Lean Value Chain (LVC) improves visibility of aircraft status and forecasting capability, and better information allows for more effective management decisions. LVC also produced significant reductions in the number of critical parts, time wasted searching for parts, part inventories, and holding costs.

Accomplishment The Manufacturing Technology (ManTech) Division of the Materials and Manufacturing Directorate, in cooperation with KBSI, Inc. of College Station, Texas, developed an LVC program that has dramatically decreased critical part shortages for Air Force and Army depots. LVC's goal to reduce critical part resolution time by 50% was exceeded, improving the mission readiness of Air Force aircraft that use General Electric (GE) F100 series engines and the Army's Blackhawk helicopters by returning them to service from routine depot maintenance faster than before.

Increasing the mission readiness of weapon systems needed by the warfighter is the greatest payoff from the LVC program, but it is not the only one. In addition to the rate increase in rotor and helicopter engine overhauls, a significant cost savings was achieved. At OC-ALC, a 52% reduction in the number of rotor repair kits on-hand (from 436 to 208) resulted in an approximate $25 million one-time savings plus $4.5 million per year in recurring savings.

Background Management procedures for the repair parts' inventory proved inefficient at the OC-ALC and the Army's CCAD for helicopters. Critical part resolution time in the OC-ALC GE rotor repair shop increased to an average of more than 140 days. A critical part is any component, when unavailable, that stops the repair of a major weapon system subassembly, keeping that system out of action. Parts were critical for reasons like sole-source contract negotiation delays, delayed deliveries from the Defense Logistics Agency, and increased part condemnation rates due to age.

These issues meant the depots were unable to anticipate and identify critical parts in advance; determine the best course for timely, cost-effective critical part resolution; and monitor and accelerate the critical part resolution process. In response to this situation, ManTech funded the LVC for Critical Part Procurement project and received support from OC-ALC and CCAD. The implementation of lean principles, re-engineered processes, and advanced technologies through largely computer-based resolution strategies proved to be the solution, since they provided a more efficient method of running the depot operation.

Researchers Develop High-Performance, Metal-Polymer Hybrid Signal Wiring for Aircraft and Spacecraft

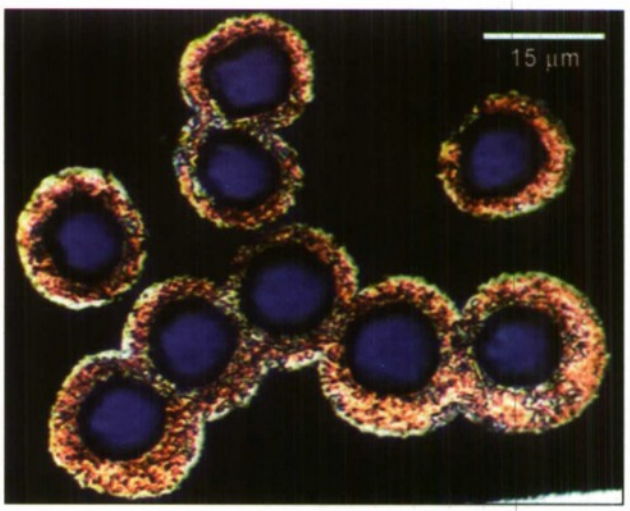
Payoff To date, researchers have successfully demonstrated the ability to combine high-strength, high-temperature polymer fibers with conductive metal precursors, resulting in the conductive, flexible, lightweight, and durable fibers needed to produce polymer signal and shielding wires. This technology demonstrates 300% strength and 50% weight advantage over copper wiring. Thus, polymer wiring shows significant potential for applications where flexibility, weight savings, and mechanical durability could increase the life, while reducing maintenance and costs associated with commercial and military aircraft and spacecraft.

Accomplishment Engineers at the Materials and Manufacturing Directorate, working with Syscom Technology, Inc. and Boeing under an Air Force Small Business Technology Transfer program, have developed a conductive, lightweight, mechanically robust polymer-based wire. Manufacturers could use this wire as an alternative to thin copper signal wire, and it may have other uses such as an alternative to aluminum braid wiring for electromagnetic interference (EMI) shielding for aircraft and spacecraft.

Background A typical Air Force bomber or transport aircraft has nearly 150 miles of power and signal wiring. In order for aircraft components to remain functional, wires within the system must be conductive and robust.

Aircraft maintenance workers have noticed the wiring commonly used in an aircraft's EMI shielding and signal-processing components can lose ductility and conductivity over time. Complicating matters further, insulation damage and corrosion result from heat generated by aircraft systems and exposure to fluids. Any malfunction within an aircraft's wiring could require untimely maintenance and impact mission readiness.

Directorate engineers are developing advances in preventative maintenance, interconnecting technologies, and new materials to meet the challenges associated with aging wiring and aircraft. Syscom Technology, Inc., along with Boeing-Phantom Works, has developed an alternative metal-polymer hybrid wiring.



The matrix material is a polymer fiber called poly p-phenylene benzobisoxazole (PBO), and Syscom prepares PBO from a nematic liquid crystalline solution. Syscom electroplates the high-performance polymer fibers with silver, copper, and nickel to form a high-strength, low-resistance, metal-polymer hybrid wire.

Syscom engineers developed the processing scheme, which is adaptable to large-scale production, and already produced 1,500 ft of the fiber. Directorate engineers are conducting a materials analysis to characterize the physical and electrical properties of the polymer wiring.

Engineers Develop First Response Expeditionary Fire Vehicle

Payoff The Materials and Manufacturing Directorate-developed First Response Expeditionary (FRE) fire vehicle bridges the gap between flight line fire extinguishers and full-sized crash and rescue fire trucks. The FRE vehicle is ideal for small aircraft and helicopter crashes, for hot pit refueling, and for tent city or deployed-base fire protection.

Directorate engineers designed the FRE vehicle to provide firefighters with a quick-reaction capability to extinguish small aircraft or structural fires before they become uncontrollable. Users can operate the vehicle with minimal training or experience. The FRE system is virtually maintenance free and is adaptable to a wide variety of mission profiles and vehicle platforms. In addition, the FRE vehicle occupies minimal pallet space on a cargo aircraft and offers reduced water requirements and equipment weight.

Accomplishment Directorate engineers have developed a deployable, lightweight vehicle that provides crash and rescue firefighting capability in a variety of mission profiles. The FRE fire vehicle, developed to meet Air Combat Command (ACC) and Civil Engineering requirements, has already established its value during Operation IRAQI FREEDOM when ACC deployed several of the units to protect helicopters, aircraft, tent cities, and other bare base operations.

Background The P-19 firefighting vehicle, using aqueous film fighting foam, is the standard fire truck usually deployed to remote locations for firefighting purposes. However, the P-19 is most effective in extinguishing two-dimensional (2-D), or pool, fires. Many times, pool fires become 3-D when fed by fuel or another flammable liquid coming from an aircraft's damaged fuel or hydraulic lines. This phenomenon makes the fire extremely difficult to extinguish.

In response to an urgent need for an easily operable, lightweight, air transportable, highly effective firefighting system, engineers at the directorate's Airbase Technologies Division, developed a system capable of effectively and successfully fighting both 2-D and 3-D hydrocarbon fuel fires.

The FRE vehicle consists of a Rosenbauer ultra-high-pressure water system with a 2-cylinder, 22-horsepower Briggs and Stratton engine and 1,500 pounds per square inch of pressure pump. The 60-gallon system provides 14 gallons per minute of foam/water to the aspirated/nonaspirated nozzle, which delivers the firefighting agents in either a mist, stream, or aspirated foam. The unit, fabricated by directorate engineers, uses a John Deere military gator as its vehicle platform.

Directorate engineers made several modifications to the FRE system to increase its effectiveness. These changes include modifying the original nozzle design to combine aspirated and nonaspirated foam functions, increasing the engine size to accommodate a higher flow rate, exchanging the foam tank for a standard 5-gallon foam can, adding a sump pump to draft water from alternative sources, and adding a 1 kW generator to operate additional tools.

The directorate delivered six prototype units to ACC and to the US Central Command Air Forces. They plan to provide two more units to the Air Force Special Operations Command. The directorate is transitioning this technology to Rosenbauer America, who will make the system available for additional fire protection and crash and rescue efforts.

Engineers Rapidly Prototype and Develop Airborne Engineer All-Purpose Remote Transport System

Payoff The Airborne Engineer All-purpose Remote Transport System (AE-ARTS) is a low-cost, survivable platform that augments explosive ordnance disposal (EOD) so personnel can easily, safely, and effectively clear unexploded ordnances (UXOs) and other debris from training ranges, air fields, and threat areas. AE-ARTS provides users a robust suite of tools with which they can accomplish force protection and active range clearance activities.

Accomplishment Working with Applied Research Associates, Inc., engineers from the Materials and Manufacturing Directorate modified the standard ARTS platform to support new requirements of the AE. The directorate rapidly prototyped, developed, and delivered the AE-ARTS to Headquarters Air Combat Command's Airborne Engineering Teams during Operation IRAQI FREEDOM for EOD, active range clearance, and debris-clearing activities.

Directorate engineers configured the AE-ARTS with new attachments including the Harley Box Rake and a remotely operated Enhanced Standoff Munitions Disruption system to dispose of small UXOs. The directorate developed and adapted a new laptop Operator Control Unit (OCU) with situational awareness and Global Positioning System tracking/location capabilities for the system. Each AE-ARTS also comes with a remotely operated clamshell bucket for clearing larger debris and obstacles from aircraft and other operating surfaces.

Background Engineers from the directorate's Air Expeditionary Forces Division developed the first-generation ARTS and shipped the unit to the Southwest Asia area of responsibility just after Operation DESERT STORM. The first-generation ARTS, a modified version of a standard light-construction tractor, had Kevlar-reinforced rubber tracks with over 3,000 square inches of contact area, resulting in ground contact pressure of approximately 2 pounds per square inch.

The vehicle profile allows for a low center of gravity and light footprint, which makes the rugged and reliable vehicle the perfect candidate for clearance operations by minimizing forces that could disturb a UXO. The VERTEK robotic conversion enables remote operation of all tractor functions including engine start/stop, propulsion, lights, and tool operation.

The standard configuration includes fixed video cameras and digital radios, which transmit command signals from the OCU to the vehicle, and an independent transmitter/receiver pair communicates audio and video from the vehicle to the OCU. The standard ARTS operator control station includes the operator console with command-input device (joysticks and switches) and video monitor, control station data encoder and transmitter, data and video receivers and antennas, and video/audio recorder.

Materials and Manufacturing Directorate Researchers Validate Capabilities of Hydraulic Fluid Purifier, Test Stand

Payoff Hydraulic fluid purification could reduce the source of the Air Force's second largest waste stream by 75 to 90% without negatively affecting the maintainability of aircraft hydraulic systems. Air Force implementation of purification processes should provide millions of dollars per year in savings by eliminating procurement and hazardous waste disposal costs.

The Air Force expects additional savings due to the simplification of the life cycle of the fluid and a reduction in quality-assurance testing. Using cleaner purified hydraulic fluid in aircraft hydraulic systems should improve reliability and extend the life of hydraulic system components in the aircraft.

Accomplishment Scientists and engineers from the Materials and Manufacturing Directorate's Nonstructural Materials Branch, recently participated in a collaborative program with program managers at Robins Air Force Base, Georgia; the Aeronautical Systems Center's Aging Aircraft and Pollution Prevention offices; and Malabar International to validate a new piece of hydraulic ground test and support equipment. Researchers verified that the system, a combination hydraulic ground test stand with a built-in hydraulic fluid purification system, is capable of reducing air, moisture, dirt, and solvent contaminants in used hydraulic fluid to acceptable levels in the required amount of time, and that used fluid can be reused rather than replaced.

Background Hydraulic fluids are critical safety components of flight materials for all Air Force aircraft. Hydraulically actuated mechanisms are responsible for a large number of aircraft functions ranging from highly sophisticated flight controls to accessory door actuation. The Air Force alone uses approximately 1,500,000 gallons of hydraulic fluid per year, costing more than $15 million in procurement and disposal costs.

Currently, during routine aircraft maintenance, Air Force mechanics drain and dispose of used fluid from aircraft and components. Recently, the Air Force changed the technical order covering hydraulic fluids to allow the reintroduction of purified fluid from an Air Force-approved purifier into the aircraft if the aircraft is authorized to use purified hydraulic fluid and if the hydraulic fluid has been purified.

Malabar International, a company based in Simi Valley, California, developed four similar hydraulic ground test and support purifier combination systems to meet varying Air Force requirements. Because every aircraft has redundant hydraulic systems, Malabar developed both two- and three-system test stands.

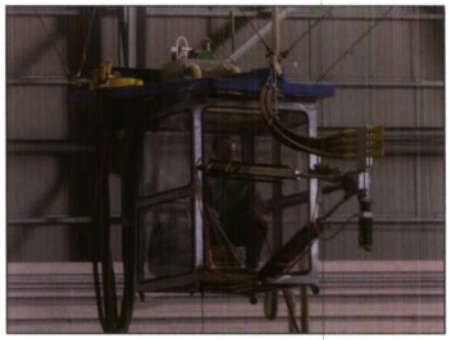
In aircraft with four hydraulic systems, as found in the B-2, Air Force mechanics can use 2 two-system test stands simultaneously to accomplish maintenance. To meet varying deployment requirements, they developed separate test stands that run on either diesel or electricity.

Electromagnetic interference testing of the test stand is the next step towards validation, followed by operational testing and evaluation of the test stand and purifier. If the tests are successful, Malabar will build and deliver 600 separate systems for the Air Force.

ManTech's AMP Provides Air Force Depots a Faster, Safer, Less Expensive De-paint Method

Payoff The Aerial Multi-axis Platform (AMP) creates a 40 to 50% reduction in the de-paint flow time and a 70 to 100% reduction in operator stress/injury, which results in a 20% reduction in overall cost associated with production paint stripping on large cargo airframes like the KC-135 Stratotanker. Using the current Air Force workload of more than 200 aircraft per year, with an average cost for de-paint of $200,000 per large aircraft, AMP has the potential to save more than $8 million per year.

Accomplishment The Manufacturing Technology (ManTech) Division of the Materials and Manufacturing Directorate, with the cooperation of private companies and the Department of Commerce, is developing AMP, a revolutionary new process for the stripping, or de-painting, of large airframes like the KC-135 Stratotanker.



Background The Air Force process for de-painting (stripping) large airframes, such as a KC-135, C-5, and C-17, has always posed problems, especially with workers and their equipment accessing every part of the aircraft. The existing equipment used for the process is difficult and time-consuming to accurately maneuver, causing frequent collisions with the aircraft. Additionally, environmental regulation changes over time have caused increased blasting time, leading to operator fatigue and increased risk of injury.

ManTech managed and co-funded the program under a cooperative agreement with US Technology Corporation, a noted leader in advanced de-painting technologies. US Technology integrated the program, partnering with AeroSystems, a manufacturer of overhead crane systems who used a technology, called the RoboCrane, developed at the National Institute of Standards and Technology.

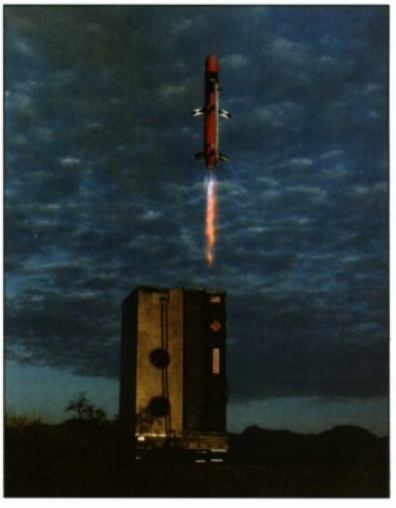
US Technology constructed and installed the prototype unit in a production facility at Robins Air Force Base, Georgia. They suspended the RoboCrane from existing hangar ceiling structures by six cables driven by six motorized winches, providing coordinated motion for the enclosed control booth.

The operator can move the sealed booth in six different directions: up, down, forward, backward, right, and left, reducing flow time by eliminating ground-based scaffolding, hoses, and other clutter that inhibits efficient movement and access around the aircraft. AMP will significantly improve the entire working environment of the de-paint program to include required preparation, and de-paint and de-prep tasks from the RoboCrane. Controlling the multiple (ganged) nozzles of the manipulator with a joystick, the operator can perform the abrasive blasting on large airframes faster, more safely, and at less cost.

ManTech Savors Initial Flight Test Success for MEMS-Based IMU in Precision-Guided Munitions

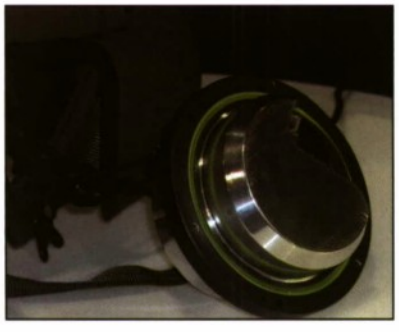
Payoff The HG-1900 Microelectromechanical Systems (MEMS)-based Inertial Measurement Unit (IMU), chosen for the NetFires Precision Attack Missile (PAM) program, represents reduced size and weight, needs less power, and is easier to produce and more affordable than any other existing tactical-grade IMU. This proven IMU is suitable for a wide variety of smart missiles and munitions of a smaller size, making it more appealing in improving surgical strike capabilities.

Accomplishment Officials from the Manufacturing Technology (ManTech) Division of the Materials and Manufacturing Directorate, have scored a huge success in the joint Air Force/Navy ManTech program—Affordable MEMS-based IMUs for Missiles and Munitions. The Army High-G MEMS IMU program builds on the success of the ManTech program by developing a G-hardened MEMS IMU, which will ultimately meet the performance requirements of 90% of Department of Defense (DoD) tactical munitions and missiles. NetFires PAM, when implemented, will provide the Army with extended-range precision munitions for deployable ground forces against hard targets such as tanks and command and control vehicles.



Specific Army ManTech successes include the transition from the HG-1900 to a high-G hardened HG-1920, the qualification of a new MEMS foundry, and reduction in overall piece part count and, thereby, price of the current IMU. By jointly working this program, the Army takes advantage of early Air Force/Navy successes and advances the MEMS IMU to DoD-wide applications.

During the 75-second flight, the PAM flew to an altitude of approximately 20,000 ft and successfully executed a number of test maneuvers using the navigation unit that consisted of the HG-1900 (MEMS-based) IMU, integrated with a Global Positioning System receiver. The demonstration also included success in updating the missile's guidance point in mid-flight, resulting in a successful intercept. With the success of this flight test, the Army's PAM developer, Raytheon, named the ManTech program's HG-1900, developed by Honeywell, as the baseline IMU for the NetFires PAM program.



Background Manufacturers use micromachining techniques to produce electrically driven, miniature mechanical structures called MEMS. In the case of silicon-based MEMS, such as those used in the HG-1900, the manufacturer performs micromachining using standard integrated circuit (IC) fabrication techniques. This allows silicon-based MEMS to leverage the existing IC industry, enabling the mass production of precision devices.

The MEMS-based HG-1900 is suitable for a variety of commercial guidance and navigation systems. A prime goal of the ManTech program has been to develop a MEMS process that allows for wider adoption and implementation through technology transition into the commercial arena as well as into additional military applications.

Advances in High-Temperature Composites Lead to Bleed Air Duct Cover Solution

Payoff Breakthroughs in high-temperature polymer matrix composites and a legacy of applying advanced composite technology to solve aircraft structural and service life challenges allowed researchers from the Materials and Manufacturing Directorate to quickly design an air duct cover to replace the older cover, which was degrading in the B-1B's high-temperature environment.

Researchers provided a material solution that is lightweight and performs successfully in a high-temperature environment. The new polyimide wrap is applied as a field-level repair during regular maintenance intervals, and it also provides the Air Force cost savings over the current practice of replacing the entire air duct structure when degradation in the old composite material threatens the integrity of the aircraft.

Accomplishment Directorate research scientists and engineers, along with the B-1B System Program Office (SPO) and Ogden Air Logistics Center (ALC), designed and prototyped a replacement cover for B-1B bleed air ducts. The ducts connect the aircraft's engine bleed air to a heat exchanger, and the cover is critical to keep volatile fluids from reaching a duct's hot surface, a situation that could prove catastrophic to flight operations. The new polyimide shell resolves duct cover degradation problems with the current duct cover.

Background The basic construction of a B-1B bleed air duct includes a metal duct structure, which is surrounded by a layer of insulation. Surrounding the insulation layer is a polymer composite shell made with a polymide resin. Air flowing through the ducts regularly reaches temperatures between 800° and 1,200°F. The shell is essential to operating the aircraft safely because it keeps volatile fluids separated from the duct's hot surface.

B-1B systems' engineers at Tinker Air Force Base, Oklahoma, contacted specialists at the directorate's Advanced Composites Office (ACO) at Hill Air Force Base, Utah, after they noticed that resin in the cover was deteriorating at the flanges where the polyimide material turns inward. This deterioration caused a significant and costly problem for aircraft maintainers because no repair procedure for the polyimide cover existed, so any duct in poor condition was condemned or replaced.

After consulting with experts from the directorate's Nonmetallic Materials Division, engineers at the ACO suggested that recently developed resin (AFR-PE-4) material characteristics qualified it as a candidate replacement for the degrading polyimide material. AFR-PE-4, a polyimide class material, is lightweight and has good thermal oxidative stability, which keeps it from degrading or burning at the elevated temperatures encountered in this application.

An ACO representative visited the directorate at Wright-Patterson Air Force Base, Ohio, to receive technical guidance and hands-on experience with the AFR-PE-4 material and its processing techniques. Using specific technical data gathered during collaboration with the directorate, ACO engineers used their expertise to design a new duct cover.

Ogden ALC at Hill Air Force Base, Utah, will manufacture and produce the air duct covers at their unique high-temperature-capable production facility. The B-1B SPO authored instructions that will enable air force maintainers to apply the new covers as a field-level repair during the B-1B's regular maintenance intervals.

Dynamic Two-Way Time Transfer Communications

Payoff Research in time synchronization performed by the Sensors Directorate extends current methodologies, such as the dynamic two-way time transfer (DTWTT), to airborne platforms using multiple communications scenarios. The specific implementation of the system lends itself to integration with standard and tactical communication links. It requires limited bandwidth and provides precise timing information without the need for costly equipment dedicated solely to time recovery.

Accomplishment In conjunction with Timing Solutions Corporation, the directorate successfully demonstrated a wireless DTWTT system having the first sub-nanosecond synchronization between an airborne clock and a reference clock on the ground. Implementations of the system included using satellite relays and line-of-sight communication links in the demonstration.

The system is Global Positioning System (GPS)-independent and a significant step forward for airborne timing users, nearly doubling current capabilities. Users can insert this technology into any architecture with communications links.

Background Static satellite time transfer, operational for nearly 20 years, required a dedicated communications channel. For approximately 6 years, the technology of time-based communications (TBC) embedded timing information into the background of active data communication channels to provide precise static time synchronization to those users with stringent timing requirements.

Users can implement TBC over most communication links, and it is applicable to both existing and planned communication systems. TBC is particularly attractive because it requires less than 4.8 kbps of bandwidth and typically occupies a minimal portion of the overall channel bandwidth.

In addition to its background capability, DTWTT is a wireless technology connecting ground-to-air platforms, and it only requires general knowledge of a platform's position and velocity. Researchers use this information in computing corrections to the timing data related to the motion of the platforms and rotation of the earth.

However, accuracies provided by GPS are not necessary, and the system demonstrated sub-nanosecond precision, using only the inertial navigation system of the aircraft. This represents a significant milestone in the fielding of an operational time synchronization system independent of GPS.

Active Flow Control Enables Safe Supersonic Weapons Release

Payoff Future generations of strike aircraft will almost certainly require the ability to release weapons at high supersonic and/or hypersonic speeds. This requirement demands the development of technology that will help stabilize the release of stores at these high-speed regimes. Through its groundbreaking experimental efforts, the Long Range Strike Aero experiment (LRSAe) has taken a huge step in proving the viability of active flow control as a solution to this problem.

Accomplishment The Air Vehicles Directorate, in cooperation with Boeing Phantom Works, successfully demonstrated the safe supersonic release of 10%-scale, 500 lb Joint Direct Attack Munition (JDAM) models from a rectangular bay using active flow control technology. The directorate conducted free-drop tests at Boeing's Polysonic Wind Tunnel in St. Louis, Missouri.

Through these experiments, LRSAe established a clear improvement of separation characteristics when they applied active flow control (AFC). The JDAM models in the baseline drops invariably changed direction immediately after leaving the bay, subsequently striking the bay while the runs with AFC consistently provided safe separation over a range of Mach numbers.

Background At supersonic flight conditions, the dynamic and unpredictable environment around the aircraft includes strong, unsteady shock systems and expansion fans—features which are not present at lower velocities. This is in addition to the turbulent shear layers, boundary layers, and separated flow that influence store separation at all flight regimes. These forces may alter the trajectory of the store towards the aircraft and cause a potential hazard to both the store and the releasing aircraft.

LRSAe's purpose is to develop flow control technologies that will eventually overcome the technical challenges associated with weapons integration on a supersonic platform. It has included several types of wind tunnel experiments using a 10%-scale weapons bay model and scaled Mk-82 JDAM models.

The directorate performed testing to demonstrate significant acoustic reductions achieved using several kinds of AFC devices. Grid survey testing showed significant differences between the baseline and AFC cases in the pitching moments applied to the store outside the bay.

Directorate researchers validated the results of this grid testing by a free-drop experiment where high-speed video captured the behavior of 12 stores released into the supersonic flow. The success of this wind tunnel entry prompted the addition of another test in which 40 weapon models were released. The combined results of all this experimentation show AFC as undeniably effective technology for enabling supersonic weapons integration efforts.

Automatic Air Collision Avoidance System Test Successful

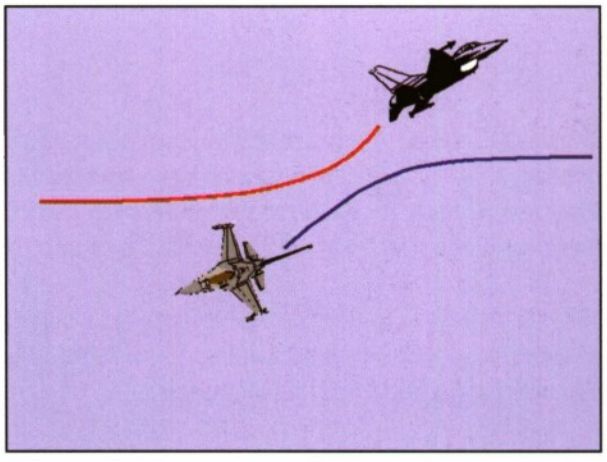
Payoff The automatic Air Collision Avoidance System (ACAS) uses Situational Awareness Data Link (SADL) data to determine if a collision is imminent and, if so, temporarily takes control of the aircraft away from the pilot for a very short time and steers each aircraft into an optimal escape maneuver. As soon as the aircraft begin to diverge, the system returns control to the pilot. If one of the aircraft involved is an unmanned air vehicle (UAV), then the UAV will always give ground unless otherwise necessary.

Accomplishment The Air Vehicles Directorate successfully tested the auto ACAS in two flight sessions held at Edwards Air Force Base (AFB), California. This particular block of tests focused on the SADL data link, a component of the ACAS located inside the aircraft that transmits data between itself and surrounding aircraft.

In all cases, the F-16 and the virtual target aircraft established the necessary data link and transmitted data between the two aircraft, and overall SADL performance improved during the course of the two sessions. Both US and Swedish pilots who have flown the auto ACAS simulations agree that it has potential as a valuable tool because it activates at the right time. They find it most beneficial during times when pilots lose sight of each other and do not realize a collision may be imminent.

Background The directorate developed ACAS as the first fully automatic air collision avoidance system for use in military aircraft. Previous collision avoidance systems were always manual—a tone gave the pilot a collision warning and the pilot performed a quick assessment and evasion maneuver.

However, a manually operated system would not work with fighter aircraft since normal pilot reaction time is too slow. The collision alarm would sound constantly during a typical, close-in, air combat scenario with multiple enemy and friendly aircraft. The ACAS allows rapidly maneuvering fighters to operate together without the concern of pilot reaction time.



The effort to develop the ACAS started in 2000 when officials from the US Air Force Safety Center at Kirtland AFB, New Mexico, wanted to look into the possibility of an automatic anti-collision system to prevent fighter mishaps. The safety center asked the directorate's Control Sciences Division to undertake this task because of its success in developing the automatic Ground Collision Avoidance System.

Other ACAS development team members included the National Aeronautics and Space Administration's Dryden Flight Research Center and Sweden's Forsvaret Materielverk. Sweden is looking into implementing the system into their Gripen fighter.

Restrictions on where UAVs can currently operate in the US are leading the effort to get unmanned aircraft outfitted with the ACAS. Currently, UAVs can only operate in limited areas or at very high altitudes over the country. In order for UAVs to be a fully operational part of the Air Force, they must fly to where they are needed and not depend on other transportation to get them there, even if it means flying in the same airspace used by private and commercial aircraft.

Bio-Inspired Algorithms Allow UAVs to Act as Teams

Payoff Just like geese, humans do not need complicated formulas to fly formations. Both geese and humans rely on simple rules coupled with simple communications and location information that interact to emerge the desired formation. The leader is the only vehicle that needs to know where its location is and where it is going; all other vehicles fly positions from the leader determined by simple rules, leaving their throughput free to run other algorithms such as threat locating or weapons management.

New bio-inspired algorithm technologies will allow groups of unmanned air vehicles (UAVs) to act as teams, similar to current manned aircraft. Embedding teaming capabilities will increase the UAV operator's span of control, decrease communication bandwidths, and increase operational flexibility.

Accomplishment The Air Vehicles Directorate's futuristic program exploring UAV strike package teaming is the Integrated Tactical Aircraft Control (ITAC) program, which has successfully demonstrated formation flight capability using biologically inspired multi-UAV control algorithms. These algorithms simplistically and elegantly capture how pilots fly formations while reducing system throughput and communication requirements, easing integration into real-world systems.

Formation management software agents collect the algorithms and integrate them into the greater ITAC architecture. The formation steering agent manages these steering modes, switching intelligently between them as commanded or as the situation requires.

The rejoin mode determines a trajectory for one vehicle to efficiently maneuver into formation with another vehicle and provides steering commands to the vehicle along that trajectory. The UAV operators switch between different turn modes to perform more energy-efficient maneuvering while in formation. Its creator received the prestigious Perkin's Award for in-house research excellence for this work.

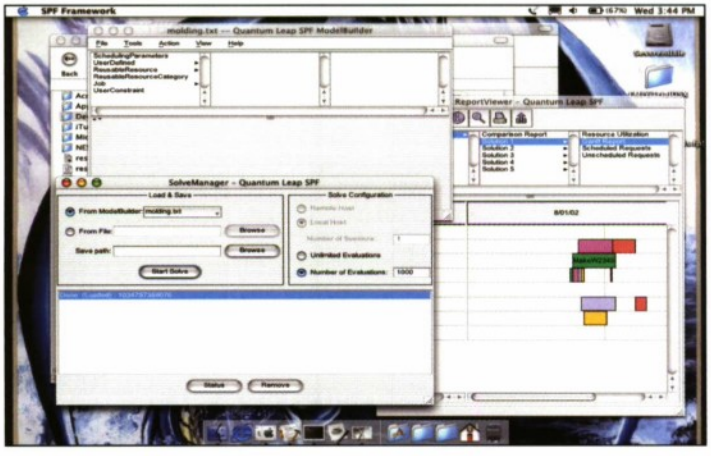
Background ITAC is the directorate's international, collaborative, autonomous control development program for multiple combat UAVs. Boeing and Dassault Aviation, in conjunction with the directorate and the French Ministry of Defense, jointly pursued the development of autonomous control technologies for combat UAVs.

The directorate is responsible for several of the software agents making up the ITAC software architecture. Besides the Formation Management Agent described above, the directorate also built the Vehicle Integrity Manager and System-Wide Integrity Manager, and they are currently transitioning these to other laboratory autonomous control technology development efforts.

AFRL Small Business Contractor Demonstrates Automated Solution to Complex Resource Scheduling Challenges

Payoff The Space Vehicles Directorate tasked Quantum Leap Innovations (QLI) of Newark, Delaware, with developing an intelligent software scheduling solution capable of solving complex scheduling problems in almost any domain. As a demonstration of the software's power and flexibility, the company developed prototype scheduling solutions for the Air Force Satellite Control Network (AFSCN) and the Space Lift Range System (SLRS).

Accomplishment The directorate awarded Phases I and II of Small Business Innovation Research (SBIR) grants to QLI to develop an artificial intelligence-based software tool capable of rapidly creating solutions to complex resource scheduling problems. The Scheduling and Planning Framework (SPF) provides an interactive graphical environment that allows the modeler to specify scheduling problems using scheduling concepts like jobs, resources, requirements, constraints, and objectives.



QLI integrated their patented optimization engine, the Problem Solving Engine, with the SPF to solve the resulting model. By comparing the trade-offs associated with the top five schedules, the scheduler can select a schedule that meets his changing priorities and constraints.

For the AFSCN, SPF scheduled 80-90% of one day's ground antenna-to-satellite contact requests in less than 1 hour. SLRS schedules are particularly complex, but SPF scheduled 50-60% of the requested launch range assets in less than 10 minutes.

In recognition of QLI's work, the company received the Small Business Administration's Tibbetts Award. The Air Force gives this award annually to approximately 65 companies out of thousands of SBIR program participants.

Background The SLRS consists of ground-based surveillance, navigation, flight operations and analysis, communications, and weather assets located at Patrick Air Force Base (AFB), Florida and at Vandenberg AFB, California. This mission provides the Department of Defense (DoD), the National Aeronautics and Space Administration (NASA), and commercial customers with a highly reliable, integrated system to support spacecraft launch, ballistic missiles, and aeronautical testing. The launch range scheduler must correctly allocate support personnel, fuel and fire trucks, tracking antennae, transmit frequencies, and even volumes of air space.

The AFSCN is a worldwide network of remote tracking stations that offers real-time satellite tracking, command relay, and telemetry reception for DOD, NASA, and commercial customers. The schedulers at Schriever AFB, Colorado, must attempt to provide support for 450-500 ground antenna-to-satellite contacts per day.

Active Aeroelastic Wing Parameter Increases Aerodynamic Efficiency

Payoff Active aeroelastic wing (AAW) technology can benefit future aircraft designs including unmanned air vehicles, advanced transports, and advanced fighter concepts such as future strike. Design studies have shown that the technology can decrease aircraft weight 5–20%, depending on the mission.

When applied to fighters, the AAW design approach enhances maneuverability by increasing wing control power and improves roll rate at higher dynamic pressures. AAW wings provide large amounts of roll power using conventional control surfaces while controlling air loads and reducing overall aircraft drag. In high-altitude, long-endurance aircraft, AAW technology can be used to alleviate gust loads and manage wing warping to increase aerodynamic efficiency.

Accomplishment The Air Vehicles Directorate, in cooperation with the National Aeronautics and Space Administration Dryden Flight Research Centers and Boeing Phantom Works, successfully completed the first phase of flight research for the AAW. The test platform was an F/A-18A, modified with a split, leading-edge flap drive system, a modified flight control computer, and a flexible wing with thinner skins that allowed the outer wing panels to twist up to 5°.

More than 1,600 sensors on the F/A-18A measured parameters such as control surface positions, wing deformation, structural strain, frequency response, and accelerations. Engineers will use this parameter identification data to develop new AAW flight control laws and design guidance for future AAW applications.

Background AAW is a multidisciplinary, synergistic technology that integrates air vehicle aerodynamics, active controls, and structures together to maximize air vehicle performance.

The concept turns wing aeroelastic flexibility into a net benefit through the use of multiple leading and trailing edge control surfaces activated by a digital flight control system. AAW techniques use air stream energy to achieve this desirable wing twist with very little control surface motion. The wing then creates the needed control forces with outstanding effectiveness. When AAW technology is applied correctly, the wing will twist less (although in an opposite direction) than a conventional wing twists during maneuvering. AAW technology will enable future designers to consider higher aspect ratio and thinner wings with less structural weight than current wing designs.

Munitions Directorate Helps Develop a New High-Performance, Low-Cost Steel

Payoff The patented Eglin Steel alloy, developed for hard-target penetrator purposes, has far-reaching military potential applications, ranging from missile parts to tank bodies to any weapon system whose main structural components require high strength and toughness. The commercial implications are numerous as well, since the alloy's high strength and toughness characteristics can increase the overall endurance of machine parts, allowing for much greater periods between replacements than conventional materials.

Eglin Steel alloy is easy to weld, making it an attractive choice for a wide variety of built-up sections. The future looks bright for this high-performance, low-cost composition as a very viable candidate for the Guided Bomb Unit-28 pre-planned product improvement warhead case material.

Accomplishment Using funding from the Dual Use Science and Technology program, Dr. Morris Dilmore, from the Munitions Directorate, and Mr. James Ruhlman, consultant for Ellwood National Forge Company, developed and institutionalized a new high-performance, low-cost steel, named Eglin Steel, along with the associated melting, forging, and heat-treating processes required to deliver superior mechanical properties. This material has great potential for both military and commercial use and already exhibits increased depths of penetration and improved stability over conventional materials in scaled testing of hard-target penetrators.

Eglin Steel is outstanding not only because it exhibits superior strength and toughness (the ability of the material to absorb energy without fracturing) to that of conventional penetrator materials that are currently used for warhead cases, but also because its cost is equal to or less than that of these traditional, lower-performance casing materials. In today's environment, cost is an important factor for all military systems, and Eglin Steel will allow potential contractors to realize a reduction in their material cost estimates, while increasing the material performance necessary to ensure program success.

Background Defeat of hard and deeply buried targets continues to be of great interest to the United States Air Force due to the ever-increasing challenge of destroying enemy assets housed either in tunnels or in deeply buried bunkers. In general, two avenues are available for destroying targets of these types: (1) an increase in the sectional pressure (weight per unit area) of a penetrator, and (2) an increase in penetrator impact velocity.

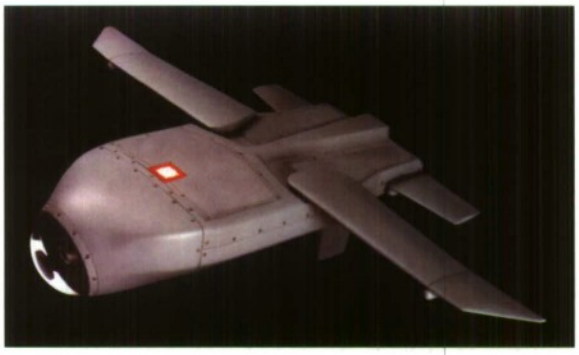
Increasing penetrator weight (cross-sectional pressure) is not an attractive choice, since the trend is toward smaller, more mobile weapon systems; therefore, an increase in impact velocity is the more desirable alternative. To survive high-velocity impact and destroy a hard or deeply buried target, the casing materials must exhibit excellent measurements of ultimate and yield tensile strengths, elongation, and toughness values.

About 4 years ago, the directorate, located at Eglin Air Force Base, Florida, initiated a program to develop a penetrator steel material having mechanical properties similar to current materials, with a corresponding cost reduction of up to 85%. Directorate engineers helped develop Eglin Steel with mechanical properties necessary to meet weapon performance requirements.

Powered LOCAAS Hits Target in First Complete System Flight Test

Payoff The Munitions Directorate successfully flight tested its powered Low-Cost Autonomous Attack System (LOCAAS), equipped with a multimode warhead. This marked the first time the system autonomously located, attacked, and fired a warhead at a target, meeting all test objectives.

Accomplishment The successful LOCAAS flight test represents a significant step in demonstrating an autonomous wide-area-search, miniature-munition capability for the warfighter. The technology demonstrated today offers the potential to transform the battlefield in the near term.



In this test, a test aircraft released LOCAAS over the Eglin Air Force Base, Florida range. After release and flying under its own power, LOCAAS used its onboard Global Positioning System/Inertial Navigation System to navigate to two waypoints prior to searching for the target—a relocatable surface-to-air missile (SAM) launcher. The Laser Radar (LADAR) seeker, automatic target acquisition algorithms, and guidance and control software worked together to provide the multimode warhead and fuze with information to time the arming sequence and mode selection, and time to detonate.

In the target area, LOCAAS rejected a non-target military vehicle intended to confuse the system, as could occur in an actual battlefield scenario. The LOCAAS acquired and correctly identified the target, tracked it, and detonated the warhead above the target at the appropriate time and location. Fragments from the warhead impacted and penetrated the SAM transporter/launcher/radar system.

Background Developed in conjunction with Lockheed Martin Missiles and Fire Control, LOCAAS is compatible with F-16, F-22, Joint Strike Fighter, B-1, and B-2 aircraft. The LOCAAS is a miniature, autonomous, powered munition, capable of broad-area search, identification, and destruction of a range of mobile ground targets.

LOCAAS is a low-cost LADAR sensor coupled with a multimode warhead and a maneuvering airframe to produce a high-performance submunition. LOCAAS can detonate the warhead as a long-rod penetrator, an aerostable slug, or as fragments, based on the hardness of the target. The LADAR allows LOCAAS to automatically determine target aimpoint and warhead selection. The powered LOCAAS uses a small turbojet engine to power the vehicle.

Canada to Implement +100 Fuel Additive

Payoff The +100 additive, developed by the Propulsion Directorate's Fuels Branch, minimizes maintenance associated with fuel degradation in aircraft engines and fuel systems. The +100 additive significantly reduces fuel-related maintenance costs for a wide range of military and commercial systems.

Accomplishment Canadian Forces recently announced their intentions to convert their ground-based air operations from North Atlantic Treaty Organization (NATO) F-40 (military JP-4) fuel to NATO F-37, also known as 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 United States and Denmark.

Background At the end of Canada's transition period, from F-40 to F-37, current F-40 suppliers in Canada, which include Shell 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.

Canada will not put +100 additive into storage tanks since aircraft not converting to the +100 additive will not be able to use the fuel. Canadian Forces will retain the flexibility to use both fuels. They will provide F-34 (JP-8) without the +100 additive to non-program or transient aircraft and will retain the F-44 (JP-5) fuel for shipboard operations.

Low-Cost Portable Wear Debris Monitor Developed for Turbine Engines

Payoff The Propulsion Directorate and the University of Dayton Research Institute (UDRI) can now diagnose potential engine bearing failures more reliably and quickly with cheaper and less bulky commercial off-the-shelf monitoring equipment, thanks to recent experiments. Flight line use of unwieldy and costly scanning electron microscope (SEM) systems may be a thing of the past with UDRI's more cost-effective alternative.

Accomplishment The directorate's Mechanical Systems Branch and UDRI developed a portable wear debris monitor that detects and identifies bearing wear debris in turbine engines. The device, based on X-ray fluorescence (XRF) technology, provides visual imaging, size measurement, and alloy composition determination. This detailed information allows flight-line personnel to track and identify wear debris taken from the engine's bearings and take appropriate maintenance actions to prevent lubrication system failures.

Background The XRF instrument is bench-top size and could potentially replace SEM technology currently in use for bearing debris analysis by the Air Force. The XRF would cost approximately 80% less than SEM instruments and weigh 72% less, while providing essentially the same capability.

The new commercial off-the-shelf system is also less expensive to maintain. Annual maintenance costs are approximately 85% less than the bulky SEM system.

Technicians could use the XRF system for commercial engine debris analysis as well as other industrial failure critical applications where metallic wear debris is available for examination. The directorate recently demonstrated the XRF for the Propulsion Product Group at Oklahoma City Air Logistics Center. The Air Force is considering the device for field demonstration in the upcoming Patriot 2003 exercise.

Propulsion Directorate Develops More Efficient ECU for Deployable Tents

Payoff A new environmental control unit (ECU), a field-deployable tent cooler that heats or cools military tents in the most extreme temperatures, promises a 28% boost in performance while reducing weight and volume by 56%. The ECU improves reliability and maintainability in a deployed environment, reduces generator requirements, saves fuel, and will cut the total power consumption at deployed airbases.

Accomplishment A Cooperative Research and Development Agreement between the Propulsion Directorate and Mainstream Engineering Corporation resulted in the building and testing of a more lightweight and efficient ECU for deployable tents. The directorate and Mainstream Engineering Corporation developed the new ECU to provide comfort for US troops and to keep vital operational equipment running smoothly under the most extreme conditions. During Operation IRAQI FREEDOM, US troops used less efficient and bulkier tent coolers for relief from the 125°F heat of the Iraqi desert and to protect military equipment stored in tents from harsh weather conditions that could degrade performance.

The current design features improved maintainability, performance, and cost, while the training required to maintain and operate the unit was simplified. The unit also uses standard commercial parts, and there are no exotic components or materials.

The Department of Defense deems the new tent cooler environmentally friendly with no ozone-depletion potential since the unit uses Puron (R-410A) refrigerant. The existing "-39" version ECU operates at low power, is bulky, and uses an ozone-depleting refrigerant (R-22).

Background The directorate recently tested the new unit at Fort Drum, New York during Patriot Exercise 2003. The directorate designed the second-generation prototype to operate in nuclear, biological, or chemical (NBC) mode or non-NBC mode.

The ECU can act as either a heater or an air conditioner and can be operated with a remote control. Compared to previous models that took up to 10% of the airbase deployment weight, the current ECU would reduce that by more than half.

Ultra-Fast Analyzer Ensures Safe Use of Jet Fuels

Payoff The Propulsion Directorate, in partnership with the University of Dayton Research Institute (UDRI), developed a rapid investigative tool using commercial off-the-shelf equipment that can characterize key fuel properties in less than 5 minutes. The equipment was developed to support the Air Force Petroleum Office deployed laboratories.

The ultra-fast gas chromatographic method determines the fuel's "fingerprint" and uses the information to predict distillation range, freeze point, flash point, and sulfur content. The fingerprint also helps to identify potential fuel contamination.

Accomplishment Directorate chemical research engineers in the Fuels Branch and UDRI created a fast gas chromatograph (GC) that runs a fuel recognition process in only 5 minutes versus a standard GC that takes about 1-2 hours. The new GC quickly detects off-spec fuel and identifies fuels differently than they were originally labeled.

The directorate developed the equipment to reduce the transportation footprint and time required to run four different tests using four separate instruments. The unit is also field-deployable and relatively inexpensive, at an estimated $35,000 for each instrument. The instrument gives warfighters rapid distillate fuel recognition of Jet Propellant (JP)-8, JP-7, Jet A, Jet Propellant Thermally Stable, diesel, and aviation gas along with composition-property relationships for flash point, distillation range, freeze point, sulfur content, heat combustion, and others.

Background The fast GC is an instrument that examines different fuel types by separating the complex petroleum mixtures and determines whether or not they are safe for military use. The GC creates a very accurate "fingerprint" depiction of each fuel type. Samples of fuels are placed in a computer-controlled auto sampler that places the bottle containing the fuel under a syringe that extracts the fuel. The fuel in the syringe is then injected into a glass tube, the inside of which is slightly larger than a human hair. The smaller the dimensions of the tube, the faster the analysis. Inside the tube, the fuel separates into its volatile and non-volatile components. The most volatile components evaporate first and the least volatile ones last longer. From this process, a gas chromatogram is formed that can then be related to various properties of fuel.

Sensors Directorate Engineer/Technician Duo Invents Switch for AFSOC Radios

Payoff Sensors Directorate personnel invented a lightweight, durable, user-friendly switch, called the Kessler-Coates (KeCo) switch, that is easily operated with gloves or in the dark. The KeCo switch enables ground-to-ground, as well as ground-to-satellite, communications with existing radio equipment used by Air Force Special Operations Command (AFSOC). Now forward-deployed troops do not have to manually switch antennas, which could have put Air Force personnel at extreme risk.

Accomplishment Lieutenant Colonel Don Kessler and Master Sargent Dave Coates, both of the Sensors Directorate, responded to the AFSOC commander's request to provide a solution to a problem the command had with their special operations radios. They invented a lightweight, durable switch that allows AFSOC soldiers to instantly switch back and forth between a satellite antenna and an omni-directional, line-of-site antenna.

Background Forward-deployed AFSOC forces carry more than 100 lbs of equipment, not including food or water. Vital to a successful mission are the special operations radios to keep in contact with satellite and ground communications systems. These radios are lightweight and use as little power as necessary; however, they are short one antenna port.

Troops must physically switch modes between ground-to-ground and ground-to-satellite capabilities. This means every time troops switch antennas, they have to break off communications, then try to re-establish them. The delays caused by manually switching the antennas left troops exposed to gunfire and delayed contact with aircraft to abort or change a mission.

Within 3 months of the request, the directorate developed and delivered to AFSOC the KeCo switch that allows for quick switching between satellite communications and air-to-air communications. The KeCo is an antenna switch specifically tailored to several communications radios used by AFSOC forces in combat and is another directorate attempt to meet an urgent need for support to the warfighter community.

AFSOC plans to produce 1,300 devices for Air Force units. The directorate anticipates that Department of Defense customers may order more than 10,000 devices within the next year or two for use throughout the world.

Compressor Research Facility Adds Heated Inlet Capability

Payoff A new heated inlet capability in the Propulsion Directorate's Compressor Research Facility (CRF) will allow researchers to operate fans and compressors undergoing testing at the actual mechanical speeds experienced in operational engines. Testing with the heated inlet allows researchers to continue matching aerodynamic parameters while matching the actual mechanical speeds encountered in an engine environment more closely. This increases the quality of aeromechanic data collected and is important for evaluating new materials and structures for use in fans and compressors.

Accomplishment Directorate engineers successfully demonstrated a new heated inlet capability during a test of an advanced military fan developed as part of the Integrated High Performance Turbine Engine Technology (IHPTET) program. This new capability recirculates hot exhaust gas from the test compressor back into the incoming atmospheric air, resulting in elevated inlet temperatures up to 750°F and enhancing CRF's ability to simulate engine conditions more realistically.

Background The CRF is a steady-state facility capable of testing full-scale fan and compressor hardware-simulating engine properties based on aerodynamic similarities. It is used to determine the performance of the most advanced compressors and fans in the world, while enhancing the understanding of their complex internal flow physics.

Previously, fans and compressors were tested at aerodynamically corrected conditions. These tests resulted in lower rotational speeds than would be experienced in actual engine environments, although these test conditions correctly matched the aerodynamic performance.

The heated inlet was first used in the structural evaluation of the highly successful Pratt & Whitney XTE67 Fan Test program. It was used to elevate the mechanical speed of the compressor to investigate potential flutter conditions. With the new heated inlet capability, the CRF can more fully support the compression system objectives and goals of IHPTET and turbine engine affordability initiatives of the Versatile Affordable Advanced Turbine Engines program. Aeromechanical data collected in the CRF is also important to increase the performance of engines as well as increase understanding of high-cycle fatigue requirements.

Communication/Navigation Outage Forecasting System

Payoff The Communication/Navigation Outage Forecasting System (C/NOFS) instrument payload will make global equatorial measurements to understand and forecast naturally occurring ionospheric scintillation that causes outages in communication and navigation data links. The C/NOFS program will sense and predict system outages caused by scintillation to improve the warfighter's capability to perform mission-essential communication and navigation tasks. C/NOFS combines data from space- and ground-based sensors in advanced computer models to predict ultra-high-frequency satellite communications and Global Positioning System (GPS) outages due to scintillation in the ionosphere.

Accomplishment The Instrument Development Team, composed of the Space Vehicles Directorate, the Naval Research Laboratory, the National Aeronautics and Space Administration's Goddard Space Flight Center, Aerospace Corporation, and the University of Texas at Dallas, recently fabricated the C/NOFS flight hardware for the space-based instrument payload. They delivered the first instrument flight unit to the directorate's Aerospace Engineering facility at Kirtland Air Force Base, New Mexico, for integrated payload testing. The flight hardware for the six C/NOFS instruments includes the electric field instrument, the planar langmuir probe, the ion velocity meter, the neutral wind meter, the GPS occultation receiver, and the radio frequency beacon.

Background The team designed and fabricated the instruments to fly on a low-altitude, low-inclination satellite and make *in-situ* and remote-sensing measurements of the equatorial ionosphere. The C/NOFS payload is very unique because it is the first dedicated instrument suite to measure the key ionospheric parameters needed to answer the question "What triggers scintillation?"

The C/NOFS payload will also demonstrate a new data-driven, physics-based forecasting system for predicting when and where scintillation events will disrupt communication and navigation data links. Following integrated payload testing, the team will transfer the instruments to the Space and Missile Center's Detachment 12 and the spacecraft contractor for integration onto the spacecraft bus.

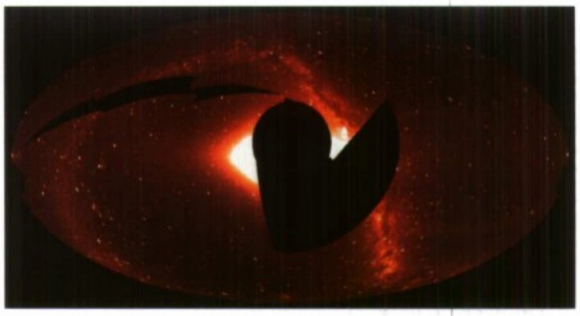
Solar Mass Ejection Imager Launched on Space Test Program's Coriolis Satellite

Payoff Distinguishing faint coronal mass ejections (CMEs) from the bright celestial background is difficult, requiring the Solar Mass Ejection Imager (SMEI) to achieve 0.1% photometry. Detection and tracking of earth-directed CMEs will help protect space assets and communications.

CMEs can cause geomagnetic storms on earth, and fast CMEs can drive shock waves. These phenomena initiate effects adverse to military and civilian spacecraft and ground-based systems including increases in trapped magnetospheric particles, degraded satellite communication and surveillance systems, increased drag, and destructive surges in power grids. Advanced warning will permit preventive measures to mitigate their effects.

Accomplishment The Space Vehicles Directorate's Space Weather Center of Excellence previously launched the SMEI on the Space Test program's Coriolis Satellite (see photo on left) to detect and track CMEs propagating from the sun to the earth. Since CMEs are a major cause of space weather effects on earth, SMEI's successful operation will significantly improve space weather forecasts. SMEI images the entire sky in white light every orbit with three baffled charge-coupled-device cameras, while occupying a circular, sun-synchronous (830 km) polar orbit.

Since launch, SMEI has detected over a dozen CMEs including some earth-directed, "halo" CMEs that caused geomagnetic storms. SMEI will produce 1- to 3-day forecasts of geomagnetic storms by tracking CMEs from the sun to the earth. SMEI's all-sky images will also aid astronomers and astrophysicists in understanding solar processes and detecting astronomical phenomena.



The photo on the right is the first all-sky image produced from SMEI data. Additional SME images are available on the Web at *http://smei.nso.edu*

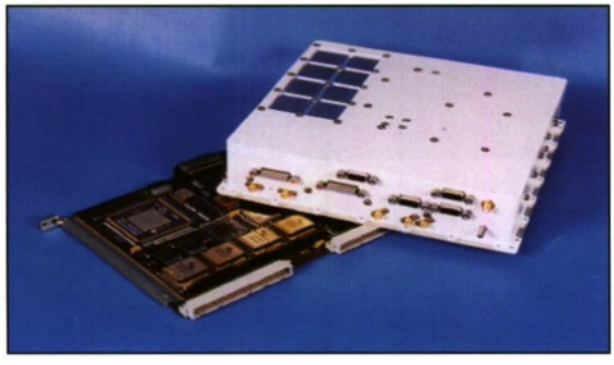
Background A team of scientists and engineers from the directorate, the University of California at San Diego, and the University of Birmingham in the United Kingdom, designed and constructed the SMEI experiment. The US Air Force, the National Aeronautics and Space Administration, and the University of Birmingham are providing financial support for SMEI.

AFRL Successfully Tests Miniature Satellite Threat Reporting System

Payoff The Space Vehicles Directorate's Miniature Satellite Threat Reporting System (MSTRS) protects a spacecraft from hostile radio frequency (RF) threats by providing a detailed analysis of the threat including the source of the threat. This capability is critical for future satellites.

Accomplishment The directorate launched the MSTRS aboard the Space Shuttle Columbia as a payload on the STS-107 mission. During flight, a directorate-led ground team and the space shuttle crew performed an experiment to verify the performance of MSTRS by characterizing ground-based RF emissions. The MSTRS experiment successfully demonstrated functionality of recently developed AFRL technology.

Background Directorate engineers mounted the MSTRS antenna array on top of a SPACEHAB module on Columbia, which had an unobstructed view of earth when Columbia's crew turned the shuttle cargo bay in that direction. The assemblies consisted of two separate three-antenna interferometer baselines with the receiver electronics mounted inside the SPACEHAB module in a shuttle mid-deck locker.



The experiment involved flying over participating ground-based emitters with known characteristics. By comparing the measured signal parameters with those reported by the ground-based emitters, the MSTRS experiment team determined that MSTRS performed properly.

The team transmitted data to the MSTRS ground control computers at Johnson Space Center, Houston, Texas, during flight. The team consisted of personnel from the directorate, Air Force Space Command, Space & Missile Systems Center, Northrop Grumman Corporation, Los Alamos National Laboratory, Naval Research Laboratory, Joint Spectrum Center, and Schafer Corporation. The MSTRS experiment team declared the MSTRS mission successful at the completion of operation.

Low-Shock Separation System Dramatically Reduces Satellite Failures

Payoff The shock of separation of satellites from the launch system (normally a rocket) causes many failures, requiring development of a satellite low-shock separation system. The Lightband system is 25% lighter, 50% smaller, 40% cheaper, and generates <5% of the shock of existing conventional pyrotechnic separation systems. The Lightband provides a capability that reduces on-orbit failures, the cost of design and redesign, and launch costs. This technology could save spacecraft programs several million dollars in life-cycle costs per spacecraft.

Accomplishment Using technology explored under the Small Business Innovation Research (SBIR) program, the Space Vehicles Directorate successfully developed and transitioned the country's next-generation, small spacecraft separation system, called the Lightband. Operating with limited SBIR funding, a directorate team developed, designed, tested, and successfully flew the world's first reusable, non-discrete point, low-shock, non-pyrotechnic separation system.

This Lightband system successfully separated the National Aeronautics and Space Administration's (NASA) Starshine-3 primary satellite from Lockheed Martin's Athena I launch vehicle on the first orbital launch out of Kodiak, Alaska. For the Starshine-3 spacecraft, the low-shock separation system reduced the shock-induced loading from 8,000 g-force (typical pyrotechnic separation system) to 300 g's.

Background During the past decade, NASA lost billions of dollars due to satellite malfunctions, resulting in total or partial mission failure. These malfunctions are often directly attributable to vibration loads during launch and satellite separation from the rocket.

Low-shock separation systems are an enabling technology for small (<100 kg) Department of Defense satellites and for the launching of fragile spacecraft components such as advanced optical systems. Small satellites are particularly susceptible to shock-related failure because of the close proximity of sensors and instruments to the shock source, necessitating a low-shock separation system.

The Air Force required a low-risk small satellite launch system that was compatible with existing systems. Due to the program's success, this separation system is baselined into AFRL's University Nanosatellite program, the Technology Satellite of the 21st century, Experimental Small Satellite-11, the Space and Missile Center's Space Test Satellite, Multiple Space Vehicle 05 (the first evolved expendable launch vehicle secondary payload adapter flight), the Naval Postgraduate School Satellite, and the university's "CubeSat."

Emerging Technologies

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Emerging Technologies

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Emerging Technologies

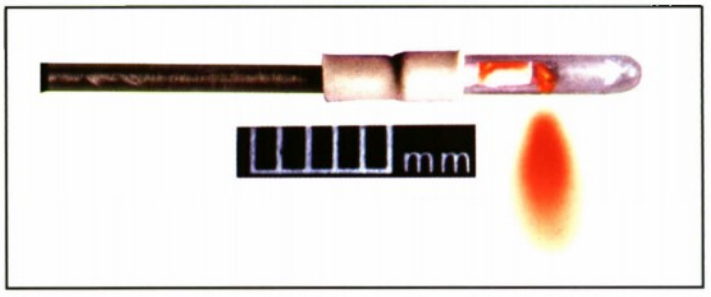
Space Vehicles

Breakthrough Optical Technology–Optical Coherence Tomography

Payoff Optical Coherence Tomography (OCT) can provide high-resolution, cross-sectional imaging similar to that of ultrasound, but it uses light instead of sound. OCT, an emerging technology based on fiber optics, often uses a compact diode light source similar to those used in compact disc players.

Accomplishment An Air Force Office of Scientific Research (AFOSR)-sponsored scientist, Dr. James Fujimoto, is the inventor and leading researcher of OCT, a new optical imaging tool for creating images used in medical diagnostics, materials science, and microscopy. Dr. Fujimoto, sponsored by AFOSR's Physics and Electronics Directorate, is a professor in the department of Engineering and Computer Science at the Massachusetts Institute of Technology in Cambridge, Massachusetts.

Background OCT is a robust, portable, low cost technology that is readily interfaced with optical fiber techniques to catheters, endoscopes, laparoscopes, and surgical probes. These attributes make it very attractive for medical and surgical diagnostics.



Ophthalmology, the study of the eye, is an area of medical research to benefit tremendously from this new technology and the first area to have commercial instrumentation introduced. Researchers performed studies investigating the feasibility of using OCT for the diagnosis and monitoring of retinal diseases such as glaucoma, macular edema, macular holes, central serous chorioretinopathy, age-related macular degeneration, epiretinal membranes, optic disc pits, and choroidal tumors.

Other AFOSR-funded researchers developed valuable extensions and applications of OCT. Dr. Zhongping Chen, of the University of California, Irvine, developed Doppler OCT, which observes moving surfaces and is particularly valuable for studying blood vessel function and fluid flow, generally in small structures.

Dr. Johannes de Boer, of the Massachusetts General Hospital (MGH), developed polarization-sensitive OCT and applied it to diagnosing burns. Drs. Brett Bouma and Guillermo Tierney at MGH, both former members of Dr. Fujimoto's group, developed very portable, high-performance OCT systems for clinical diagnostic studies. The US Army Institute for Surgical Research in San Antonio, Texas, is currently collaborating with several AFOSR-funded scientists to apply OCT to military medical needs.

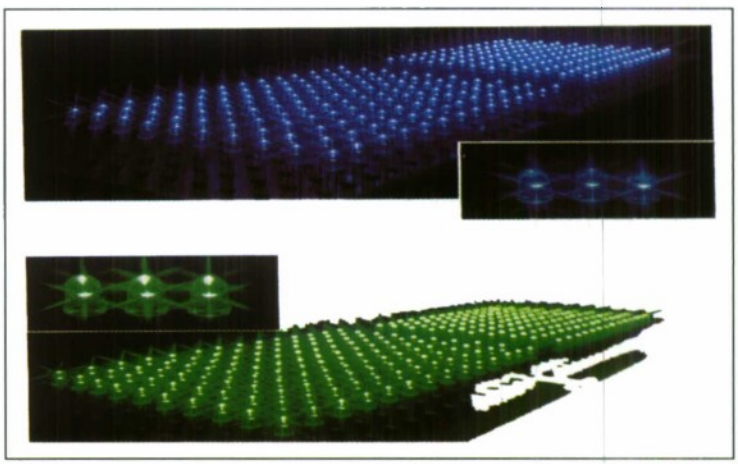
Breakthroughs in Group III-Nitrides

Payoff Group III-Nitrides, such as gallium nitride (GaN), are promising candidates for a variety of Air Force applications. They possess excellent physical and electrical properties to operate in harsh environments. Scientists predict that devices based on GaN materials will have numerous Air Force and Department of Defense applications and an enormous impact on high-power radars such as those employed on remote-sensing platforms. Other applications include displays and indicators based on light-emitting diodes, laser diodes for optical data storage, and sensor and detector surveillance systems.

Accomplishment Important research and significant advances by Air Force Office of Scientific Research (AFOSR)-funded scientists are attracting worldwide attention in the area of semiconductors. Several institutes in Korea and Japan, working in conjunction with the Materials and Manufacturing Directorate, are conducting semiconductor research in Group III-Nitrides such as GaN.

Background Due to a widespread increase in Asian research in the area of nitride semiconductors, the Asian Office of Aerospace Research and Development sponsored initiatives with several institutions in Asia to address efficient device performance. AFOSR managers capitalized on tapping into the burgeoning field, especially in Korea and Taiwan, largely because of the astounding achievements of a single researcher, Dr. Shuji Nakamura, the world's foremost expert in nitrides. Dr. Nakamura, formerly of Japan, is a professor at the University of California at Santa Barbara (UCSB).

While Dr. Nakamura was the first to successfully establish the means for growing crystalline GaN layers for devices, many characteristics of nitrides remain unclear. This is because the world lacks a viable GaN substrate upon which to grow high-quality crystal lattice-matched structures and subsequently fabricate high-performance devices.



Korea's Samsung Advanced Institute of Technology found an effective alternative substrate or template upon which to grow good material. These lattice-matched structures characterize and optimize important material system parameters and allow AFRL researchers to understand and thereby minimize the performance-limiting defects that plague these materials.

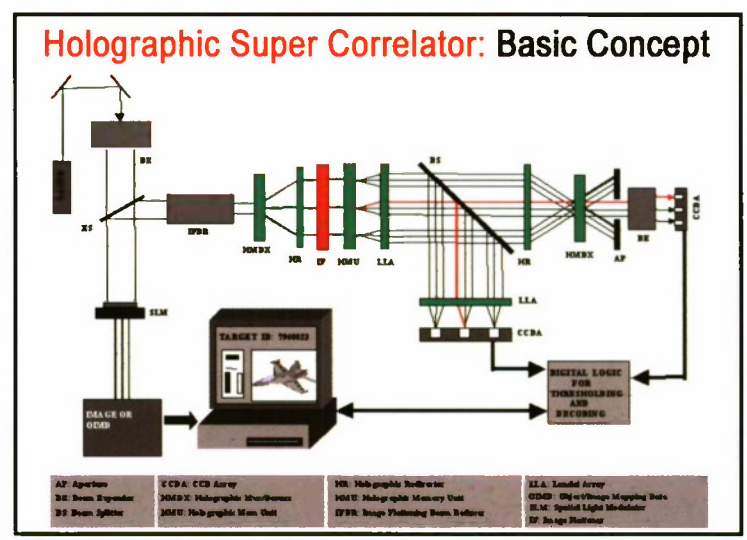
Other improved nitride material projects involve collaborations between Japanese researchers at Tsukuba University and UCSB Professors Steven DenBaars and Shuji Nakamura. Since 1996, this US-Japan team worked together to champion the basic physics and preparation of GaN crystal layers.

Another effort to understand and ultimately control defects is the collaboration between Science University of Tokyo (Ohkawa) and UCSB (Dr. Nakamura). This partnership establishes the interfacial physics involved in the chemistry of nitrides, particularly how nitrides behave in chemical reactions.

Improving Digital Signal Processing Through Holographic Recording and Storage

Payoff Identifying enemy aircraft and missile threats may become easier thanks to the efforts of two Air Force Office of Scientific Research (AFOSR)-funded scientists. Working on related but separate projects, Professors Dmitri Psaltis and Selim Shahriar discovered different methods of improving digital signal processing (DSP) through holography.

Accomplishment Professor Psaltis teamed with fellow California Institute of Technology electrical engineering professors, Zhiwen Liu and Gregory Steckman, to develop a holographic system to record fast events. The resulting performance is comparable to the current state of the art for a multi-camera system. Professor Shahriar and fellow researchers at Northwestern University joined scientists at the Massachusetts Institute of Technology and Digital Optical Technologies in Somerville, Massachusetts, to improve DSP speeds by using a simple holographic optical corrrelator.



Background Holography allows users to search in a parallel fashion. If users are trying to track and identify an enemy plane, the plane could appear at different distances and in different orientations, requiring as many as 10,000 pictures in the database for all possible orientations of just one plane. In simplest terms, Professor Shahriar's approach deals with massive storage for image processing applications such as satellite pictures. Professor Psaltis' approach looks at recording extremely fast events, which causes an issue of storage capacity versus speed.

Professor Psaltis and his colleagues developed a holographic method for recording fast events on nanosecond timescales. They extended their technique by using shorter pulses and generating the signal beam pulse train through wavefront division or nonlinear optics.

While Professor Psaltis' and Shahriar's holographic methods have obvious military applications, their research might also benefit biologically based identification processes such as fingerprinting or comparison of dental images. The AFOSR's Physics and Electronics Directorate currently supports Professors Psaltis' and Shahriar's research.

New Silicon-Based, Light-Emitting Technology Sets a World Record for Efficiency

Payoff STMicroelectronics' new silicon-based, light-emitting technology sets a world record for efficiency. It traces its creative origins back to important research funded by the Air Force Office of Scientific Research and conducted jointly in 1993 by the Air Force Research Laboratory, at Hanscom Air Force Base, Massachusetts, and the Massachusetts Institute of Technology. The team's work in rare-earth-doped, light-emitting diodes leads the nation and inspired STMicroelectronics' innovation that implants ions of rare-earth metals, such as erbium or cerium, in a layer of silicon-rich oxide.

Accomplishment STMicroelectronics discovered groundbreaking technology that allows silicon-based light emitters to match the efficiency of traditional light-emitting compound semiconductor materials such as gallium arsenide. STMicroelectronics is the world's third largest semiconductor manufacturer.

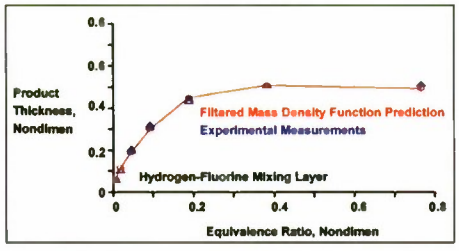
This new technology opens up many potential applications to combine optical and electrical functions on a single silicon chip. Although silicon is ideal for building memories, microprocessors, and other complex circuits, this was not previously possible because it could not act as an efficient light emitter.

Background Mr. GianGuido Rizzotto, STMicroelectronics director of Corporate Technology Research and Development, identified a number of promising applications and solved key manufacturing issues to rapidly move this technology into production. One of the first applications is building power control devices in which the control circuitry is electrically isolated from the power-switching transistors. Currently, manufacturers achieve electrical isolation, mandatory in many applications for safety reasons, by using external devices such as relays, transformers, or discrete optocouplers.

STMicroelectronics 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.

LES Used to Design Future Aero Propulsion Combusters

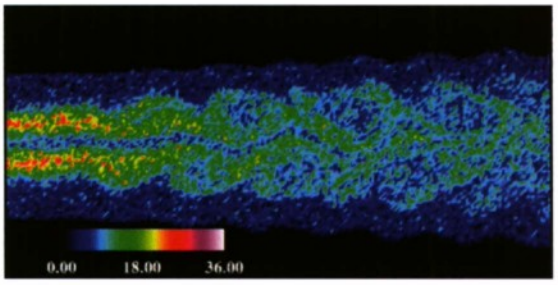
Payoff Large Eddy Simulation (LES), developed by Air Force Office of Scientific Research (AFOSR)-sponsored research, represents the next generation of models that offers the promise of delivering quantitatively accurate assessments of combustor behavior in a computationally tractable manner. Using the 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.



Accomplishment Dr. Sunil James, of the Rolls-Royce Corporation in Indianapolis, Indiana, is currently testing and incorporating an LES-based combustor design modeling capability he created. Many regard this as the next major step in computational tools for aero propulsion system design. Dr. James took fundamental aspects of an LES model for turbulent combustion, formulated by AFOSR-sponsored research of his former professor Dr. Peyman Givi, at the State University of New York at Buffalo, to design combustors for future aircraft propulsion.

Background In the past 20 years, engineers used computational modeling as 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, based on trial-and-error testing, proved 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. RANS models are very useful for qualitative analysis of an engine's performance; however, they do not allow for a true quantitative predictive capability.



The combustion research community is actively pursuing LES models for turbulent combustion. LES solves the conservation equations for mass, momentum, energy, and chemical species at the largest physical scales of the combustor.

LES 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 contributed a unique approach for SGS through a statistical treatment of the mass-weighted, small-scale properties of combustion in a scalar-filtered mass density function. Dr. Givi demonstrated both the accuracy and computational efficiency of this approach by comparing his prediction with experimental measurements for a turbulent mixing layer.

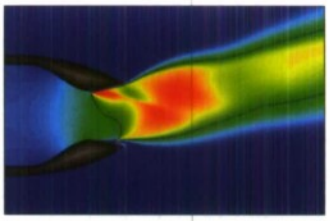
The Rolls-Royce Corporation produced aero propulsion system designs used on several items in the Air Force's inventory. Among those are the AE2100D3 turboprop used in the C-130J transport, the AE3007H turbofan on the Global Hawk surveillance aircraft, and the F136 turbofan for use on the F-35 Joint Strike Fighter.

Research Leads to Lighter Weight UAV Nozzle

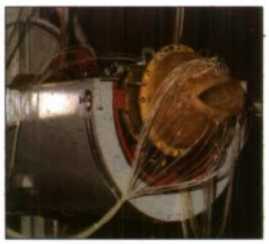
Payoff Air Force Office of Scientific Research (AFOSR)-funded research is yielding computer-based models for fluid flows that are key enablers for developing new capabilities for the Air Force. Thanks to advances in computational fluid dynamics (CFD), Lockheed Martin Aeronautics engineers are developing fluidic thrust control for aircraft that provides thrust vectoring with no moving nozzle parts.

Many future unmanned air vehicles (UAVs) are tailless and will depend on thrust vectoring for flight control. The F119 nozzle achieves conventional thrust vectoring using a mechanical system with moving flaps. Fluidic "fixed-geometry" thrust vectoring can result in substantial weight savings for aircraft. Lockheed Martin studies show that fluidic thrust control could boost control power for tailless UAVs, while slashing nozzle weight and cost in half.

Accomplishment Under AFOSR sponsorship, the University of Calgary and Lockheed Martin collaborated on the development of CFD simulation methodologies used to identify promising concepts for nozzle flow control. Engineers used the CFD simulations to study the effect of pulsed fluidic control jets on the nozzle stream.



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 relationships among numerous geometric and fluid properties that were poorly understood.



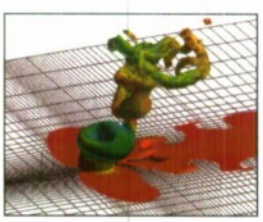
Background The University of Calgary and Lockheed Martin undertook a systematic study of both steady and pulsed-injection jets blowing into a nozzle crossflow using CFD methods. The CFD methodology involves dividing a flowfield into discrete volumes, or grid cells, and then applying a numerical algorithm with mathematical relationships governing fluid motion and a model of turbulent flow physics.

Prior research from AFOSR grants with Princeton's Professor George Mellor and Stanford's Professor Parviz Moin led to the development and use of physical models for turbulent flow in these studies. The CFD tools allowed these researchers to explore parameters such as injection momentum, frequency, and geometry, more rapidly and less expensively than possible in a purely experimental approach.

The researchers compared the computational results to experimental data taken at the University of Calgary. Those comparisons also guided the choice of computational methods, thus ensuring accurate predictions.

AFRL is currently investigating thrust vectoring in structurally fixed nozzles based on this research effort. These tests demonstrated thrust vector angles of greater than 10° with good thrust efficiency.

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

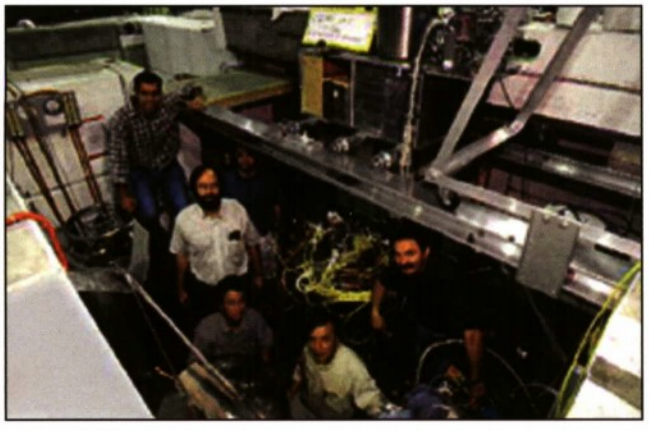


Looking In from the Outside: Antimatter Atoms

Payoff The antimatter atoms collaboration, known as the ATRAP Collaboration, developed a novel field-ionization technique that permits direct observation of antihydrogen atoms that eliminate residual background signals. ATRAP can detect more antihydrogen atoms in an hour than the sum of all antimatter atoms ever reported.

Accomplishment Dr. Gerald Gabrielse, a Harvard University professor of physics, worked with scientists from Germany, England, and the United States to observe the internal structure of antimatter atoms. Since 1988, the Air Force Office of Scientific Research's (AFOSR) Physics and Electronics Directorate helped sponsor Dr. Gabrielse's efforts at the European Laboratory for Particle Physics, also known as CERN, in Geneva, Switzerland.

Background AFOSR's support permitted CERN to build the antiproton decelerator (AD) storage ring in order to observe cold antihydrogen. Antihydrogen is an atom composed of two antimatter particles, an antiproton and a positron; a normal hydrogen atom is composed of a proton and an electron.



The antiparticles have the same mass as their normal counterparts, but they carry the opposite charge. Current theories predict that antihydrogen and hydrogen should have the same properties including their internal structure.

The ATRAP Team creates antihydrogen atoms by colliding antiprotons with cold positrons. The team creates antiprotons from CERN's AD and positrons from a radioactive source. They cool them both and gently collide them to form antiatoms, namely antihydrogen. The antihydrogen forms in a nested Penning trap, a device developed by ATRAP scientists. Then the team studies them spectroscopically.

The ultimate goal of ATRAP is to trap neutral cold antihydrogen atoms and study their spectra with the same precision as plain hydrogen atoms. Researchers hope that the antihydrogen atoms will create enough atoms to allow lasers to probe for any tiny differences between antihydrogen and hydrogen atoms. Such measurements would test fundamental theories of physics and might even provide some information about the mystery of why our universe is composed of matter rather than antimatter.

Antihydrogen—and antimatter in general—has many potential benefits to the military and defense of our nation. It is a potential candidate for extremely high-energy-density applications including ultra-lightweight satellite and unmanned air vehicle power supplies, high specific impulse engines, and missile defense interceptors.

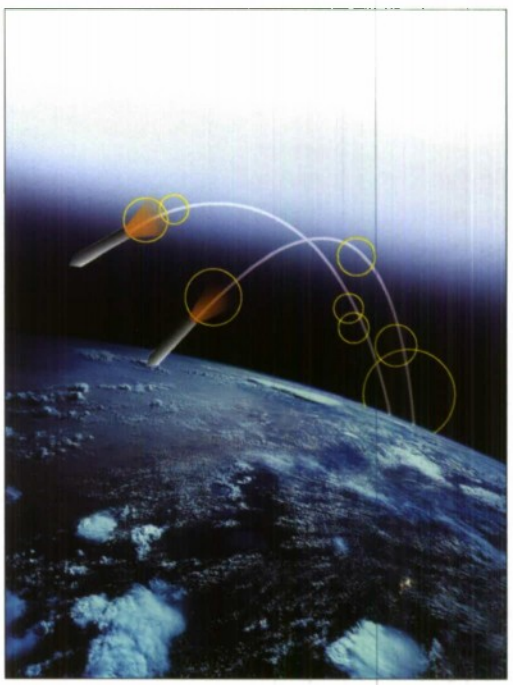
Molecular Recombination

Payoff The research of Dr. Raymond Flannery, an Air Force Office of Scientific Research-funded physicist, may lead to important advances in the Air Force's ability to detect missiles during their boost phase. By studying the molecular recombination within and around a rocket's exhaust plume and the detailed signature information it gives off, scientists can improve missile detection capabilities. Dr. Flannery's research will also enhance the detection of satellites, warheads, and missiles re-entering the atmosphere; and it will improve techniques to counter enemy detection of friendly missiles.

Accomplishment Dr. Raymond Flannery, Regent's Professor at the Georgia Institute of Technology, developed a microscopic theory of three-body recombination processes of electrons and ions in gases. His work gives scientists a better understanding of collisions between atoms and molecules in highly excited states.

Background The Propulsion Directorate plans to use Dr. Flannery's research to aid in their understanding of the interactions that take place in plasma deposition and etching—the processes most often used in manufacturing large-scale integrated circuits. His work is also helpful in understanding conduction of electricity through plasmas and gases, ignition of flames, and other processes relevant to the development of advanced air and space propulsion systems.

Dr. Flannery's work will also help the Air Force continue its environmental efforts. His research will enable scientists to better understand how pollutants influence atmospheric recombination and help environmentalists to develop new methods of effectively dealing with the mitigation of these pollutants.



The Division of Atomic, Molecular, Optical and Plasma Physics of the United Kingdom's Institute of Physics, recently awarded Dr. Flannery the 2002 Sir David Bates Prize in recognition of his work in the field of theoretical atomic physics and for his studies of recombination processes with applications to astrophysics and plasma physics. He was also the winner of the 1998 Allis Prize, awarded by the American Physical Society, for his work on ionized gases.

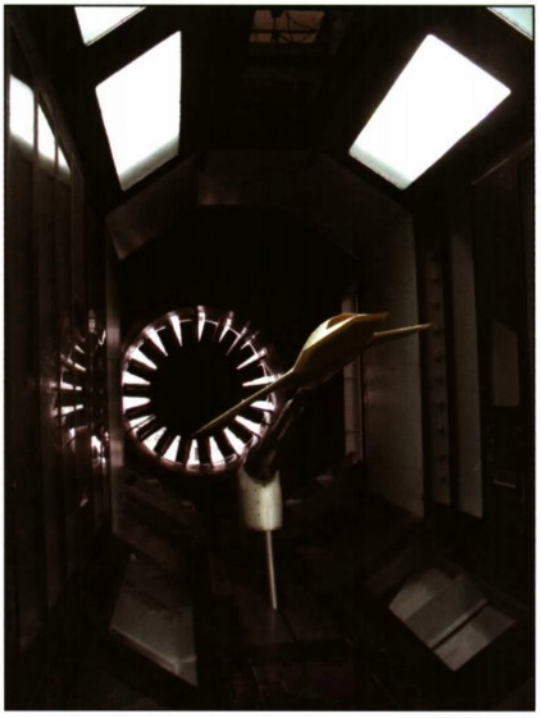
His current research includes development of theories of Rydberg plasmas and the formation of antihydrogen by three-body recombination. In particular, he recently helped solve, a 40-year-old problem explaining the mixing of angular momentum substates of a Rydberg atom by the time-dependent electric field generated by collision with a charged ion—a process known as collision Stark mixing. The process is of basic significance to Rydberg plasmas, whether at high-temperature or ultra-cold energy regimes.

Rapid Model Fabrication for Responsive Aerodynamic Testing

Payoff Rapid prototyping (RP) is a robust, accurate, and affordable method to support aerospace research and development throughout Department of Defense organizations, industry, and academia involved in experimental ground testing. In the past, it took months to manufacture models for ground testing. Recent innovations in RP have made it possible to produce models within days. Rapid fabrication results in a faster and better response to the warfighter's needs by permitting concurrent study of new concepts in the wind tunnel and via computer simulation.

Accomplishment Using the Air Vehicles Directorate's Subsonic Aerodynamic Research Laboratory, the Air Vehicles (VA) and Materials and Manufacturing (ML) Directorates collaborated to modify and test a model of the X-45A Unmanned Combat Air Vehicle fabricated by Johns Hopkins University/Applied Physics Laboratory. Scientists used state-of-the-art RP methods to modify the model, and its testing improved understanding of the application of RP technology.

Background VA conducts aerodynamics research at a variety of in-house test facilities at Wright-Patterson Air Force Base, Ohio. The capabilities of these facilities range from very-low-speed subsonic flows to very-high-speed hypersonic flows. VA's history of aerodynamic research and development began in the 1920s when the United States Army Signal Corps established the Technical Services Office at McCook Field, Dayton, Ohio. Since that time, testing has evolved from being developmental in nature to supporting basic and applied research programs. RP will play an essential part in this role.



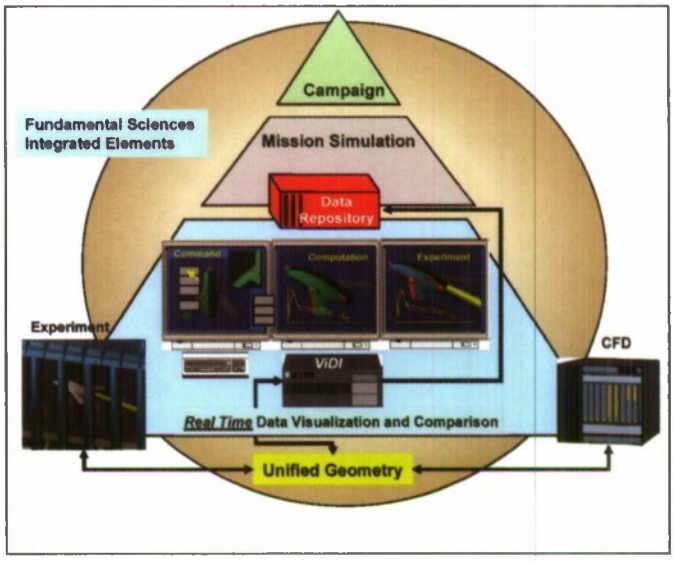
RP is a highly useful tool in today's experimental environment, leading to innovative technologies, significantly compressed design cycle times, and reduced costs. Current RP technologies include stereo lithography, selective laser sintering, laser engineered net-shaping, and fused deposition modeling. VA and ML collaborated to compile information on several of these techniques and their respective applicability to the suite of ground testing research facilities operated by VA.

The resulting information database matches research facility operating conditions with RP material capabilities and will provide the basis for other organizations to pursue and implement RP. Current wind tunnel model manufacturing techniques are slow, resulting in a lag between physical configurations tested by ground testing methods in the wind tunnels and configurations modeled with computational fluid dynamics (CFD). However, RP manufacturing techniques are maturing rapidly and enable the engineer to quickly fabricate a test article from the same digital model used for computer simulations done with CFD.

Linking Computational and Experimental Methods

Payoff A collaborative effort in rapid technology assessment between the Air Vehicles Directorate, Innovative Scientific Solutions, Inc., and the National Aeronautics and Space Administration's Langley Research Center successfully demonstrated the ability to provide a near-real-time comparative evaluation of experimental and computational simulations. The process eliminated the significant time lag between numerical analysis and the acquisition of experimental test data to validate the analysis, which impedes aerospace technology breakthroughs.

Accomplishment The directorate initiated a joint Computational Fluid Dynamic/Experimental Fluid Dynamic (CFD/EFD) test program to investigate and analyze the aerodynamic flow field of the X-45A Unmanned Combat Air Vehicle at the Subsonic Aerodynamic Research Laboratory. The testing involved a multitude of cross-functional specialties ranging from experimental global measurement techniques and computational fluid dynamics to state-of-the-art material manufacturing technologies.



Researchers strategically employed rapid technology assessment tools, such as pressure sensitive paint, projection moire interferometry, Doppler global velocimetry, and virtual diagnostics interface to take real-time measurements. In turn, these measurements were compared to computational results in near real time and used to alter the test matrix, better understand the flow physics, and improve the fidelity of the numerical code simulation.

Background Advanced technology assessment strategies that exploit simulation-based research and development rely heavily on the accuracy and fidelity of numerically based predictive methods. Ensuring reliable technology assessment requires validating computational methods with experimental measurements. These measurements are made using a model fabricated to contain multiple components such as pressure ports and cavities to house measurement and telemetry hardware, electronic systems, and tubing. This fabrication is time consuming and costly. Furthermore, in conventional EFD, individual measurement systems are deployed sequentially, which significantly increases the time and cost associated with acquiring the necessary information. Without simultaneously deployed global diagnostics, understanding and modeling aerodynamic cause-and-effect relationships are difficult.

Ideally, measurement techniques would be deployed simultaneously to minimize wind tunnel occupancy with comprehensive parallel data reduction in near-real-time. This process would provide a mechanism to confirm spurious results, identify the source of unpredicted behavior, and provide on-line comparisons of CFD/EFD data sets. Rapid technology assessment is making this ideal a reality.

Directed Energy Directorate Demonstrates High-Accuracy Orbit Updates for Low-Earth-Orbiting Satellites

Payoff Directed Energy Directorate scientists and engineers used the 3.6- and 1.6-meter telescopes at the Air Force Maui Optical and Supercomputing (AMOS) site to track orbiting satellites and provide high-accuracy trajectory updates. This capability is a combination of state-of-the-art telescope pointing accuracy as well as world-class astrodynamics expertise unique to the AMOS facility.

Accomplishment Directorate scientists made high-accuracy observations of low-earth-orbiting satellites at the one- to two-arcsecond levels with the 3.6- and 1.6-meter telescopes. The resulting calculation of satellite trajectories showed a significant decrease in orbit error from several hundred meters to tens of meters. This high-accuracy orbit update capability represents an unprecedented achievement in orbital prediction.

Directorate scientists then fed this data into a Kalman filter to update the calculated satellite trajectories showing a decrease in orbit error from the several-hundred-meter levels to the tens-of-meter levels. While normal satellite catalogue maintenance focuses mainly on achieving required accuracy for all satellites, this approach provides high accuracy for any specific satellite.

Background Directorate scientists and engineers rebuilt the research and development capability of the AMOS site since taking oversight of the facilities from the Air Force Space Command. The directorate's Metrics Research and Development program made great strides in the last year due to continued sensor development, high-accuracy data collection, and the arrival of data exploitation expertise. This combination makes AMOS a national asset to the Department of Defense for space surveillance, and orbit determination and prediction research.

The directorate's AMOS Branch recently worked with the Missile Defense Agency Theater High-Altitude Area Defense program as part of a risk-reduction effort for the augmented recursive dual-channel estimator for registration (ARCHER) algorithm demonstration. For missile defense, it is critical that sensors sharing data provide the data in an unambiguous manner; otherwise, inaccurate data will result in miscorrelations between actual radar tracks and externally supplied information.

ARCHER is an innovative approach for radar data registration in support of missile defense sensor networks. Directorate engineers used the high-accuracy orbit update capability at AMOS to develop "truth" orbits for this risk-reduction effort. In addition, the high-accuracy orbit update capability has applications to space control, space situational awareness, active tracking, and for Air Force missions requiring precise knowledge of satellite trajectories.

Directed Energy Directorate Produces a 7.5 Magnitude Sodium Guidestar for Adaptive-Optics Atmospheric Turbulence Correction

Payoff Directed Energy Directorate scientists, from the High-Power Solid-State Lasers Branch and the Starfire Optical Range (SOR), produced an artificial guidestar in the mesosphere (90-kilometer altitude) with the radiance of a 7.5-magnitude star by exciting atomic sodium resident at that altitude with just 10 watts (W) of projected power into the sky. Large ground-based telescopes equipped with adaptive optics can use a sodium guidestar to measure atmospheric turbulence and remove its distortions, enabling high-quality, ground-based observations of space objects and propagation of laser beams through a turbulent atmosphere. Astronomical imaging, using this technology, can rival the imaging capability of the Hubble Space Telescope.

Accomplishment Directorate scientists designed and built a solid-state laser system that produces world-record 20 W of continuous power in a high-quality (diffraction-limited) beam at a wavelength of 589.159 nanometers—far exceeding the previous record of 0.4 W. They achieved this by combining two infrared lasers (1064- and 1319-nanometer wavelengths) within an optical cavity containing a nonlinear-optical crystal of lithium triborate. The crystal added the frequencies of the two beams by a process known as sum-frequency generation.

Scientists then used this laser system to create the world's brightest continuous sodium guidestar in the mesosphere. The beam is highly visible in the photo as it leaves the SOR's beam director due to Rayleigh scattering from air molecules. The separate inset photo, obtained from a telescope camera view, shows the decrease in the Rayleigh scattering as the beam leaves the atmosphere and the guidestar. Future efforts include a high-power source designed to produce 50 W. The project goal is to have a facility-class sodium guidestar pump laser operational on the SOR telescope by late 2004.

Background The directorate's SOR at Kirtland Air Force Base, New Mexico, is researching the use of large ground-based telescopes to propagate laser beams through the atmosphere and to image satellites. To attain high intensity at the destination with the projected laser beam, the effects of the earth's atmospheric turbulence must be removed. Scientists can achieve this by using an adaptive-optics system that observes an artificial guidestar to measure the atmospheric distortions and compensate for them. The mesospheric sodium guidestar is especially useful for greater than 3-meter-diameter, ground-based telescopes because of its higher altitude compared to Rayleigh beacon guidestars.

Development of this laser attracted the attention of the international astronomy community, and the directorate plans to transition this guidestar technology to large ground-based telescopes around the world. For example, the Gemini Observatory, a 7-nation partnership including the US, built two 8-meter, world-class telescopes on Mauna Kea, Hawaii and at Cerro Pachon, Chile, to provide complete sky coverage of the Northern and Southern Hemispheres. Each will require at least one sodium guidestar to achieve full imaging resolution potential.

Directed Energy Directorate Captures AFSPC GT-32PA Mission

Payoff Directed Energy Directorate scientists and engineers, using the 3.6 m, 1.6 m, and 1.2 m telescopes at the Air Force Maui Optical and Supercomputing (AMOS) site, acquired, tracked, and collected critical data on a Peacekeeper missile launched from Vandenberg Air Force Base, California. They gathered the data during the latest Air Force Space Command (AFSPC) Glory Trip mission–GT-32PA.

Over the past several years, AMOS used the Glory Trip missions to collect valuable data and improve site operations. The focus of AMOS activities was to passively acquire and track the target, collect visible/infrared imagery, collect metric data, and provide AMOS missile operations crews a training opportunity in tracking a ballistic target.

Accomplishment Directorate scientists used AMOS to successfully track GT-32PA with all three telescope mounts beginning at 30° elevation as the target rose, to 1° elevation as the target descended. The target's maximum elevation (culmination) was at 51.2° at a range of 1200 km.

AMOS acquired the post-boost vehicle using information from the Pacific Missile Range Facility radars. Directorate engineers witnessed re-entry vehicles (RVs) during the deployment phase of the mission.

The directorate considers this AMOS mission an outstanding success with numerous firsts for the site. Some of these firsts include tracking an RV down to 1° of elevation, tracking multiple RVs with the 3.6 m telescope, using Vandenberg's interrange vectors in the mount control systems, tracking hand-over from the 3.6 m to the 1.2 m telescopes, and verifying enhanced long wave infrared detectors developed for associated Missile Defense Agency (MDA) projects.

Background The directorate's AMOS site has tracked missiles since the late 1960s. However, when AFSPC took command of the site in 1995, missile support operations dwindled with the focus shifting to satellite tracking.

The directorate resumed command in 2000, and AMOS has since rebuilt and enhanced its missile support program. Over the past year, the MDA chose to exploit the site's capabilities and entered into numerous collaborative efforts with AMOS.

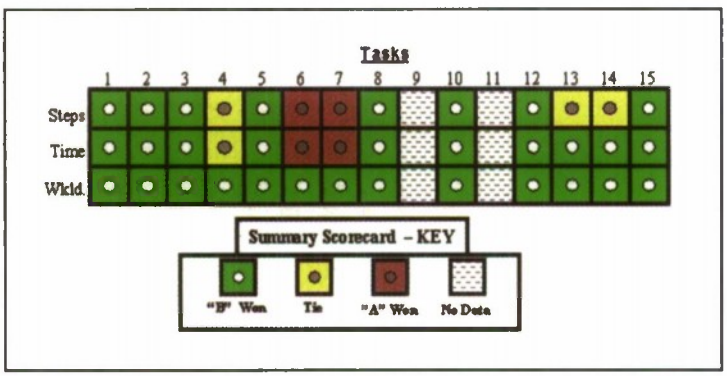
Evaluation Reduces Risk for AWACS Interface

Payoff The Human Effectiveness Directorate developed a better-designed human-machine interface (HMI) to produce a future Airborne Warning and Control System (AWACS) that is more mission effective while minimizing errors.

Accomplishment Directorate researchers recently conducted a critical test to help determine the future HMI of the AWACS Block 40/45 aircraft. The directorate's historical strengths in HMI evaluation techniques and tools were vital in producing an evaluation procedure that directly contrasted two interface designs to each other and to the current AWACS Block 30/35 interface design.

The results of the performance evaluation answered critical questions regarding interface vendor selection. This process culminated with the announcement that the Air Force will use Interface B for the AWACS Block 40/45 interface.

Background There were two main contenders for the AWACS Block 40/45 HMI, referred to here as Interface A and Interface B. Directorate researchers worked closely with the AWACS user community to provide timely input to AWACS Block 40/45 decision makers by designing and conducting the interface evaluation.



The directorate centered the evaluation on the performance and subjective workload associated with 15 common AWACS operator HMI actions. They based the interface comparison on the ease of use for typical AWACS operators' interface tasks.

The results showed that Interface A performance was not improved relative to the current AWACS Block 30/35 interface. In contrast, not only was Interface B substantially improved compared to the AWACS Block 30/35 baseline, it was also much better than Interface A.

The directorate presented the results of the performance evaluation in the form of a scorecard for easy interpretation of the overall pattern of results. The scorecard (see picture) summarizes Interface B versus Interface A results. Interface B won 79% of the direct comparisons.

Human Effectiveness Directorate Research Sparks Industry Milestone

Payoff The ability to conduct operations regardless of terrain or weather conditions is critical to the warfighter and commercial pilots. Synthetic vision technology provides crews with greater situation awareness regarding terrain, threats, and navigation.

Accomplishment As part of a Dual-Use program, research by the Human Effectiveness Directorate, in conjunction with Rockwell Collins, led to the first-ever industry demonstration of low-level military approaches using synthetic vision technology. Directorate personnel conducted the first flight tests using synthetic vision technology displays for a zero decision-height/zero-visibility approach to landing blind at an assault airstrip.

Background Military applications of synthetic vision technology include flying complex approaches using satellite-based navigation systems to facilitate landing at austere locations in reduced visibility conditions. Other military applications include reducing controlled flight into terrain (CFIT) incidents, avoiding noise abatement areas, and increasing air traffic throughput at airports.

The directorate's flight evaluation of synthetic vision technology had a twofold objective: (1) enable US Air Force aircraft to fly in instrument meteorological conditions as precisely and with as much terrain awareness as in visual meteorological conditions, and (2) prevent CFIT accidents. The directorate's technical approach was to develop and demonstrate in flight a heads-up display, incorporating primary flight information, command path guidance, and synthetic terrain suitable for flying complex precision approaches in varying visibility conditions.

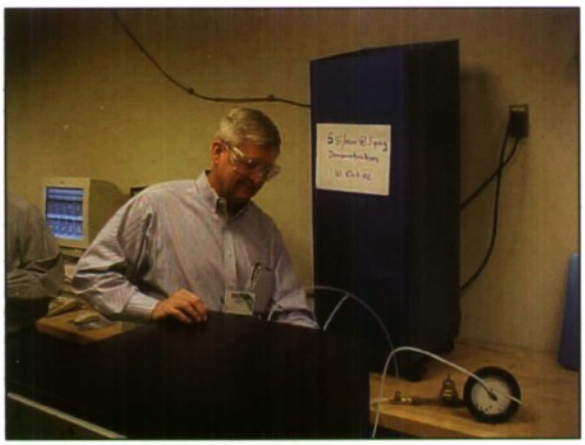
While synthetic vision technology has military applications, it also allows the blending of sensor and synthetic imagery for the commercial success of civil applications. With the recent award of two Dual-Use program contracts for the topic "Integration of Real-time Information with Synthetic and Enhanced Vision Displays," the directorate will continue its collaborative research efforts with industry.

Solid Electrolyte Oxygen Separator Breadboard Successfully Demonstrated

Payoff A newly developed Solid Electrolyte Oxygen Separator (SEOS) breadboard device uses a heated ceramic membrane to separate oxygen from ambient air to produce an oxygen flow with a purity of >99.9%. SEOS technology does not require an air compressor, can produce purities of >99.9%, can guarantee protection from chemical and biological agents, and has only one moving part to improve reliability.

Researchers believe this revolutionary technology will eventually replace molecular sieve-based technology. This Human Effectiveness Directorate 6.2 Science and Technology Congressional Add program milestone represents significant progress towards an oxygen generation at point-of-use capability for the Department of Defense aircrew and passenger breathing systems. SEOS systems have a wide range of potential applications such as aeromedical evacuation, battlefield oxygen, deployed medical facilities, trickle charging of aircraft oxygen systems, and aircraft oxygen-generating systems.

Accomplishment Air Products and Chemicals, Inc. of Allentown, Pennsylvania, teamed with Ceramatec, Inc. of Salt Lake City, Utah, to demonstrate an SEOS breadboard device that represents the highest verified flow rate achieved to-date for a ceramic-based oxygen generator. The breadboard produced >99.9% purity oxygen at a flow rate of 5 liters/minute and pressure of 5 pounds/square inch, meeting all objectives of the directorate's 6.2 Science and Technology Congressional Add program to advance SEOS oxygen-generation technology for military ground-based and airborne applications. Air Products and Chemicals, Inc. demonstrated the SEOS breadboard device at their Allentown facility to representatives from the US Army, US Navy, and US Air Force.



SEOS uses a heated ceramic electrolyte material and direct current voltage. Ambient air passes over the electrolyte where oxygen molecules are ionized, and negatively charged oxygen ions pass through the crystalline structure of the electrolyte. Upon reaching the opposite side of the electrolyte, the oxygen ions recombine to form molecular oxygen.

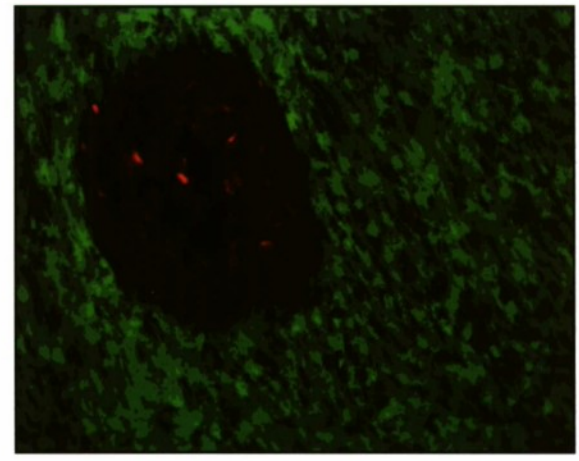
Background Aircrews must breathe oxygen to prevent hypoxia. Currently, aircrews receive oxygen from one of three systems: liquid oxygen, high-pressure gaseous oxygen, and onboard oxygen-generating systems (OBOGS). Both liquid and high-pressure gaseous oxygen systems require pre-flight filling. However, the military desires to eliminate the costly and bulky infrastructures associated with these systems.

At this time, some aircraft have OBOGS that use molecular sieve technology to separate oxygen from engine bleed air. However, molecular sieve technology has some limitations: ground-based systems (such as aeromedical systems) require a separate air compressor, airborne systems require significant amounts of engine bleed air, oxygen purity is limited to 93%, and molecular-sieve based systems cannot guarantee chemical and biological protection.

New Cell Cultures Key to Experimental Verification of Laser Eye Damage

Payoff Scientists from the Human Effectiveness Directorate demonstrated the capability of using artificially pigmented ocular cells, cultured *in vitro*, to assess eye damage resulting from both acute and chronic laser exposure. This cell culture, when coupled with novel biomolecular assays, can assess damage mechanisms and thresholds for exposure to lasers without having to conduct live animal testing.

Accomplishment The directorate's laser bioeffects team, headed by Dr. Ben Rockwell and Dr. Michael Denton of Northrop Grumman, developed a novel *in vitro* assessment for determining retinal damage endpoints. Studies of laser bioeffects performed *in vivo*, especially in the eye, have led standard-setting bodies to treat laser pulses arriving at a rate faster than 20 kHz (50 kHz for near infrared) as equivalent to a continuous wave (CW) exposure.



Using a newly developed artificially pigmented cell culture system, the laser bioeffects laboratory confirmed that damage threshold is experimentally equivalent for a CW and quasi-CW exposure, but the mechanisms for damage are different. Knowledge from this analysis will provide valuable insight for laser safety in battlefield situations involving the application of mode-locked femtosecond and picosecond lasers.

Background Previous data shows that within the visible wavelength region, a pulsed laser with a repetition rate greater than 20 kHz (quasi-CW) damages the retina at the same total energy as one with the energy distributed evenly over the exposure (i.e., CW exposure). Fundamentally, femtosecond mode-locked (MHz) beams deliver energy differently than CW beams, depositing discrete packets of very high energy (peak power) followed by periods of no photon delivery (nanosecond timescale). These high peak powers do; however, average over time as overall lower total energy is delivered.

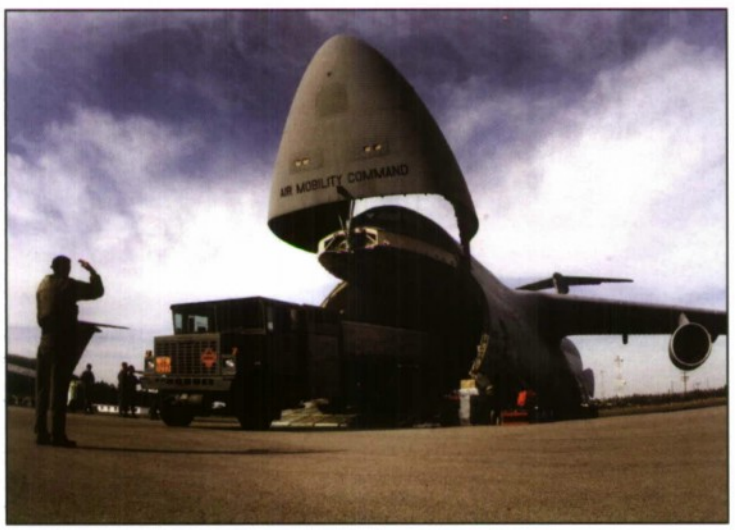
Because thermal relaxation in biological tissues requires longer timescales than that provided between pulses of a femtosecond mode-locked beam, incoming pulses deposit their energy faster than the tissue can dissipate the heat generated. This leads to heating of the tissue at rates similar to those achieved by CW laser exposure. Earlier experiments proved this to be true in live animal testing but noted differences in retinal pathology.

To test the theory in an *in vitro* setting, scientists chose the human retinal pigment epithelial cell line hTERT-RPE1, which is immortalized by the introduction of the human telomerase reverse transcriptase gene. The hTERT-RPE1 cells were proven to be highly efficient at cellular uptake (phagocytosis) of isolated melanosome particles and stably retain the pigment granules. Because melanosome-dependent laser bioeffects are known, the use of the artificial pigmentation of hTERT-RPE1 cell cultures as a defined system for analyzing the effects of pigmentation in laser-tissue interaction were proposed.

AFRL Software Agents Address AMC Needs

Payoff Generating an Air Mobility Command (AMC) flight schedule requires the collaborative efforts of many individuals, each with specific responsibility and authority. Individuals may control both required and requested tasks as well as resources needed to accomplish those tasks.

SRI, Inc. developed agents technology and will apply work on dynamic mediation (developed under the Defense Advanced Research Projects Agency Autonomous Negotiating Teams [ANTs] program) to AMC scheduling issues. Dynamic mediation is a real-time negotiation protocol that is adaptive and incremental. SRI will integrate this technology with a dynamic scheduler.



Accomplishment The Information Directorate's Information Technology Division performed the technical management of the ANTs program. The directorate recently awarded SRI's effort as part of the Information Systems Division's Integrated Flight Management (IFM).

The transfer of ANTs technology to the IFM is reflective of the ongoing collaboration between the two projects. Ideally, the agents-based scheduling work will continue on the transition path to AMC via the same successful process used for both the worldwide aeronautical route planner and the intelligent distribution of notices to airmen.

Background SRI, Inc. will identify a set of representative scenarios from the AMC problem domain that requires automated support for collaboration among schedulers. SRI will develop methods to support collaboration, as proof of concept, using those scenarios as motivation.

For example, when AMC is resource-restrained, it may be useful to negotiate with the wings for more assets. The wings are scattered around the world. Consequently, the negotiations may occur during initial scheduling of the requirement or during schedule modification in response to events during execution.

The negotiation that occurs between the wings and AMC involves resolution of issues such as who should provide extra capacity or whether or not to drop missions. Factors that can influence those decisions include mission priority, the degree to which the wing is already over contact level, physical constraints at the wing (such as availability of the proper type of plane and distance from the mission destination), and the priority of other requirements on unused capacity at the wing.

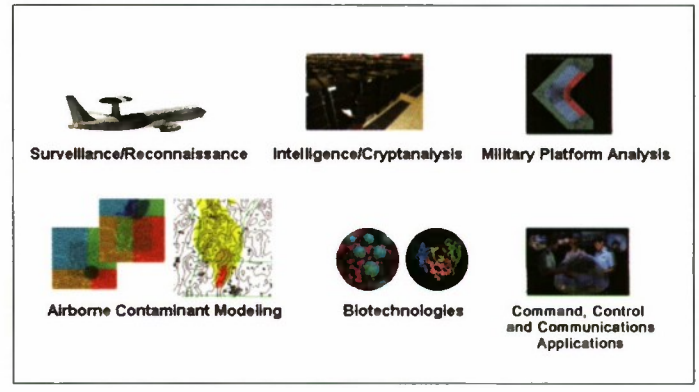
Once such issues are settled, the barrel allocator assigns missions to wings, and the scheduler sends orders to wings. The wings can then assign the exact number of planes and crews. SRI will support collaboration in two dimensions: first, by providing automated support of the negotiation of resource conflicts, and second, by monitoring local state information for helpful actions that can further the scheduling activities of another user of the aggregate team activity.

High-Productivity Computing Systems

Payoff Recent Department of Defense (DoD) studies indicate a national security requirement for high-productivity computing systems (HPCS). For DoD, revolutionary change in HPCS means making supercomputing resources easier to use and easier to program. It means accessing large data repositories located around the world and merging scientific computing with pervasive computing on the battlefield.

HPCS requires ever-present multiple levels of security, autonomous systems management, and the application of real-world requirements to the challenges of HPCS to make everything work. The Information Directorate, serving in its role as the Air Force member of the review panel, will provide transition opportunities and challenge problems.

Accomplishment The Defense Advanced Research Projects Agency (DARPA)-sponsored HPCS program is a three-phase program scheduled to extend to 2010. Current Phase I tasks include industry research and development (R&D), technology component development, and application analysis and performance assessment of a broad spectrum of potential HPCS applications.



The challenge for industry R&D is to develop a productive system with the ability to double in value every 18 months (Moore's Law) over the next 2 decades. Throughout this task, DoD operational and research software applications will serve as the requirements driver for architecture and software research and systems assessment. DARPA and the directorate envision industry adoption of the architectures as a central strategy to ensure cost-effective solutions are available to the national security community.

The major technology areas requiring development in support of the next generation of productivity systems are system architecture, programming models, software technology, and hardware technology. This task demands an industry whole-system perspective.

It is vital that researchers analyze a broad spectrum of potential HPCS applications to extract the key HPCS system design characteristics, parameters, constraints, and programming environments. Researchers are currently studying applications that include operational weather and ocean forecasting; planning exercises related to analysis of the dispersion of airborne contaminants; cryptanalysis; military platform analysis; survivability/stealth design; intelligence/surveillance/reconnaissance systems; virtual manufacturing/failure analysis of large aircraft, ships, and structures; emerging biotechnologies; and command, control, and communications applications.

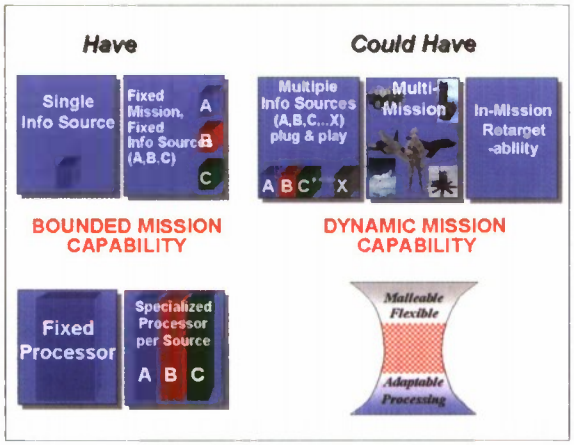
Background The HPCS program will provide DoD with significant technology and capability advancements for the national security and industrial user communities by filling a high-end computing gap that exists between today's HPCS, based on late 1980s technology, and the promise of quantum computing. The end product will be economically viable computing systems with both scalable vector and commodity system functionality for the national security as well as commercial, research, and industrial user communities.

Polymorphic Computing Architectures

Payoff Today's embedded computing systems, developed for fixed mission scenarios, cannot provide the robust embedded processing capability necessary to fully support retargetable and multi-mission systems. This lack of versatility to dynamic mission requirements and the reduced performance or poorly matched processing performance result in degraded capabilities for our fighting forces and can dramatically limit the military's ability to effectively project forces around the world.

Polymorphic Computing Architectures (PCA) will institute a paradigm shift from static-open-loop to reactive-closed-loop mission algorithms, application software, and hardware implementation. The processing capability is mission and technology invariant yet highly optimizable for each specific in-mission and multi-mission and/or technology instantiation, providing for tactical and strategic tempo opportunities as well as technical upgradability.

Accomplishment The Information Directorate's PCA program is developing a family of novel malleable microarchitecture processing elements including computer cores, caches, memory structures, data paths, network interfaces, network fabrics with incremental instructions, operating systems (OS), and network protocols. These elements will have the ability to reconfigure to match changing mission and scenario demands.



To support the use of polymorphous computing systems, directorate researchers are creating a model-based software framework for reactive monitoring, optimization, modeling, resource negotiation and allocation, regeneration, and verification. Specific PCA goals allow post-silicon optimization through the incorporation of polymorphous concepts within commercial processing research and development, and fabrication infrastructure.

Other goals include developing an environment that provides resource allocation, negotiation, and monitoring; implementing verification and validation at multiple system levels; developing test beds and conducting proof-of-concept experiments; facilitating technology transitions using strategic teaming; and establishing benchmark and standards groups to create community standards that enable broad application and commercial support of polymorphic computing architectures. The PCA program is concentrating on four critical research areas: polymorphic system characteristics, scenarios, constraint metrics, and abstraction test suites; polymorphous computing research; proof-of-concepts experimental test beds; and morphware stable interfaces.

Background The PCA program is a 5-year Defense Advanced Research Projects Agency-sponsored program. Phase 1 is pursuing the identification of high-value dynamic embedded computing mission characteristics, application functionality, initial polymorphous computing concepts and implementations, and early concept experimentation and prototyping. Phase 2 research will investigate innovative approaches and techniques leading to or enabling revolutionary advances in the state of the art.

Polymorphic architectures break the current failure-prone development approach of hardware first and software last by moving beyond conventional silicon to flexible polymorphous computing systems. This is possible through the development of a family of novel malleable microarchitecture processing elements including computer cores, caches, memory structures, data paths, network interfaces, network fabrics with incremental instructions, OS, and network protocols.

Engine Supplier Base Initiative Casting Sector Program

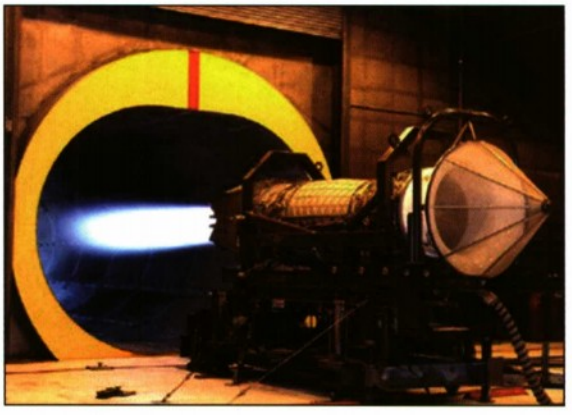
Payoff The Engine Supplier Base Initiative (ESBI) Casting Sector program produced a better than five-to-one return on investment of more than $100 million. The program met or exceeded five of the six program goals. ESBI met the goal of a 50% reduction in airfoil tolerance, exceeded a 50% reduction in structural rework, met a 50% reduction in single crystal scrap, exceeded a 25% reduction in tooling procurement time, and exceeded a 30% reduction in structural production cycle time. ESBI achieved a 44% reduction in new part design and process development time compared to the program goal of 50%.

Accomplishment The Manufacturing Technology (ManTech) Division of the Materials and Manufacturing Directorate, under a cooperative agreement with Howmet Corporation, successfully completed the ESBI Casting Sector program. In addition to ManTech and Howmet, General Electric Aircraft Engines, Lockheed Martin Aeronautical Systems, Pratt & Whitney, Precision Castparts Corporation, and Rolls-Royce Corporation were key players in the success of ESBI. The success of the program illustrates that competitors can work together for the common good of an industry sector.

Background In the past 20 years, the cost of advanced military engines has risen approximately fivefold. Affordability of advanced weapons systems is of paramount importance to the Department of Defense.

A cost breakdown reveals that precision investment cast airfoil and large structural components of nickel-based and titanium-based alloys for man-rated gas turbine engines comprise about 40% of the total weight and 34% of the total cost of an advanced military fighter engine. The directorate established the ESBI Casting Sector program to identify, implement, and deploy manufacturing technology that would improve the US industrial base and enhance US international competitiveness in the man-rated turbine engine industry. The directorate expanded the activities to include the F-22 Raptor's aft side of body titanium casting that keeps each wing attached to the fuselage.

ESBI addressed the total value chain from raw materials to finished products. The casting industry, working jointly with the original equipment manufacturers and the Air Force, performed joint prioritization of projects.



ESBI allowed for immediate implementation of favorable results, while a sector-wide approach allowed for the solution of common problems not solved by individual companies. The directorate executed ESBI as a first attempt at combining collaboration with a competitive aspect.

ESBI achieved cost reductions through component manufacturing cycle- time reductions and through product and process quality improvements brought about through technical advances. These steps also included the application of lean business practices.

CoRTM Process Reduces Fabrication and Assembly Costs for Composite Structures

Payoff The cocuring of the substructure and skin by means of the Cocuring of an uncured skin to a Resin Transfer Molded (CoRTM) process is an effective way to reduce the cost of composite fabrication and assembly. The CoRTM process reduces part count, tool count, weight, and cost. The dimensional precision and repeatability of the resin transfer molding process also enables the use of Z-reinforcement technologies such as Z-pins and three-dimensional preforms, increasing the potential applications by enhancing structural performance.

Accomplishment The Composites Affordability Initiative (CAI) Team, consisting of the Materials and Manufacturing Directorate, the Air Vehicles Directorate, the Office of Naval Research, Boeing, Lockheed Martin, and Northrop Grumman, demonstrated a process that can dramatically reduce the costs of composite fabrication and assembly. The CoRTM process, developed by Northrop Grumman, produces large, integrated, weight-efficient, precise, and repeatable structures.

The CAI Team used a vertical stabilizer from the Joint Strike Fighter (JSF) to demonstrate the technology. Using CoRTM to manufacture that part could lead to nearly $14,000 in savings derived through a 52% reduction in part count, a 38% reduction in tool count, a 7% reduction in weight, and a 17% overall cost reduction when compared to the typical JSF construction process and the associated fit-up, liquid shimming, and surface mold line treatments for air vehicles.

Background Traditional aircraft structures consist of multiple piece assemblies that manufacturers pre-fit together, filling gaps between mating surfaces with shim materials to create a snug fit, and then mechanically fastening in place. This results in very lengthy manufacturing flow times and high acquisition costs.

Through CAI, the CoRTM process is a viable and promising alternative for affordable composite structures. CoRTM combines two cost-effective processes: fiber placement (the automated placement of bands of high-strength fibers combined with resin onto a tool) for skin structures, currently used on JSF, F-18, V-22, F/A-22, etc.; and resin transfer molding (the injection of high-strength resin into a mold containing high-strength fibers formed to a specified shape) for substructures currently used on the F/A-22 Raptor and other aircraft.

Instead of fastening the skin to the substructure, the CoRTM process designs and fabricates the skin and the substructure as a single component, eliminating the need to fasten them together. After the fiber placement process lays up the uncured skin, the manufacturer builds up the substructure by placing and tooling dry fiber preforms on top of the uncured skins. The manufacturer then injects the preforms with resin and cures the whole assembly to form the structure.

Title III Titanium Matrix Composite Turbine Engine Component Project

Payoff A viable titanium matrix composite (TMC) supplier base for military and commercial applications with affordable TMC products provides commonality and volume production. Also, TMC provides improved engine performance of range, payload, and fuel efficiency in support of the warfighter.

Accomplishment A Title III project with the Manufacturing Technology Division of the Materials and Manufacturing Directorate, under a cooperative agreement with the Titanium Matrix Composite Turbine Engine Component Consortium (TMCTECC), established a viable supplier base and reduced the cost of manufacturing TMC components for military and commercial applications. This marked the first production of a TMC component in aircraft gas turbine engines. General Electric Aircraft Engines will use a TMC Nozzle Compression Link in the General Electric-built F110 engine for the F-16.

Background TMC is an advanced composite material of titanium reinforced with either silicon carbide particulate or filament. Parts fabricated with TMC are significantly stronger, lighter, and considerably more resistant to the stress of extreme temperatures than conventional titanium or superalloys. They also provide increased performance (range, payload, and fuel efficiency).

This technology is key to improvements in propulsion systems for the next generation of commercial and military aircraft. The directorate expects substantial cost, performance, and durability benefits from the use of TMC components in transport and fighter aircraft engines. Other potential applications for TMCs include airframes, medical equipment, and chemical processing.

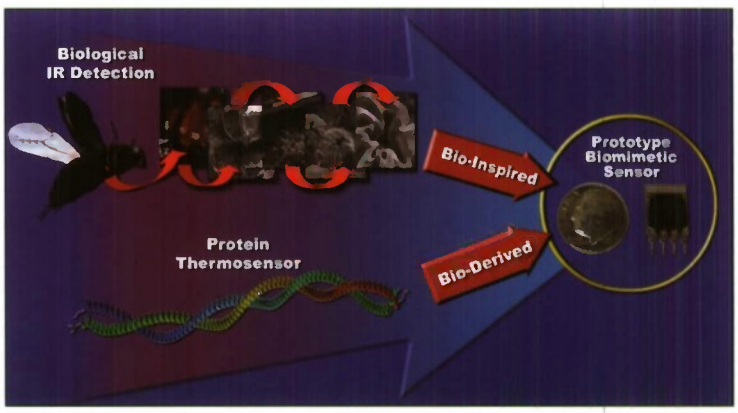
TMCs are very expensive, and the production base did not exist to routinely produce affordable, high-quality components. The directorate's Title III program objective was to ensure the TMC supplier community was self-sustaining without the need for government subsidy. Under the Title III project, the TMCTECC aim was to mature the TMC fabrication industry and deploy advanced gas turbine engines in the form of fan blades, fan frames, actuators, rotors, vanes, cases, ducting, shafts, and liners.

A major step in that direction was to reduce the cost of manufacturing the nozzle compression link by more than 66%. While its competing metal part remains less expensive, continuing cost reduction actions and improvements in manufacturing processes will make TMC components more economically attractive for a broader range of military and commercial applications.

Technologies Imitating Life Could Enhance Performance and Lower Costs of Critical Defense Technologies

Payoff Continued research in biotechnology and biomimetics could lead to the development of dynamic materials, devices, and processes that directly support the warfighter. Advancements in the understanding of the natural world benefit science, provide opportunities for innovative commercial applications never before possible, and could heighten the performance of vitally important military technologies while reducing costs.

Accomplishment Scientists in the Materials and Manufacturing Directorate's Survivability and Sensor Materials Division, working with the Air Force Office of Scientific Research and researchers at various universities, made significant advancements in the areas of biotechnology and biomimetics, which means literally to imitate life. Materials researchers continue to be intrigued by various organisms' ability to sense infrared (IR) radiation using the readily available elements carbon, hydrogen, oxygen, and nitrogen.



Their efforts support the Air Force goal of producing hybrid materials with properties superior to those made of either entirely synthetic or biological alternatives. This research increases the understanding of living creatures possessing unique properties and abilities that could someday enhance the performance and affordability of critical defense technologies.

Background Directorate scientists have advanced the understanding of how certain biological organisms sense electromagnetic radiation outside the visible-light region. This phenomenon is important to the Air Force due to the proliferation and reliance upon sensors and detection systems that operate in the IR region of the electromagnetic spectrum. The quest for understanding this phenomenon escalated even further as a result of the extreme sensitivity reported in biological IR/thermal detection and because biology achieves this without cryogenics.

In a practical sense, biomimetics refers to interdisciplinary efforts to understand biological principles, then applying them to improve existing technologies or create new ones. Technologies imitating life could have a profound impact on national defense. Investigations have yielded critical insights and helped scientists progress toward the development of bio-inspired and bio-derived technologies.

The biological processes associated with biotechnology and biomimetics are enormously complex and multistep, and they often operate nonlinearly. Also, the molecules involved in these processes are sometimes fragile, and integration with other systems can be problematic.

Despite these drawbacks, the research is very promising. Biotechnology and biomimetics frequently use composite materials that provide combinations of properties not achievable by any single material. This allows researchers to detect minute differences such as distinguishing nearly identical compounds and different inorganic crystal faces.

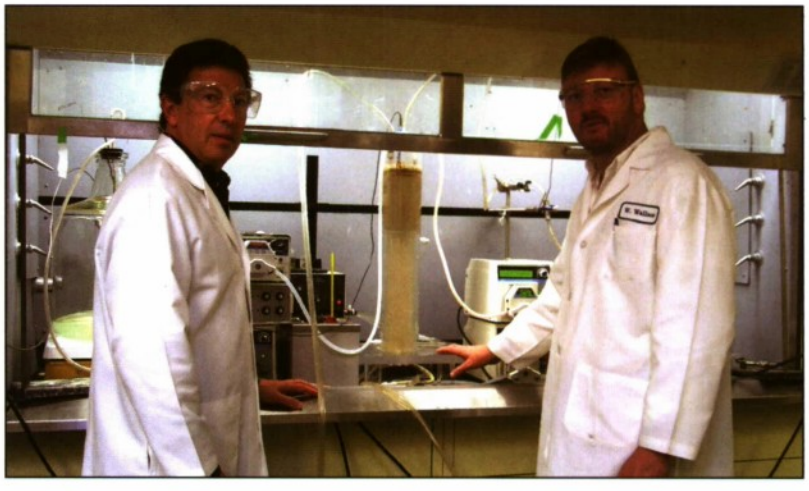
Researchers Explore Microbial Hydrogen Production as Key to Alternative Energy Source at Bare Base Facilities

Payoff When successful, Materials and Manufacturing Directorate researchers will have demonstrated that hydrogen production from bare base waste streams is a feasible alternative source of energy for fuel cells. Fuel cells driven by hydrogen will lower diesel fuel consumption and will lessen the logistical burden at the bare base.

The hydrogen generation from waste will be an environmentally friendly process, reducing noise and air pollution created by current diesel energy generators and reducing the removal and treatment of sewage waste by the nation hosting the base. Success of the project will expand opportunities to develop the process as an alternative energy source for other industrial operations.

Accomplishment Directorate researchers are developing a biological method of producing hydrogen from waste streams created by base dining halls, kitchens, latrines, hospitals, laundry facilities, and showers at bare base facilities. The directorate will develop a two-reactor system to produce a clean source of hydrogen for fuel cells while reducing waste disposal and treatment needs, in addition to the logistical and pollution burdens associated with using current diesel energy generators for energy production.

Background Bare base facilities have as many as 1,100 personnel who live in temporary housing. Their mission often requires the base to function for several years with the host nation providing little or no services. Currently, mission-essential power (MEP)-12 diesel generators produce the electrical power needs of the base. The MEP-12 generators require 4,000 gallons of diesel fuel per day, which require transportation to and storage at the facility.



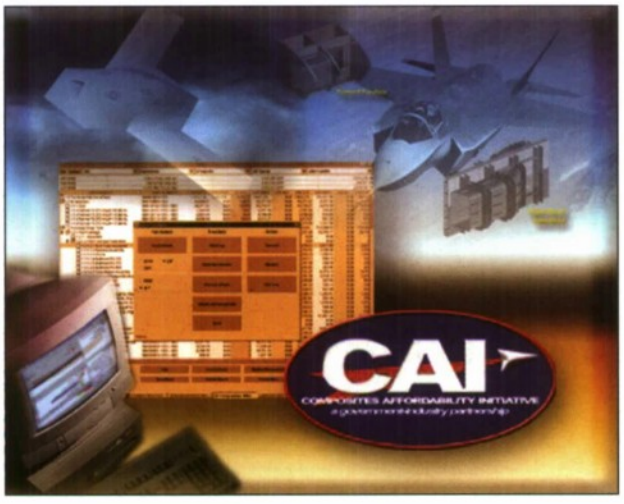
The personnel at bare base facilities produce various waste streams from dining hall waste, sewage sludge, and wastewater. Researchers from the directorate's Weapons Systems Logistics Branch initiated a project that may make it possible to exploit waste streams to produce hydrogen needed to supplement base energy needs. The possibility of using hydrogen as an alternative fuel is an exciting option due to its high conversion efficiency and nonpolluting nature.

Though hydrogen is the most abundant element on earth, it is bound to other elements and must be separated before it can be used in energy generation. Using sunlight as an energy source, specific enzymes contained in microorganisms can produce hydrogen from waste materials, providing a seemingly inexhaustible source of material for hydrogen production. Hydrogen production from waste materials will encourage additional waste recycling and waste management in bare base operations.

Composites Affordability Initiative Test Database Opens Information Flood Gates

Payoff The Composites Affordability Initiative (CAI) test database will provide company designers, engineers, and weapon system program offices with the data they require to consider introducing advanced technologies into future and current weapon systems. The directorate expects the database to minimize the financial burden of testing required to implement a new technology as well as reduce the risk and accelerate the transition.

Accomplishment The CAI Team, consisting of AFRL's Materials and Manufacturing Directorate and Air Vehicles Directorate, the Office of Naval Research, Boeing, Lockheed Martin, and Northrop Grumman, developed a relational database to archive all test data and make the data accessible to all team members for current and future use.



Background The vast majority of composites development and demonstration efforts develops data to support technology transition. This data is critical to support the transition, and the contractor often only shares the data with the weapon system program office.

More successful programs organize their data to support additional transition opportunities. In consideration of the large CAI Team, it was imperative to generate data that is trusted by all the organizations and data that is available to aid in current and future technology transition opportunities to reduce the duplication of testing.

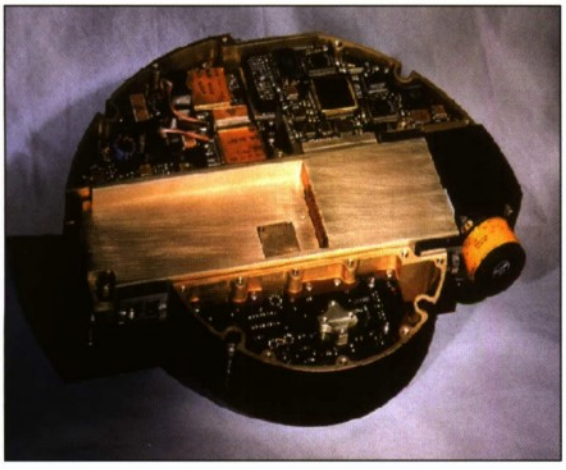
To accomplish this task, team participants first came to an agreement on test standards to follow. For the first time, the entire industrial base of aerospace prime contractors, as well as the Air Force and the Navy, agreed to a single set of testing standards to validate the performance of composite structures created with new materials and processes.

The CAI test database contains mechanical property test data that is traceable back to the process that produced it including processing parameters used as well as the material and its integrity. This interrelationship between materials, processes, and performance produces a legacy of data that elevates the integrity of the data and facilitates the transition of materials and processes.

The first 18 months of CAI generated data for more than 7,000 tests. Data from full-scale development projects resulted in transition to real systems, such as the F-35, while participants continue adding technology maturation efforts to the database. These data offer the potential to minimize testing, thus supporting additional technology transition opportunities.

Viper™ Mid-IR Laser Aircraft Defense System Returns Huge Savings on Investment

Payoff Northrop Grumman, under contract with the Materials and Manufacturing Directorate's Manufacturing Technology (ManTech) Division, successfully developed significant cost-saving procedures in the manufacture and assembly of the Viper Mid-Infrared (IR) Laser. The directorate estimates a net savings of $4.2 million for the first 250 units, as well as a dramatic increase in yield and reliability improvements in life-cycle costs and increased system availability, without degrading the performance of the Viper.



Accomplishment The Viper Mid-IR Laser is one of the primary components in the Large Aircraft IR Countermeasures (LAIRCM) system, designed to protect C-17s, C-130s, and other large aircraft from IR-guided surface-to-air missiles. The LAIRCM will autonomously detect and signal the flight crew when the aircraft is threatened. It will track and then jam the missile's guidance system, saving both aircrew and aircraft.

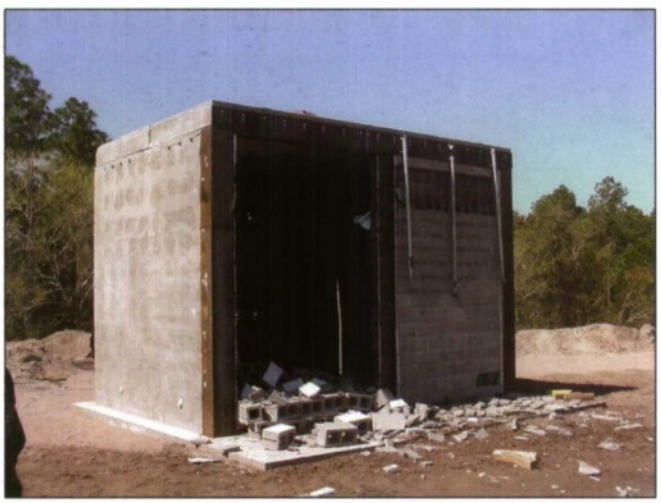
ManTech and Northrop Grumman representatives reduced costs for the Viper by addressing manufacturability, maintainability, reliability, supportability, and availability issues. These cost reductions would, in turn, save money on the LAIRCM program.

Background One example of the steps taken by ManTech and Northrop Grumman representatives to accomplish cost reductions was the insertion of lean practices and principles to increase yield, reduce rework, and touch labor costs. In general, they made design and manufacturing process changes that reduced deficiencies and the number of assembly and adjustment steps for the electronic and optical components.

Another example was the high-value electronics, optics, and other materials that were available only from a single supplier. ManTech obtained multiple supplier sources, creating more competition and driving down the cost by substituting standardized components for specialized ones.

Polyurethane Elastomer Coating Shows Promise for Strengthening Buildings Against Terrorist Explosions

Payoff A polyurethane elastomer coating applied to exterior walls will prevent blast fragments or pieces of the wall from penetrating the inside of Department of Defense (DoD) facilities where they can cause harm to personnel. Materials and Manufacturing Directorate researchers cannot harden some facilities in conventional ways due to economic or political restrictions. They expect the new coating process to overcome these restrictions, while providing significant cost savings, as compared to hardening a facility with thick concrete walls, reinforcing steel, and composite materials and fabrics.



Accomplishment Directorate engineers developed a coating for concrete block walls, common nonload bearing walls, and lightweight manufactured structures that provides additional protection for people inside during a terrorist explosion. The directorate's full-scale explosive testing on those structures coated with a polyurethane elastomer revealed that the samples expanded to twice their thickness, demonstrating that the elastomer coating will allow a concrete wall to flex, thus preventing blast fragments or pieces of the wall to penetrate the inside of a building.

Background For more than 20 years, the DoD has faced the global threat of terrorists who cause injury and death to many innocent people and serious damage to important assets. In fact, in the last 15 years, 80% of the DoD's total casualties were the result of terrorist activities.

The directorate's Force Protection Branch, part of the Airbase Technologies Division at Tyndall Air Force Base, Florida, has an impressive record for developing effective methods of retrofitting existing structures to improve resistance to a blast. To better determine the mechanical properties of the elastomer, the engineers conducted several tests using only the elastomer and discovered it was, by itself, a highly effective alternative to the high-strength fabric retrofitting technique. Directorate engineers conducted several tests overseas as part of a joint international cooperative program.

As part of the test program, force protection engineers studied 25 commercially available polymers to determine their range of mechanical properties. Typically used in pickup truck bed liners, the lining for municipal water tanks, and in commercial food preparation areas, elastomers constitute a large commercial enterprise.

Of the 25 tested, directorate engineers found one product yielded the most favorable results and contained the desired range of properties needed for blast protection. The main benefits to the technology are the availability, and quickness and ease of application, which provide rapid response capabilities. The Air Force has released the technology to the engineering community to provide guidance for upgrading lightweight structures to protect people and facilities from explosive blasts.

Revolutionary Test Method for Kissing Bonds Ensures Strong Adhesion for High-Performance Aircraft and Civil Structures

Payoff A revolutionary test method will speed up certification of adhesively bonded composite materials for widespread usage in aircraft construction. This certification will allow adhesively bonded structures to compete economically with traditional riveted aluminum structures.

Additionally, this new technology allows aircraft designers to use the distinctive properties of composite materials to great advantage in highly original and efficient aircraft designs. New lighter, stronger, and more efficient adhesively bonded design concepts are no longer constrained by traditional joining methodologies.

Accomplishment Dr. Robert L. Crane, a scientist in the Materials and Manufacturing Directorate, found a way to detect both nonexistent bonds, or kissing bonds, and weak or low-strength bonds while performing research on the detection of high-cycle fatigue damage in the first-stage compressor blades of an F100 jet engine. Dr. Crane's discovery will allow technicians to test adhesive bonds for mechanical performance nondestructively during manufacturing and depot-level repair.

The technology employed in the new testing method works wherever manufacturers use adhesive bonding, with composite and metal as well as hybrid composite and metal structural components. This new testing method is so effective at identifying kissing bonds, it could easily make composites the material of choice for most high-performance aircraft and civil structures. Other major application areas for composite materials affected by this technological advance are spacecraft, automobiles, prostheses, and sports equipment.

Background A kissing bond refers to a condition in adhesive bonding where there is intimate contact between the adhesive and the structure or component, but no adhesion between these two entities. Inspectors traced a sizeable number of premature service failures to kissing bonds. Consequently, aircraft designers were reluctant to use adhesive bonding in primary or flight-critical structures, despite the advantages of this joining technique.

Since the 1950s, the nondestructive inspection community within the United States searched intently to find any technique capable of predicting bond performance and detecting kissing bonds. Two challenges stopped progress towards this goal.

First, manufacturers most often use methods restricted to areas that carry little or no structural loads when detecting these defects. Second, from an ultrasonic inspection point of view, there is no difference between a kissing bond and a coherent bond because both are in intimate contact and; therefore, undetectable with ultrasonic methods. Even if inspectors can detect kissing bonds, it is still possible for a low-strength bond to slip through the inspection process and result in unexpected structural failures.

The directorate and The Boeing Company, which is currently patenting the technology, jointly conducted the research that validated this concept. Since the discovery of this new testing approach, several organizations have expressed intense interest in using the new method for the inspection of primary or critical bonds.

Lean Production Approaches Benefit Space Vehicle Integration and Test

Payoff Under contract with the Materials and Manufacturing Directorate's Manufacturing Technology (ManTech) Division, researchers at Northrop Grumman developed a lean production approach to produce multiple unique space vehicles faster and in a more cost-efficient manner. Applying this production approach to multiple space vehicle builds can save up to 50% in costs and 70% in cycle time related to mechanical build cycles.

Manufacturers realize savings through simplified operations and reduced learning curves, defect occurrences, span times, and capital equipment requirements. Additional significant savings are possible through design reuse as a result of electronics packaging hardware developed on this program.

Accomplishment ManTech and Northrop Grumman created the Flexible Space Vehicle Production Line (FSVPL) program for flexible, or variable, production volumes for the high-performance military and civilian satellite market. FSVPL focused its efforts in two primary areas.

The first area—a design for lean production—focused on developing designs that could be more readily producible in a volume environment modeled after the "lean production" methodology developed by Toyota and used throughout the automotive and aviation industries for decades. The second area—standardized electronics packaging—designed, developed, produced, and qualified a mechanical package to house electrical components. This package, commonly referred to as the electronic "box," includes all the mechanical housings inside the box that hold critical electrical components.

ManTech and Northrop Grumman then demonstrated the program's technical efforts in a pilot plant demonstration. They ran full-scale mock-ups of space vehicles through a simulated factory environment to validate program designs and approaches.

Background Space vehicle integration and test (I&T) is a very costly and time-consuming portion of any satellite program, with cycle times ranging from 6 months to several years in duration. The increasing need to quickly launch new technology resulted in a focus upon reducing all aspects of space vehicle development and build cycles including I&T.

In the area of design for lean production, the FSVPL Team developed a flexible architecture approach to accommodate many missions and orbits with a variety of configurations. This modular and scaleable approach focuses on populating panels with equipment, so that the panels can be built up in parallel with structural and other subsystem elements.

This parallel build approach means that several teams of workers can produce different components of the space vehicle in separate areas concurrently, instead of one team of workers building everything in sequence. The architecture approach reflected in FSVPL design guidelines translates lessons learned to all new programs.

The crowning achievement of the FSVPL Team was the standard electronics packaging design. This design accommodates a highly robust mechanical package, allowing for easy installation, access, troubleshooting, and removal and replacement.

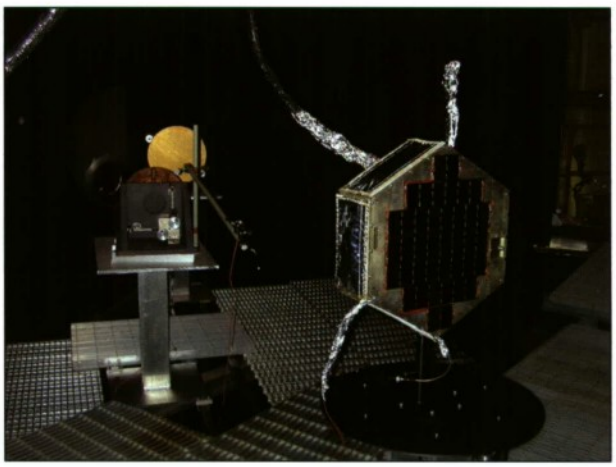
LHMEL Simulates Space Environment for Advanced Materials and Space Systems Testing

Payoff The collaboration between the Materials and Manufacturing Directorate's Hardened Materials Branch and the Air Force Space Battlelab provides the Department of Defense (DoD) with the capability to test articles in a simulated space environment prior to launch and activation. The joint venture enabled the Laser Hardened Materials Evaluation Laboratory (LHMEL) to activate a highly capable, 27 ft tall, 20 ft diameter, cryogenically shrouded vacuum chamber.

The speed at which the chamber "pumps down" and the addition of a cryogenic and vacuum-compatible turntable, which is used to mount and rotate samples in the chamber without breaking the vacuum, allow researchers to conduct multiple experiments daily. The directorate values these research capabilities, used to simulate the high-vacuum, cryogenic temperature, and solar radiation effects of the space environment on materials and systems, at over $25 million.

Accomplishment A cooperative effort between the directorate and the Space Battlelab recently resulted in an upgrade of the LHMEL, a world-class material characterization facility. The directorate expanded the capability of the facility beyond laser effects testing to include large-scale, thermal testing and space environment simulation.

Background Originally built by the Propulsion Laboratory, now the Propulsion Directorate, in the early 1960s, researchers used the vacuum chamber for space materials and systems qualification work. When the Space Battlelab, which operates under the direction of the Air Force Space Command, required a large-scale vacuum for testing a satellite, engineers at LHMEL began making the modifications required to make the chamber operational. The directorate's Hardened Materials Branch, which oversees LHMEL operations, and the Space Battlelab shared the cost of the modifications.



The LHMEL, a one-stop infrared testing resource, provides the Air Force with basic material response data, optical material characterization, hardening concept validation, and thermal simulation capabilities using a unique collection of laser wavelengths, power levels, and operating modes. LHMEL supports the directorate's mission to provide laser protection materials and hardening expertise for DoD personnel and systems.

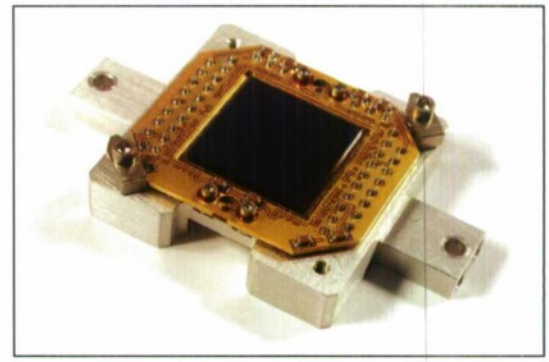
The directorate's LHMEL offers nationally unique material testing and laser processing opportunities to accommodate a wide variety of testing. Operated by Anteon Corporation, LHMEL supports laser and space simulation testing for almost any user on a reimbursable basis, whether that user is a DoD organization, a government-sponsored contractor, or an industry-funded entity. In recent years, facility use has nearly doubled, increasing income and allowing the Air Force to maintain the multimillion dollar facility at a fraction of the annual operating cost and at a reduced economic burden to the Air Force.

Advanced Development of High-Performance LWIR FPAs for Space-Based Global Missile Defense

Payoff Infrared focal plane arrays (IRFPAs) are critical components to space sensor payloads because they enable detection, tracking, and discrimination of long-range tactical and strategic missiles. The research and development effort of the Materials and Manufacturing Directorate and Rockwell Scientific Corporation (RSC) improves the performance of the arrays and ensures both timely delivery and high-quality products at an affordable cost. Continued success could lead to significant reductions in both payload costs and the number of satellites required for global coverage.

Accomplishment Scientists at the directorate and RSC have made significant advancements in the development of high-performance, long-wavelength infrared detectors needed to produce IRFPAs to build a space-based global defense system. The directorate completed fabrication of the first focal plane array (FPA) demonstration lot and used screening techniques and best growth techniques to fabricate and evaluate FPAs. A detector array (SCM1250-64) had extremely high performance against space test criteria. These performance results are state of the art for long-wavelength infrared (LWIR), low-background detection applications and demonstrate the success of the processes developed to date.

Background The directorate made significant progress during the first year of this program by developing compositional control, wafer-screening techniques including infrared, dark field, and Normarski contrast microscopy as well as laser profilometry. The directorate and RSC also employed automated defect counting techniques with automated frame-grabber software.



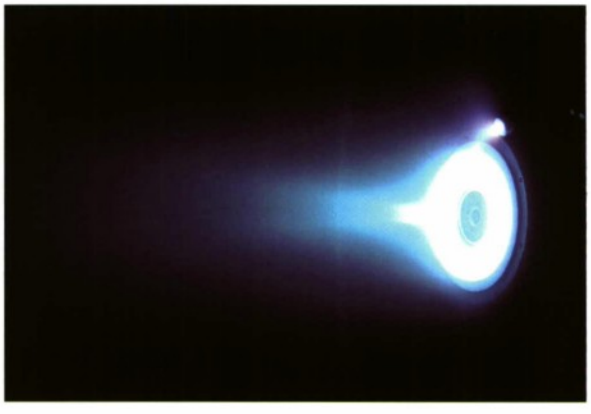
These techniques demonstrate that the substrate precipitates are the primary source of voids and microdefects in molecular beam epitaxial mercury cadmium telluride layers that limit their performance. Researchers developed and implemented routine nondestructive wafer mapping of composition and layer thickness to improve yield in detector cutoff.

Researchers Develop Ceramic Materials and Manufacturing Methods to Improve Hall Thruster Insulators for Spacecraft

Payoff Materials and Manufacturing Directorate researchers, along with industry partners, identified erosion-resistant ceramic materials that could increase the life of Hall thruster components as part of the Integrated High Payoff Rocket Propulsion Technology program. In addition, the directorate expects to lower the cost of the components' manufacturing process by adapting advanced, rapid prototyping techniques, which they expect will shorten the materials' evaluation cycle and allow flexibility in component configuration.

Accomplishment Directorate scientists and engineers identified ceramic materials that could increase the life of Hall thruster insulators for spacecraft including satellites and microsatellites.

Background Hall thrusters are low-thrust electric propulsion devices used on satellites to keep them in the correct orbit and to make orientation adjustments for proper alignment of telescopes and antennas. Electric propulsion is an attractive alternative to chemical propulsion for these applications because, although it produces less thrust, it is more efficient.



Unlike chemical rocket thrusters, which rely on the combustion of propellants and the expansion of hot combustion gases through a nozzle to produce thrust, Hall thrusters use a gaseous Xenon propellant ionized through collisions with electrons emitted from a cathode. An electromagnetic field accelerates and expels the charged Xenon ions from the chamber at high velocity to produce thrust.

Erosion of the ceramic insulators that make up the walls of the discharge chamber currently limits the lifetime of Hall thrusters. The high-velocity Xenon ions expelled from the thruster collide with and erode the insulators, eventually degrading thruster performance. Current Hall thruster insulators are composed of boron nitride or boron nitride-silica mixtures, which have good mechanical and thermal properties, but only marginal erosion resistance.

In laboratory-scale screening tests, directorate scientists and engineers identified two ceramics that eroded at rates two to four times less than the current boron nitride materials. The directorate's next step is to fabricate insulators from the erosion resistant ceramics and test them in an actual Hall thruster.

To manufacture prototype insulators from the erosion-resistant ceramics, the directorate partnered with Javelin 3D, a small business located in Salt Lake City, Utah. Javelin 3D will use a rapid prototyping technique, called the Laminated Object Manufacturing (LOM) method, to fabricate the prototype insulators. LOM is one of a variety of techniques developed to produce parts directly from computer-aided drawings.

Researchers Develop Integrally Woven Ceramic Composite Structures to Reduce Weight of Nozzles for Liquid-Fueled Rocket Engines

Payoff Integrally woven ceramic matrix composites for liquid-fueled rocket engine nozzles have the potential to reduce the weight of the nozzle by up to 50% and reduce the cost of the nozzle by up to 20%. Current nozzles, made from conventional stainless steel and nickel-based alloys, are very heavy structures. They are also expensive, using costly tube-forming operations, and brazing and welding processes in their construction.

Accomplishment Scientists and engineers at the Materials and Manufacturing Directorate partnered with the Rockwell Scientific Company and Boeing-Rocketdyne to develop ceramic materials and manufacturing processes as part of the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program for use in actively cooled rocket nozzles for next-generation, reusable launch vehicles. Directorate researchers expect nozzles constructed from advanced ceramic composites to have high strength at high temperatures and to be lightweight and reusable for multiple launches.

Background In a liquid-fueled rocket engine, the engine injects a fuel and oxidizers into a thrust chamber where they mix and react. The fuel/oxidizer reaction produces high-temperature gases, which expand through a bell-shaped nozzle to produce thrust. Manufacturers currently make nozzles from conventional stainless steel and nickel-based alloys.

Nozzle walls consist of many small tubes through which coolant can flow to keep the nozzle materials from melting. The nozzles are heavy, complex, and expensive and require large amounts of cooling. Researchers collaborating as part of this IHPRPT program expect to demonstrate high-temperature materials that can significantly reduce the weight and cost of nozzles.

The directorate partnered with Rockwell Scientific Company to fabricate lightweight nozzle sections. The nozzle sections consist of a silicon carbide matrix reinforced with a carbon fiber preform.

A key attribute of this technology is the special weaving process that allows optimum placement of the carbon-reinforcing fibers. The Rockwell Scientific Company integrally weaves the fibers into an entire tube-wall panel in a single piece, as opposed to single tubes constructed separately and then joined together as is the case for the conventional metallic tube-wall nozzles. This simplifies nozzle construction and results in a strong component with fewer joints.

In the future, Rockwell Scientific Company will join the separate nozzle sections together to form a small-scale, bell-shaped nozzle. Researchers will test the nozzle in an actual rocket environment at the National Aeronautics and Space Administration Glenn Research Center's rocket test facility.

The goal of the current effort is to make the bell-shaped, tube-wall nozzle structure from a lightweight ceramic composite. Not only will the nozzle be lightweight, but because ceramics can withstand higher temperatures than metals, the nozzle will require less cooling, thereby improving performance.

Advances in Net-Shape Powder Metallurgy

Payoff Successful development of powder metallurgy (PM) bladed disk or "blisk" fabrication methods, incorporating high-strength, environmentally compatible superalloys, enables revolutionary advances in turbopump rotating-element materials and designs. New materials and fabrication methods enable the aerospace industry to manufacture cryogenic-compatible turbine blisks combining the highest performing nickel-based superalloy turbine materials, normally reserved for airbreathing gas turbine engines, with the high reliability and low maintenance of the typical low-strength superalloys.

Continuing research is leading to important innovations in hot isostatic pressing (HIP) technology for net-shape PM parts. These include extensive use of very-high-strength alloys difficult to produce using conventional manufacturing methods, avoiding welds, and providing functionally optimized local alloy composition variations.

Accomplishment The Materials and Manufacturing Directorate, working with industry, has made significant advancements in the development of new fabrication methods and protective coating processes for high-performance, low-cost, net-shape PM components for aircraft and rocket engines. Net-shape PM has intrigued researchers and industry for more than 40 years because it eliminates complex machining operations, thereby reducing costs.

Working with Boeing Rocketdyne and LNT USA, the directorate's Metals, Ceramics, and Nondestructive Evaluation Division is developing rotating pump component materials and processes for turbine engines that can trim parts' weight by 35%, reduce production costs by 45%, and lower the projected costs of fabricating a net-shape PM-manufactured blisk by more than 40%.

Background Manufacturers fabricate turbine rotors used to propel jet aircraft and rockets from forged disks with mechanically attached cast blades, or they machine them from one-piece forgings. The state-of-the-art method for manufacturing the disks is to build them from either conventional high-strength, nickel-based superalloys and coat them for environmental protection or manufacture them from moderate strength alloys fully compatible in the applicable environment.

Coatings introduce reliability and cost issues, while the moderate strength alloys sacrifice performance. Net-shape PM is a method for "casting" with solid metal powder and consolidating to a net shape, which combines inherent design and processing benefits with the performance benefits of forgings to produce parts with structure and properties comparable to forgings.

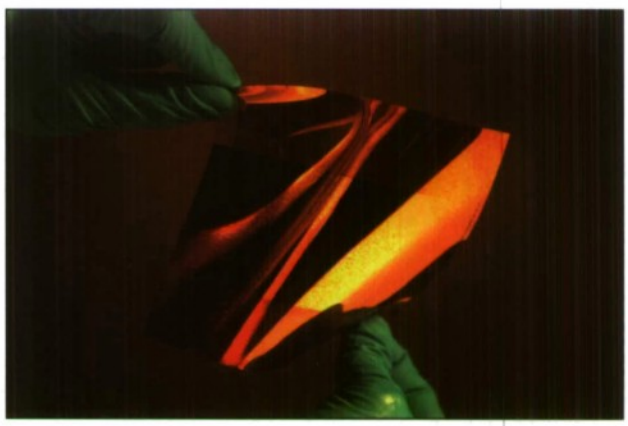
Boeing Rocketdyne, supported by the directorate and LNT USA, has developed a technology for fabricating a high, specific-strength blisk made via selective net shape (SNS) PM processing with an environmentally compatible HIP-bonded surface layer. The SNS PM process uses a precision-machined, low-carbon steel mold, analogous to an investment-casting mold.

LNT USA machines the part details into a mold, which are assembled, welded into a capsule, and then filled with metal powder, evacuated, and undergoes HIP to compact the powder. LNT USA then uses conventional machining and chemical milling to remove the carbon steel tooling.

Organic Solar Cells Increase Potential for Flexible, Lightweight Power Source and High-Efficiency Satellite Arrays

Payoff Organic photovoltaic devices are flexible, lightweight, and inexpensive and will support both the Air Force and broad commercial applications. The incorporation of nanotubes during development and testing of the solar cells shows a fivefold improvement in charge transport capabilities. In addition, the introduction of alternative electron-accepting materials yields a threefold improvement in solar cell efficiency.

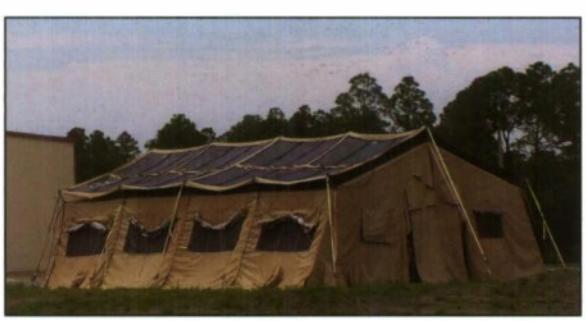
Accomplishment Scientists and engineers at the Materials and Manufacturing Directorate have made significant advancements in developing flexible, organic-based solar cells and photodetectors for use in a variety of Air Force systems. One of the devices developed under contract during the basic research phase of this effort is a flexible, dye-sensitized solar cell with greater than 10% power conversion efficiency.



The directorate's Polymers Branch and the Airbase Technologies Division collaborated to explore a diverse range of near-term applications such as power generation for military tent structures and mobile military units. Potential long-term applications include providing power for satellites and communication systems.

Background A variety of potential Air Force systems need highly efficient, flexible solar cells to convert solar energy to electrical power. Historically, the development of solar cells and photovoltaic devices was limited to the use of crystalline silicon wafers or thin film deposition of other inorganic materials, a process that typically requires expensive manufacturing technologies.

The Airbase Technologies Division is working on replacing conventional electrical power generators at deployed airbases with a more distributed system of power generation. By incorporating the new solar cell technology in tent structures, researchers expect to lighten the logistical burden of deployment and to facilitate agile combat.



Special operations personnel could benefit from the lightweight, flexible solar cell technology through reduced weight of equipment and supplies carried into the field. By combining solar cell technology with rechargeable batteries, the overall weight of the required supplies and their electrical power systems will decrease.

Solar arrays and photodetectors for space satellites yield longer-term applications provided they overcome the most stringent requirements of the space environment. The directorate, in collaboration with the Space Vehicles Directorate, has initiated preliminary space irradiation and durability testing on organic materials for photovoltaic devices.

Nickel Nanostrands™ Expand Nanotechnology Engineering Capabilities

Payoff Manufacturers can engineer nickel nanostrands to meet the diameter and length specifications in many fields of submicron and nanostructure design. They have produced diameters ranging from 50 nanometers (nm) up to 2 microns with aspect ratios generally in the 50:1 to 500:1 range.

Researchers hope to produce nanostrands in the range of 10-30 nm in diameter. Further development could lead to advancements in nanotechnology directly benefiting the Air Force, aerospace community, and industry at large.

Accomplishment Researchers at the Materials and Manufacturing Directorate, working with Metal Matrix Composites of Heber, Utah, developed a new form of nanostructured nickel that dramatically expands nanotechnology design engineering capabilities. The new materials are called nickel nanostrands and were developed under Phase I of an Air Force Small Business Innovation Research program.

Nickel nanostrands are strands of submicron-diameter nickel particles linked in chains—microns to millimeters in length. They are very similar to carbon nanofibers but provide the additional properties of nickel, significantly expanding the variety of options available for developing tomorrow's nanostructure technologies.

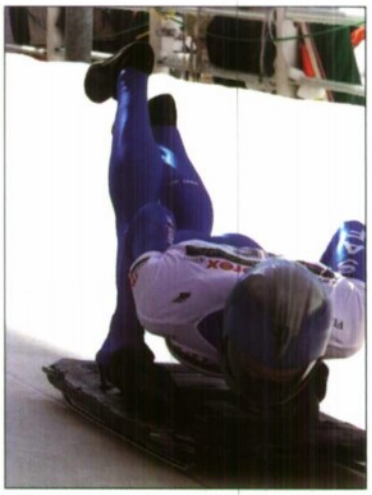
Background Nickel nanostrands are analogous to carbon nanofibers (or multiwall carbon nanotubes) but bring the additional electromagnetic, chemical, catalytical, and metallurgical properties associated with nickel to the nanostructure design engineer's toolbox. These new materials demonstrated their utility in creating conductive resins, paints, adhesives, and thermoplastics for a wide range of conductive polymer and conductive composite applications. Researchers at Metal Matrix Composites, for example, have created paints with a sheet resistance of less than 1 ohm per square, and adhesives and thermoplastics with conductivities of 40 Siemens per centimeter (S/cm) and 150 S/cm, respectively.

Nickel nanostrands can also further enhance the conductivity of fiber- or particle-reinforced composites, thus providing a three-dimensional conductive lattice in the otherwise insulating polymer resin matrix. A loading of only 2% of volume in an otherwise standard prepreg, for instance, doubles the conductivity of a carbon-fiber composite. This is important for the Air Force and industry because infiltrated carbon composites have proven highly useful in lightning strike protection for aircraft and other composite structures.

Additionally, when manufacturers add nickel nanostrands to elastomers, the resulting composite material exhibits remarkable changes in conductivity with respect to tensile or compressive strain. Since nickel nanostrands are a magnetic material, researchers can magnetically align them while the carrier is still in the liquid phase, yielding a whole range of unique applications such as magnetically oriented inks or magnetically aligned conductive fibers. The unique microstructure and chemistry of nickel nanostrands could also lead to important advancements in filtering, catalysis, energy storage, and nanometallurgy.

Advanced Composites Carry Olympic Hopeful to National Sled Racing Title

Payoff Engineers at the Materials and Manufacturing Directorate's Advanced Composites Office (ACO) at Hill Air Force Base, Utah, redesigned the aerodynamic component of skeleton racing sleds raced by world-class Air Force athletes vying for positions on the US Men's Winter Olympic Team. ACO engineers used the techniques learned and perfected during redesign of the skeleton sleds to build a horizontal tail advanced technology demonstrator, several elevator skin prototypes for the A-10, and subscale composite spars for composite design and manufacturing classes.



Accomplishment Major Brady Canfield won a bronze medal at the World Championships in Nagano, Japan, and the 2003 US Men's National Skeleton Championship using the new design. The redesign effort provided hands-on, computer-aided design (CAD) and three-dimensional (3-D) modeling experience for new engineers at ACO, resulting in improved lay-up techniques.

Background Skeleton racing originated in St. Moritz, Switzerland, during the late 1800s and is the oldest known competitive downhill sled racing sport in the world. The sled is composed of steel chassis, steel runners, and a steel (sometimes fiberglass) sheet or pod affixed to the underside of the chassis to provide aerodynamic benefits similar to the underside of Formula One race cars. The athlete lies face down on top of the sled in a head-first position and whips through a curving, ice-coated track for fastest time, sometimes at speeds exceeding 80 mph.

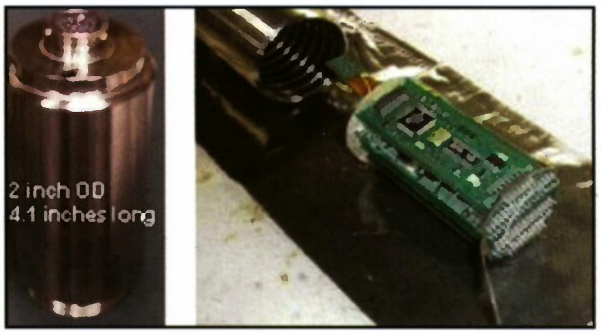
A hand-built model of the sled pod was used to generate a 3-D representation, which was then placed into the CAD program used to change the shape of the part. To optimize the airflow contour of the part, ACO engineers made two different part designs, each conforming to the standard 2-feet wide by 3-feet long dimensions. Next, they downloaded the model to a five-axis router and cut a wooden master. They used the master to make a fiberglass female mold and then produced a hand lay-up part from the mold using the same graphite epoxy sometimes employed on aircraft. Finally, they autoclave-cured the new pod to provide the needed strength and stability.

The ACO manufactured a total of five graphite/epoxy sled pods for the Air Force skeleton racing athletes. During the 2002 Winter Olympics qualifying races, Maj Canfield won fourth place and Senior Airman Trevor Christy finished in the top 10. These results demonstrated significant improvement in the race times of both athletes using the ACO composite pods. Using the new composite sled design, Maj Canfield achieved an overall World Cup ranking of 11th place, which qualified him for the World Championships in Japan. Canfield finished third, winning the bronze medal. He further solidified his standings by winning the Men's National Skeleton Championship in Lake Placid, New York.

Low-Cost All-Electronic Penetration Fuze Exceeds Penetration Testing Objectives

Payoff Fuzes that survive high-impact conditions increase the ability of penetrating munitions to defeat underground bunkers. The Multiple Event Hard-Target Fuze (MEHTF) provides an accurate and low-cost solution to fuzing for hard-target defeat.

Accomplishment The Munitions Directorate developed the first low-cost, all-electronic penetration fuze with an improved ability over existing fuzes to survive rigid body deceleration shock. The MEHTF smart penetrator fuze uses an accelerometer to measure distance traveled in order to initiate weapon activation at the desired depth. Directorate engineers also demonstrated control of multiple fuzes for multiple warhead events through static testing.

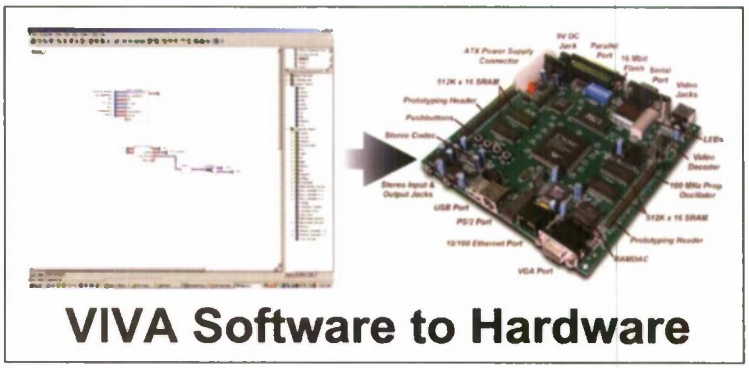


Background The directorate initiated the MEHTF program to address anticipated fuzing needs for future penetrating weapons. Directorate researchers identified several future applications requiring a smart penetration fuze.

Directorate engineers identified specific technology limitations and structured the program to address these limitations. These limitations include (1) surviving the severe shock environment associated with high-speed penetrator impact, (2) reduced fuze size to facilitate use in small penetrators, (3) low cost to be competitive with time-delay fuzing, (4) accurate target media discrimination capability, and (5) providing a multiple-event capability for complex multiple-function warheads.

Reconfigurable Computing Software Enables Easy Programming of Hardware

Payoff Government and industry have invested many millions of dollars over the past decade to develop a way to easily program algorithms into field programmable gate array (FPGA) integrated circuits to meet the changing requirements of their users. Reconfigurable computing (RC) technologies enable lower integration cost, faster fielding of systems, in-field upgrading of systems, and longer system life. Traditional approaches to programming algorithms in FPGAs are laborious and time consuming. Star Bridge Systems® of Midvale, Utah, developed an electronics design automation tool called Viva® that solves these problems.



Accomplishment The Munitions Directorate (MN) and Star Bridge Systems formed a Cooperative Research and Development Agreement (CRADA) to test and demonstrate the Viva tool for munitions applications. This CRADA demonstrated the capability to program third-party commercial off-the- shelf hardware with Viva.

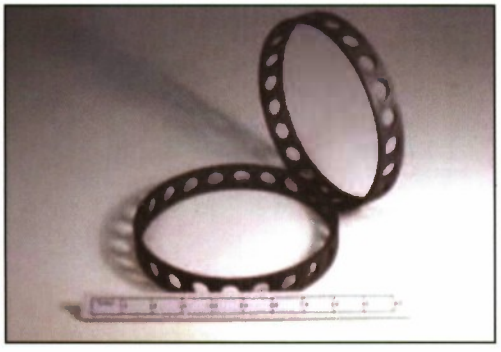
Until now, Star Bridge Systems only demonstrated Viva on the company's FPGA boards called Hypercomputers®. Directorate engineers chose to demonstrate the inexpensive XESS XSV-300/800 Virtex prototyping board, which has a XILINX's Virtex FPGA embedded in a framework for processing video and audio signals. Directorate engineers will use the XESS prototyping boards for cooperative control and automatic target recognition research at the RC laboratory at North Carolina A&T (NCAT) State University.

Background Star Bridge Systems developed their reconfigurable computer technology for desktop high-performance computing with real-time processing. The directorate began investigating RC technology under its Revolutionary Technology program and, through this effort, helped create the RC laboratory at NCAT University (a historically black university).

Since RC was a new area for directorate scientists, they also began collaborating with the Information (IF) and Space Vehicles (VS) Directorates due to their previous research in the RC area. This collaboration led to a joint MN-IF Small Business Innovation Research (SBIR) RC effort. It also brought forth a leveraged VS-MN SBIR RC effort.

MN is also collaborating with the National Aeronautics and Space Administration (NASA) Langley Research Center, Los Alamos National Laboratory, and the National Security Administration (NSA). NSA and NASA are using Star Bridge Systems' Hypercomputers, which are programmed with Viva, for high-performance scientific computing, research, and national security applications; whereas MN is using Viva for embedded hardware applications implemented in various FPGA hardware systems including the XESS XSV-300/800 Virtex prototyping board used by MN on this project.

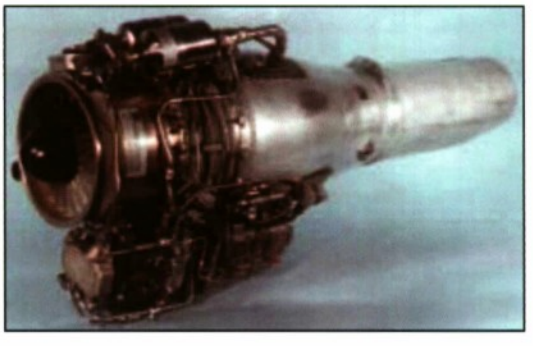
Composite Bearing Cages Show Great Promise for Advanced Turbine Engines



Payoff Engineers from the Propulsion Directorate and Allcomp, Inc., developed carbon-carbon (C-C) composite cages that demonstrate significant payoff in high-performance, marginally lubricated bearing applications. The most recent success involves their use in bearings, evaluated by Williams International (WI), for small aircraft turbine engines.

Accomplishment WI recently conducted full-scale bearing tests using C-C composite cages under an independent research and development effort. C-C composite cages demonstrated significant performance advantages over cageless and steel-cage bearing designs in over 1,000 hours of accumulated test time.

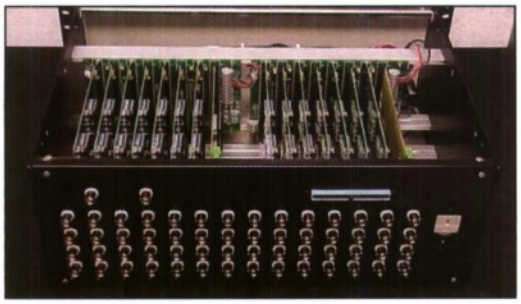
Background WI is considering the composite cages for small turbine engines such as the XTL 87 and WJ24 8 engines. Researchers transitioned composite cages into the Allison Advanced Development Company (AADC) XTL 16 Joint Expendable Turbine Engine Concept technology demonstrator engine and are planning to transition them into the AADC XTL 17 and AADC/General Electric Aircraft Engines (GEAE) XTC 77/1 demonstrator engines.



GEAE and Pratt & Whitney are considering the technology for large fighter-class turbine engines such as the Integrated High Performance Turbine Engine Technology and the Versatile Affordable Advanced Turbine Engine demos. Hamilton-Sundstrand is also considering this technology for the Miniature Air Launched Decoy TJ30 production engine. Directorate engineers Drs. Nelson Forster and Lewis Rosado, along with Mr. Wei Shih, of Allcomp, Inc., jointly developed C-C cages (Patent No. 5,752,773, May 1998).

Test Modification Prevents IHPTET Delays

Payoff A team of engineers and scientists in the Propulsion Directorate's Turbine Engine Fatigue Facility (TEFF) kept a national collaborative program on track by expanding and modifying their test hardware to measure a one-of-a-kind engine component, all without significant cost. The TEFF Team completed the entire test program in the 2 weeks between engine tear down and required delivery to the machine shop for modification.

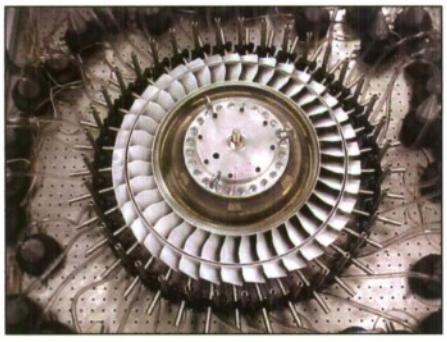


The team's quick response in making the necessary modifications to the test and data acquisition systems provided high-fidelity data to the program without any adverse effects on the planned schedule. The TEFF Team maintained the test schedule for the XTC 76/3B, which is critical to reaching Integrated High Performance Turbine Engine Technology (IHPTET) Phase 3 goals as demonstrated through the XTE 77/1.

Accomplishment The TEFF Team of engineers and scientists developed and implemented a redesign to their traveling wave excitation system in order to support the third phase of the IHPTET program. The team used the excitation system to measure high-response resonant modes with laser scanning vibrometry and test the unique core-driven fan stage (CDFS) of the XTC 76/3 demonstration engine.

In less than 6 weeks, directorate engineers redesigned and expanded the excitation system electronic circuitry from 18 to 37 necessary channels for the experiments. They also expanded the laser scanning vibrometry capability—in both number of excitation channels and laser scan field-of-view—to enable coverage of the 40-inch bladed disk (blisk).

Background The CDFS is a unique integrally machined blisk stage incorporating two distinct stacked blade rows in a single stage. This design is unique to General Electric Aircraft Engines and Allison Advanced Development Company and is one of only two components of this type ever produced.



Due to its geometric features and unique design, conventional finite element analysis and laser vibrometry produced inconsistent results. Since large amplitude vibrations were experienced in the 1st flex (trailing-edge dominated) mode at partial power and the 2nd stripe mode near maximum power during engine testing, directorate engineers needed insight into the structural dynamics characteristics of the entire blisk to ensure proper redesign and modification by the manufacturer. Directorate engineers required complete testing to avoid large amplitude resonances when the engine returns to test as the XTC 76/3B in early fiscal year 2003.

Using acoustic excitation, directorate engineers performed chirp tests covering a frequency range of 0 to 9000 Hz on both the fan and the core airfoils. The engineers used the scanning vibrometer to obtain the dynamic response characteristics of all airfoils, on both inner and outer panels, for all resonant modes that exist in the operating range of the engine.

Directorate engineers also measured mistuning patterns, stress localization, and phase relationships between inner and outer panels. The data obtained in this test program validated the intended modifications to the blisk and permitted the return to the demonstrator engine safely and expeditiously.

Integrated Powerhead Demonstration Project Enters Fast-Paced Test Phase

Payoff Testing of critical components for integration into the world's first full-flow-cycle hydrogen/oxygen boost engine is under way. A recent test of the Propulsion Directorate's Integrated Powerhead Demonstration (IPD) project in California established a technical first for the US and marks the first advancements in boost engine technology since the initial development of the Space Shuttle Main Engine (SSME) in the 1970s.

Accomplishment Testing of the Department of Defense's (DoD's) IPD project is under way at the Aerojet E-Complex test facilities in Sacramento. Directorate engineers successfully tested the IPD fuel preburner to 50% power, satisfying all pretest predictions and meeting all test objectives. The fuel preburner will eventually deliver hot hydrogen drive gas to power an advanced hydrogen turbo pump in the engine system.

This successful test kicks off a new stage in the IPD program where directorate engineers will test combustion and turbo machinery components at both Aerojet and the National Aeronautics and Space Administration's (NASA's) Stennis Space Center in Mississippi. Following this test phase, directorate engineers will integrate all components into the world's first full-flow-cycle hydrogen/oxygen boost engine.

Background The IPD program supports the DoD Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program. The goal of this program is to double the capability of boost engines for access to space. The IPD program is also a very successful partnership between AFRL and NASA's Marshall Space Flight Center in Huntsville, Alabama, which provides additional technical expertise and program support.

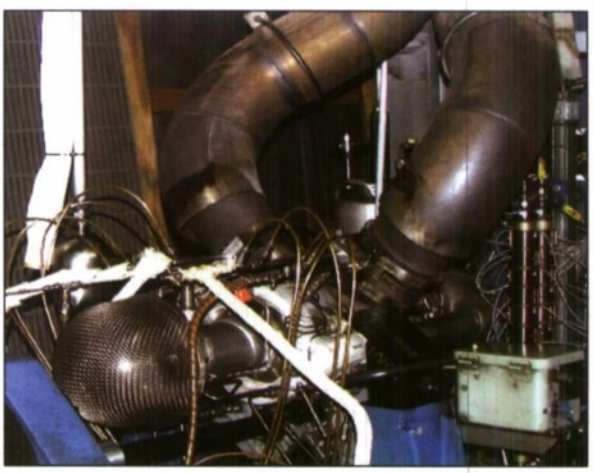
IPD's full-flow staged combustion engine is a technical first for the US. The program brings together combustion device components from Aerojet, and turbo machinery and system integration expertise from Boeing-Rocketdyne of Canoga Park, California. This combination will extend the life cycle of boost engines and reduce the amount of maintenance between missions. IPD is also the first cryogenic boost engine technology program since the development of the SSME.

The IHPRPT program is a DoD/NASA/industry-coordinated effort to develop revolutionary and innovative technologies by the year 2010. This effort will double rocket propulsion capabilities over early 1990s state-of-the-art technology.

First Evaluation of Particulate Mitigation Additives Completed

Payoff The Propulsion Directorate recently completed the first evaluation of fuel additives to mitigate soot particulate emissions from turbine engines. The directorate's experimental detergent-type additive reduced particulate number density by 67%, resulting in a calculated particulate mass reduction of 53%.

Accomplishment The Turbine Engine Division's Fuels Branch tested 17 additives originally designed to reduce emissions and/or improve combustion characteristics in internal combustion engines in a T63 helicopter engine. Directorate engineers analyzed engine particulate exhaust using a suite of state-of-the-art instrumentation to characterize particulate number density (number of particles per cubic centimeter), size distribution, mass, and particulate chemical composition.



Background Directorate experiments show that commercial additives and cetane improvers are ineffective in reducing particulate emissions or altering particle size distribution. However, researchers observed dramatic reductions in particulate emissions with one of the experimental proprietary additives. Further research into this and other additives of similar chemistry is ongoing to help explain the mechanisms by which the additive reduces particulate emissions in the T63.

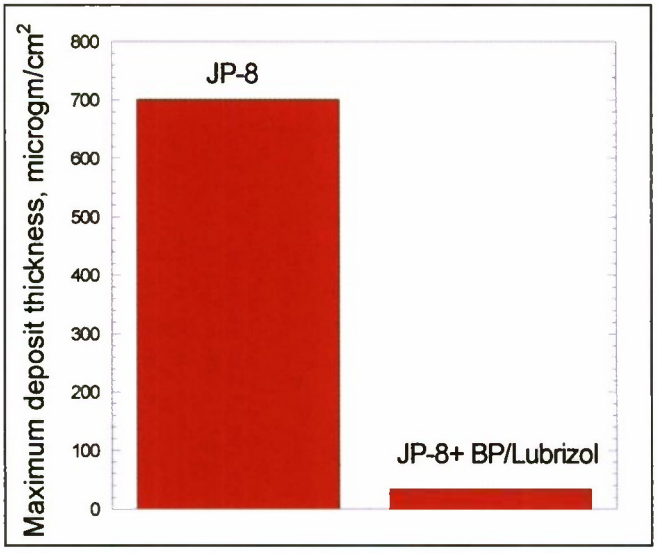
New +100 Additive Passes the Test

Payoff A second source for a newly formulated JP-8 thermal stability fuel additive successfully completed a rigorous thermal stability test regimen laid out by the Propulsion Directorate's Fuels Branch. This is a major milestone for fielding the additive in JP-8 fuel—the primary fuel for many US military aircraft and commercial systems—and is an important step in creating competition that should reduce the cost of the additive to the Air Force and other North Atlantic Treaty Organization countries.

Accomplishment The directorate developed the +100 additive to minimize maintenance associated with fuel degradation in aircraft engines and fuel systems and increase the heat sink of the fuel. The BP/Lubrizol Team developed the formulation and successfully completed its rigorous thermal stability test regimen.

Background In order to gain approval, an additive must pass a series of thermal stability tests. Directorate scientists and engineers verified that the BP/Lubrizol additive successfully completed the required thermal stability testing. The additive will now go to the original equipment manufacturers for engine testing and to the Materials and Manufacturing Directorate (ML) for materials compatibility testing. The engine manufacturers and ML agreed to create a cooperative process to field the additive.

The fielding of the original +100 additive manufactured by BetzDearborn has been a major success; it significantly reduced fuel-related maintenance costs for a wide range of military and commercial systems. The Danish and Canadian military have adopted the +100 additive.



Improved Compressor Research Facility Ready to Meet IHPTET and VAATE Goals

Payoff The Propulsion Directorate successfully integrated a new state-of-the-art High-Performance Data Acquisition System (HPDAS) in the directorate's Compressor Research Facility (CRF). The HPDAS provides a 75% increase in channel count measurement capability over the original 25-year-old system.

Accomplishment HPDAS meets the demands of the Integrated High Performance Turbine Engine Technology (IHPTET) program and expected requirements of the Versatile Affordable Advanced Turbine Engines (VAATE) technology program.

Background The new data acquisition system allows direct connection of the sensors to the signal conditioners, eliminating the need for patch panels. This reduces set-up time and improves accuracy and reliability in comparison to the old system.

The footprint of the new system is only 10% that of the old system, making more than 300 sq ft available for special test equipment anticipated for future CRF testing. The old system was nearing the end of its life cycle and required an inordinate amount of maintenance. The new system reduces the maintenance burden by $250K/year, which results in a payback of the new system's cost in only 3 years.

Previously, the directorate calibrated each channel using a dedicated standard, each of which was calibrated against a National Institute of Standards and Technology (NIST)-traceable standard. Calibrating all channels directly with one NIST-traceable standard eliminated the intermediate calibration step and the associated loss in accuracy as a result of that step.

The new system exhibits a consistent 100% availability, while the failure rate of the older system was 2-3%. The directorate will use the new system to effectively and accurately evaluate the advanced technology developed under the IHPTET and VAATE National Turbine Engine Technology programs.

The IHPTET program is a national collaborative effort among the Air Force, Navy, Army, the Defense Advanced Research Projects Agency, and industry to double aircraft propulsion capability by 2005. The VAATE program is focused on achieving a 10-times improvement in turbine engine affordability.

Edwards Research Site Evolves New Class of Fluorinated POSS Polymers

Payoff Researchers at the Propulsion Directorate's Edwards Research Site are helping meet the Air Force's demand for a new generation of lightweight, high-performance polymeric material. The research led to the development and large-scale production of the first new polymer feedstocks in the past 40 years. For the past decade, the Edwards Research Site pursued the development of new chemical feedstock technologies based on polyhedral oligomeric silsesquioxanes (POSS).

Because of its chemical nature, POSS technology is easily incorporated into common plastics via copolymerization, or blending, and requires little or no alteration to existing manufacturing processes. POSS additives radically upgrade the thermal and physical properties of most plastics.

Accomplishment A new class of POSS compounds evolved from research at Edwards Space and Missile Propulsion research facilities. These compounds are fluorinated and have the highest molecular weight yet produced in POSS research. Fluoroalkyl and fluoroaryl POSS compounds have the potential to blend with various fluoropolymers used in spacecraft coatings and low-creep seals.

POSS-enhanced plastic polymers allow users to produce products with capabilities not previously possible. The POSS technology-derived polymers are revolutionary in their ability to mimic ceramic class attributes.

In addition to their greater strength and space-survivable features, they may also demonstrate abrasion resistance. As additives, POSS may be useable in heat-abrasion-resistant paints, coatings, and fire retardants. In plastics, POSS is useable in medical materials, space-resistant resins, packaging/coatings, resins, and elastomers.

Background POSS research at the Edwards facilities is a rapidly evolving area of dual-use technology development that provides innovative plastic polymer materials to military and industrial users. The plastics industry is interested in POSS research, and *R&D Magazine* recognized POSS as one of the top 100 most significant products for 2000. The nanotechnology publication, *Small Times Magazine*, recently selected the directorate's POSS spin-off company, Hybrid Plastics, as one of five finalists for their 2002 Best of Small Tech Award.

Space-Survivable Materials Get Boost with New Polymers

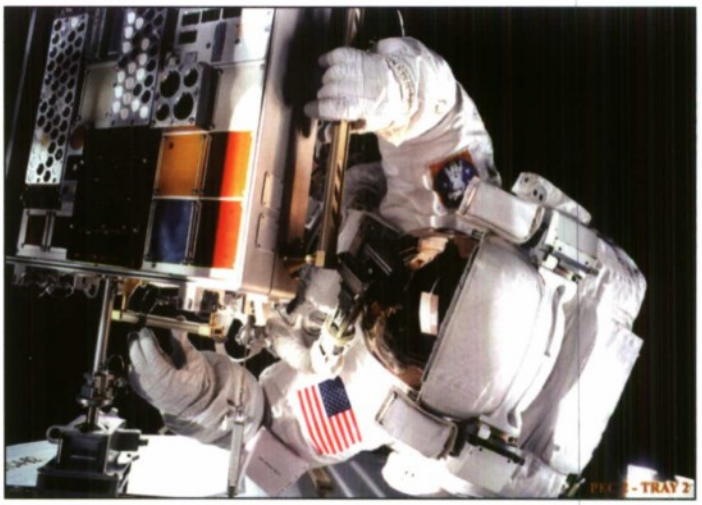
Payoff Hybrid inorganic and organic polymer research at the Propulsion Directorate's Edwards Research Site demonstrated the ability to prevent damage from a simulated space environment. Test samples are currently flying on the International Space Station.

Polyhedral oligomeric silsesquioxane (POSS) technology research is bridging the gap between ceramics and plastics. Directorate scientists and engineers believe that the incorporation of POSS into polymers could increase the survivability of polymeric materials in low-earth orbit (LEO) indefinitely. This would result in increased satellite lifetimes.

Accomplishment Directorate analysis of POSS-copolymers exposed to a simulated LEO environment revealed the formation of a protective silica layer on the surface of the polymer. This layer prevented degradation of the underlying polymer when exposed to atomic oxygen flux.

In fact, tests showed that exposure to simulated LEO conditions healed microcracks initially present in certain POSS-copolymer samples. The dispersion of POSS throughout the polymer matrix provided efficient self-healing of damaged areas. The Materials for the International Space Station Experiment is currently testing POSS materials in space, with plans to test other samples on future missions.

Background POSS technology research at the directorate is a rapidly evolving area of dual-use technology development. The Edwards Research Site provides military and industrial users with innovative polymer materials that will double or triple satellite lifetimes.



POSS-copolymer materials technology is a revolutionary step toward the development of space-survivable materials and will enhance the long-term deployment of space-inflatable structures, antennas, solar arrays, and solar sails. Polymeric materials offer many advantages for LEO applications including ease of processing and reduced payload-to-orbit costs from the reduction in weight.

However, polymers currently used in the construction of space vehicles undergo severe degradation, resulting in reduced spacecraft lifetimes since they must endure high fluxes of atomic oxygen, bombardment by low- and high-energy charged particles, extreme temperature changes, and solar radiation. Degradation of these materials may also be detrimental to electrical components on spacecraft.

Explosive Safety Detonation Test Successful

Payoff Researchers from the Propulsion Directorate's Edwards Research Site conducted an explosive safety test involving two small intercontinental ballistic missile (ICBM) stages. By using real rocket motors, researchers designed the test to enhance storage and launch safety procedures for strategic missiles and space boosters.

Accomplishment The test provided Air Force system safety organizations full-scale blast and fragment data for validating proper storage and explosive safety of national assets. It used nearly 25,000 lbs of a solid rocket fuel, equivalent to 14 tons of Trinitrotoluene, commonly known as TNT. Space and Missile Propulsion Division researchers provided test data to Lawrence Livermore National Laboratory and other interested organizations to help validate Air Force and industry explosive hazards' computer models.

The test data also supported efforts to validate new North Atlantic Treaty Organization explosive hazard classifications for insensitive munitions. The high-powered, ground-level explosion provided seismic calibration to the US Geological Survey seismic measurement activities at Caltech.

Background The purpose of the test was to provide simultaneous detonation or reaction between two rocket motors, in this case, a first and third stage of small ICBM motors. Directorate researchers separated the motors at representative distances found in storage bunkers positioned in worst-case scenario conditions and instrumented the motors to provide scientific data for numerous users.

Caltech measured the seismic force of the test, which dug a 20-foot-deep crater at the test site, at a 1.61 magnitude. The test also provided experimental data on shock-to-detonation initiation pressures and fragment throw data.

Large Rocket Test Stand Reactivated at Edwards Research Site

Payoff The Propulsion Directorate reactivated Test Stand 1-D, one of its largest and most historic rocket test stands at Edwards Air Force Base (AFB), California, during a ribbon-cutting ceremony in January 2003. The liquid oxygen and kerosene-based, 15-story test stand is considered state of the art and capable of testing rocket engines and components with millions of pounds of thrust.

Accomplishment With Test Stand 1-D's refurbishment, the directorate's Space and Missile Propulsion Division scientists, engineers, and technicians are ready to help validate innovative technologies for current and future rocket engines. Originally built as an Apollo-era F1 rocket engine test facility, the directorate took Test Stand 1-D from a mothballed storage state in the dry desert climate and, in less than 18 months, modernized it to increase national rocket engine test and research capabilities.

The $12 million modernization cost, which included state-of-the-art data acquisition and control systems, was much less than the estimated $500 million needed to build a new test stand from scratch. The directorate met or exceeded environmental standards for fuel tanks and plumbing as well as cooling waters for the rocket test stand.

Background The test stand's capabilities fit into the overall Department of Defense (DoD) National Rocket Propulsion program called Integrated High Payoff Rocket Propulsion Technology (IHPRPT). The directorate's Space and Missile Propulsion Division coordinates the program that encompasses liquid rocket engine, solid rocket motor, and advanced propulsion technologies. IHPRPT's future large liquid rocket propulsion demonstrations can now use the stand's massive thrust capabilities.

The program's DoD/National Aeronautical and Space Administration/ industry partnership is working toward a national doubling of propulsion capability. That means more thrust, fewer parts, improved manufacturing, and innovative materials application.

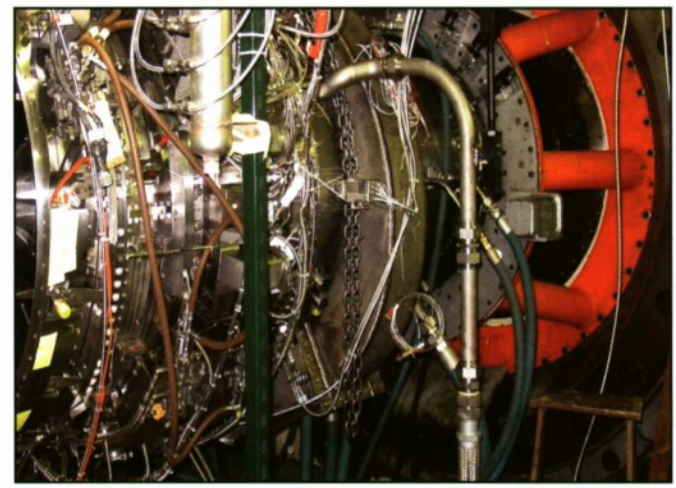
The stand is part of the directorate's nearly $3 billion worth of test facilities at Edwards AFB. Nearly every American rocket can trace its research and testing to the Edwards facilities, which have given the nation rocket propulsion research, development, and test capabilities for over 50 years.

XTE 67 Achieves 100% Design Performance

Payoff The Integrated High-Performance Turbine Engine Technology (IHPTET) XTE 67 three-stage fan achieved its 100% design performance goals in recent testing at the Propulsion Directorate's Compressor Research Facility. By achieving its design goals, the program demonstrated that Pratt and Whitney (P&W) design tools are mature enough to provide fan designs that achieve advanced technology goals without reworking the fan designs after testing.

Accomplishment The IHPTET XTE 67 three-stage fan compressor achieved its predicted efficiency, mass flow, and stall margin at design pressure ratio and speed. This significant achievement resulted from the close teamwork between the directorate's Turbine Engine Division's test team and P&W personnel.

In the next phase of testing, directorate engineers will install the fan in an engine, incorporating other IHPTET technologies to demonstrate component interaction engine environment readiness. Advanced technologies demonstrated on this fan test are directly applicable to the Joint Strike Fighter (JSF) F135 propulsion system.



Background The IHPTET program is a national collaborative effort among the Air Force, Navy, Army, National Aeronautics and Space Administration, Defense Advanced Research Projects Agency, and the aerospace industry to double aircraft propulsion capability by 2005. The program began in 1987, and the Air Force has already transitioned many of the advancements made to-date into the F/A-22 Raptor and the Air Force's newest fighter, the F-35 (JSF).

Joint service technology demonstrator engines like the XTE 67, built by P&W, have validated improvements in advanced design, performance, and cost. These demonstrators provide low-risk technology transition, resulting in high readiness and increased safety and performance for the warfighter.

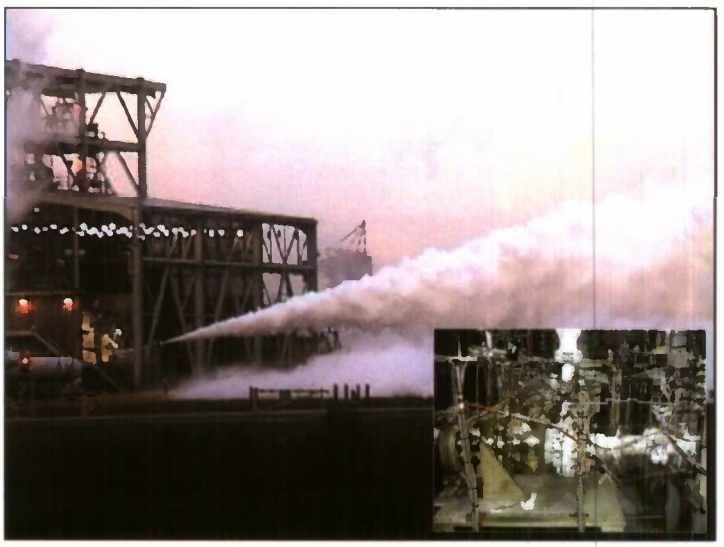
P&W is the propulsion system prime contractor for all three variants of the JSF aircraft. The F135 for the JSF evolved from the F119 engine that powers the F/A-22 Raptor. P&W will deliver the first production engine for operational service in 2007, and the F135 engine will cost 35% less to own than legacy systems (engines in service for decades).

The engine will have three times the hardware and software reliability and will require 30 to 50% fewer maintenance technicians and 50% fewer airlift assets in deployment. The F135 is also designed to reduce the time for fault detection and repair by 94% and increase the time between shop visits by 225% over legacy systems.

Liquid Oxygen Turbopump Testing Successful

Payoff The Propulsion Directorate successfully completed testing of critical components for integration into the world's first full flow cycle hydrogen/oxygen boost engine. The Integrated Powerhead Demonstration (IPD) technology development provides the world's first hydrogen-fueled rocket engine with oxygen-rich staged combustion. IPD is currently the only hydrogen boost rocket engine development program in existence today.

Accomplishment Directorate tests of the IPD program were completed at the National Aeronautics and Space Administration's (NASA) Stennis Space Center test facilities in Mississippi. These tests mark the first advancements in boost engine technology since the space shuttle's main engine was initially developed in the 1970s. IPD technology is the first American-designed and -fabricated oxygen-rich turbine drive pump. The series of tests finished with a hot-fire test that demonstrated a steady-state run of 95% power, which is considered the most challenging of the series.

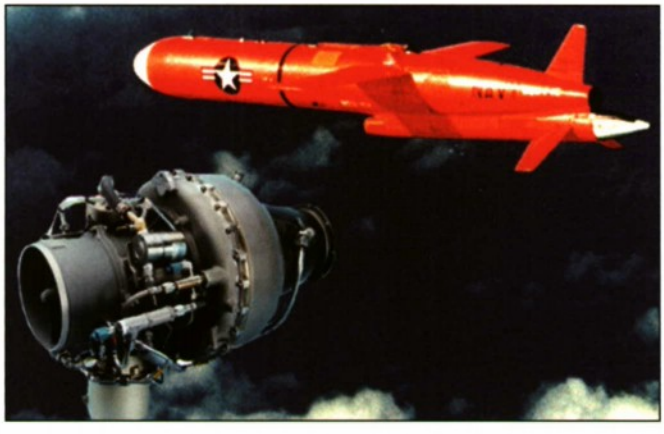


NASA's Next Generation Launch Technology program is also a cornerstone of the IPD technology. The program provides technology advances needed to overcome two major technical problems: turbine life and bearing wear. Hydrostatic bearings are the key innovations in the high-performance turbomachinery that fully supports the rotor of both the fuel and oxidizer pump.

Background The IPD program is part of a national program known as the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program involving all Department of Defense services, NASA, and American rocket industry partners. IHPRPT's intent is to double the performance and capabilities of rocket propulsion systems over the 1993 state-of-the-art systems and to decrease costs of access to space for military and commercial customers.

Compliant Foil Bearings for Advanced Oil-Free Turbomachinery Successfully Tested

Payoff Compliant foil bearings support the rotor on a hydrodynamic air film, eliminating the need for rolling element bearings and the associated liquid lubrication system. Potential benefits for turbomachinery include increased rotational speed and operating temperature, improved storability, reduced maintenance, decreased life-cycle costs, and a 30% reduction in cruise missile engine cost and weight.



Accomplishment Mohawk Innovative Technology, Inc. (MiTi®) of Albany, New York, and Williams International (WI) jointly funded an Independent Research and Development effort to demonstrate a compliant air foil journal bearing in a WJ24-8 turbojet engine. This bearing is similar to the one developed for WI's Joint Expendable Turbine Engine Concept (JETEC) engine demonstrator (XTL 87).

The WJ24-8 is a 240-pound thrust single-spool turbojet that provides propulsion for the US Navy BQM-74 target drone. Fuel lubricates the WJ24-8's forward bearing, while oil mist normally lubricates the aft bearing.

In the demonstration test, WI engineers replaced the aft bearing and oil mist system with a MiTi airfoil journal bearing. The ongoing engine test program has accumulated over 12 hrs of cyclic and mission simulation testing with operation to maximum design speed and gas temperature and 70 start-stop cycles.

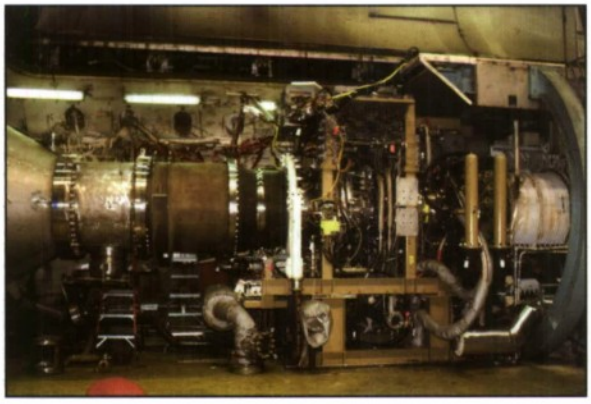
A preliminary post-test analysis of bearing hardware revealed no evidence of wear. Testing will continue to quantify benefits, such as reduced power loss, and investigate bearing life issues. WI estimates that this modification could reduce the cost of the WJ24-8 by as much as 20%. Propulsion Directorate researchers and WI engineers may use this test data to assess the applicability of foil bearings to other gas turbine engines for both military and commercial systems.

Background The directorate recently completed a Phase II Small Business Innovation Research program called "Compliant Foil Bearings for Advanced Oil-Free Turbomachinery" with MiTi. This program successfully developed and rig-tested a high-speed foil bearing for demonstration in WI's Integrated High-Performance Turbine Engine Technology Phase III JETEC XTL 87.

XTC 67 Jet Engine Core Test Successfully Completed

Payoff The Pratt & Whitney (P&W) XTC67/1 core demonstrator recently demonstrated the highest steady-state turbine rotor inlet temperature (T_{41}) ever achieved by a P&W engine. The high T_{41} operating temperatures provide increased engine thrust levels and are key to meeting the Integrated High Performance Turbine Engine Technology (IHPTET) program goal of doubling jet engine thrust-to-weight ratio. The hot section technologies of the core engine have excellent technology transition potential to the Joint Strike Fighter F135 engine and the F/A-22's F119 engine.

Accomplishment Propulsion Directorate engineers recently completed 96 hrs of testing at the Arnold Engineering and Development Center, validating improvements in thrust-to-weight ratios and decreases in production and maintenance costs for the P&W XTC67 turbine engine core technology demonstrator. The XTC67 core engine, part of the IHPTET program, met the required test objectives and clears the way for testing the full engine demonstrator, or XTE67/1.



This XTC67 core engine demonstrator also verified the highest steady-state fuel/air ratio ever run in a P&W engine. Key technologies tested include a four-stage high-pressure compressor with gamma titanium-aluminide stators that incorporate mistuning techniques to help reduce material failures due to high-cycle fatigue; high fuel-air ratio floatwall combustor; thinwall supercooled turbine blades; and micro-circuit turbine blade outer air seals.

Background The IHPTET program is a national collaborative effort among the Air Force, Navy, Army, the National Aeronautics and Space Administration, the Defense Advanced Research Projects Agency, and the aerospace industry to double aircraft propulsion capability by 2005. Joint service technology demonstrator core engines, like the XTC67/1, validate improvements in advanced design, performance, life, and cost.

PEAPRS is a Low-Cost Supplement for Aircraft Communication

Payoff The Precision Emergency Automated Position Reporting System (PEAPRS) is a low-cost supplement to the standard method of aircraft communication. During an emergency airborne situation, this system is triggered with a sensor, or pilots or other crew members can activate it by pressing a button, which automatically engages the PEAPRS equipment.

Accomplishment In an effort to discover alternative ways to communicate with aircraft in trouble, the Sensors Directorate planned and conducted an experiment using amateur radio operators within the international Automated Position Reporting System (APRS) network. Directorate researchers measured the timeliness and accuracy of the amateur community's reports. The directorate received reports from over 200 amateur radio operators from across the country and around the world via telephone, APRS message, and e-mail within one minute of transmission of the first emergency beacon.

Background The directorate's test involved an aero club aircraft with a simulated emergency flying over upstate New York. The test demonstrated that aircrew members could use the APRS system to supplement the current communications that either commercial or private aircraft use to convey an emergency in progress.

APRS, a form of packet radio, sends packets of digital information via high frequency, very high frequency (VHF), or ultra high frequency (UHV) radio across the country and around the world using digital repeaters. The packets in APRS contain position data, weather data, and sometimes a text message.

The directorate's test simulated a simple mechanical or electrical defect that required the pilot to make an emergency landing. This technology is also useable during a catastrophic disaster or terrorist hijacking, which occasionally makes the primary communications, generally VHF or UHF airband radios and interchange file format transponders, intentionally or unintentionally inoperative.

PACTS Provides Sensors Directorate a More Reliable VFT Capability

Payoff The Sensors Directorate developed a controller called Programmable Attenuator Control and Test System (PACTS) that uses basic logic and inexpensive integrated circuits (under $5) to make the directorate's virtual flight test (VFT) capability more reliable. The PACTS provides output signals to an attenuator in the same mode and timing that the radio frequency (RF) controller uses to control the attenuators in the VFT simulation.

Accomplishment A bank of programmable attenuators caused significant RF glitches in the directorate's Advanced Concepts Exploration Global Positioning System's (GPS) VFT simulation. Attenuators use RF signals generated from the GPS and threat simulators to reduce the power to simulate real-world terrain effects and propagation losses observed at the platform.

Mr. Ron Franks, a 2002 Cedarville University co-op student, analyzed these wavelengths in the time domain (milliseconds) versus the traditional frequency domain (sine wave). Running direct current voltage through the attenuator demonstrated a notable pause as the internal relay switched, causing the attenuator to spike. To address this, Mr. Franks constructed PACTS and created the solution within 3 days.

Background For over 4 years, significant RF glitches in the VFT simulation led to occasional spikes, which caused anti-jamming systems undergoing testing to see this phenomenon and, at times, invalidate the testing. Directorate engineers analyzed the data extensively in the frequency, but not in the time domain.

Directorate engineers investigated several possible hardware fixes over time, but found them far too costly and time-consuming as viable options. The PACTS provided output signals to an attenuator in the same mode and timing as used by the RF controller, thus solving the problem.

Fighter Aircraft Evaluate Real-Time Information Capability

Payoff The Integrated Real-Time Information into the Cockpit (RTIC)/Real-Time Information Out of the Cockpit (RTOC) for Combat Aircraft (IRRCA) program made F-117 history when the aircraft sent its first-ever attack sequence images via satellite data link during IRRCA Phase II flight testing. Personnel from the Sensors Directorate, Lockheed Martin Aeronautical Systems, and the F-117 Combined Test Force in Palmdale, California, conducted the flight testing.

The ability to send images of an attack sequence to a command and control element within minutes of the attack allows commanders to assess the effectiveness of an attack and rapidly redirect an attack against the target, if necessary. This capability is essential for time-critical targeting operations.

Accomplishment The IRRCA program developed an onboard mission manager (OMM) that facilitates the transfer of RTIC and RTOC. The OMM also contained a modified version of the common low-observable auto-router (CLOAR) that allows a dynamic, signature-managed replan of the F-117's flight path in response to target retasking messages and pop-up threats. The IRRCA avionics configuration also supports sending selected images with mission reports via satellite data links that provide beyond line-of-sight communication with the aircraft.

Background The directorate initiated the IRRCA program in 1998 and restructured it in January 2000, adding extended hot mock-up (HMU) testing. HMU testing, completed in June 2001, allowed for additional configuration testing and consisted of mission updates, text, and image messages sent from the Raytheon, Ft. Wayne, Indiana location to the F-117A HMU facility in Palmdale, California, over ultra high frequency demand-assigned multiple access satellite communications (UHF DAMA SATCOM).

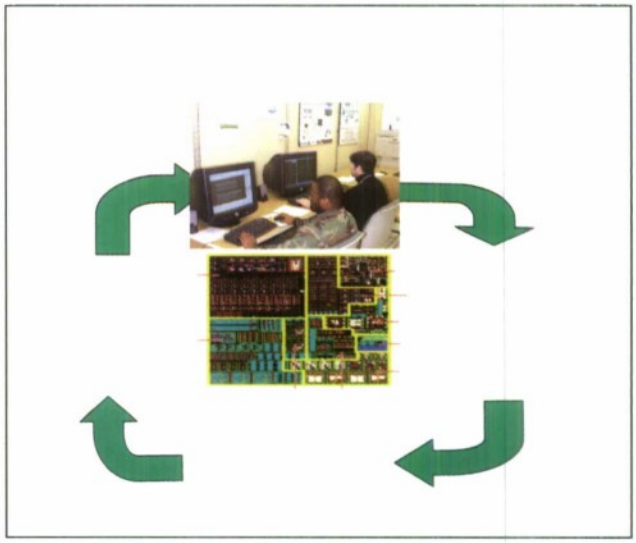
The multimission advanced tactical terminal received threat updates transmitted on the national threat broadcasting system and passed the threat updates to the OMM. The CLOAR replanned the route, which was dependent upon the mission updates and threat information passed to the OMM. During the attack phase of the mission, the HMU captured a series of images from the infrared targeting system and sent them via UHF DAMA SATCOM to a simulated air operations center.

Mixed-Signal Design Center

Payoff The Sensors Directorate's Aerospace Components and Subsystems Technology Branch developed a mixed-signal design center that is capable of rapidly solving the challenges associated with mixed-signal integrated circuit design, synthesis, fabrication, and characterization.

Accomplishment Over a period of 18 months, the directorate's mixed-signal design center developed prototype synthesis tools and novel on-wafer characterization methods as a means to evaluate new mixed-signal integrated circuits developed by the Department of Defense (DoD), commercial businesses, and universities. Through direct team participation in multiproject fabrications, directorate engineers assisted radio frequency developments to technologies such as fully depleted silicon-on-insulator complementary metal oxide semiconductor and 7HP silicon germanium.

Background The mixed-signal design center represents a parallel approach to merge advanced design tools with appropriate analysis methods so their combined paths lead to more complex and highly functional integrated circuits. Working with other DoD agencies, industry, and academia, the state-of-the-art center represents over $2 million in shared investment. The resulting microelectronics are capable of mixed-signal operation, and directorate engineers can feed the highly accurate models back into system-level architectures to perform more complicated tasks such as receiver-on-a-chip operation.



The mixed-signal design center resources comprise an invaluable piece of the larger directorate and DoD technology push for increased functionality to multibandwidth receiver applications. The mixed-signal design environment possesses the capability for partnerships as novel opportunities arise, and the knowledge gained through research projects allows our scientists and engineers to act in the capacity of intelligent technology brokers.

Sensors Directorate Develops Model for See-and-Avoid System

Payoff The Federal Aviation Administration (FAA) see-and-avoid requirement is qualitative and provides no clear success criterion. FAA Directive 7610.4J states that unmanned air vehicles (UAVs) must provide an "equivalent level of safety, comparable to see-and-avoid requirements for manned aircraft" to operate in the national air space.

The Sensors Directorate's Electro-Optic Threat and Target Detection Technology Branch, in conjunction with Defense Research Associates, through a Small Business Innovation Research program, developed a model that quantifies "the equivalent level of safety" requirement. This model has successfully compared capabilities of manned and unmanned aircraft.

Accomplishment Directorate engineers developed a model in MATLAB® for calculating the detection range required to avoid a collision for both manned and unmanned aircraft. The model allows variation in sensor and target velocities; initial separation and look angle; latencies associated with communications, decisions, and maneuvers; a safety factor (final miss distance); and specific UAV maneuvering capabilities (flight speeds, climb rates, and turn rates as a function of altitude). Directorate engineers applied this model to the Global Hawk and Predator UAVs to determine the detection requirements for a see-and-avoid system placed on each of these platforms.

After completing the requirements definition phase and flight demonstration of an aircraft detection system, directorate engineers compared the results of both. The UAV air traffic detection system performance exceeded that of a trained human pilot.

Background The FAA defines "equivalent level of safety" detection range requirement with a single constraint: a see-and-avoid system must detect and avoid air traffic with at least the same capability as a human pilot. To determine the "equivalent level of safety" detection range requirements for the Global Hawk and Predator UAVs, directorate engineers performed an analysis as if a human pilot was onboard, using human response inputs from the Human Factors Directorate, Aeronautical System Center's Global Hawk and Predator System Program Offices, and studies by the FAA.

In addition, directorate engineers used the Optical Encounter model to determine the range at which a trained pilot would detect an F-16 from a co-altitude, nose-on perspective under various atmospheric conditions and sun positions. Directorate engineers developed a prototype system that went beyond this constraint. The system can detect approaching aircraft at a sufficient range to allow a maneuver that avoids a collision.

Mobile Trailer System Permits Missile Firing in a Safe Control Area for Sensor Research

Payoff The ability of Sensors Directorate engineers to control a missile's flight via a cable improves the research potential to investigate the sensor's ability to detect missiles in a high-clutter, urban environment. This cable apparatus is a low-cost solution; however, at the same time, it provides high returns in research capability.

Accomplishment Directorate engineers demonstrated an innovative mobile trailer system, which allows them to fire missiles in a safe, controlled area for sensor research. This improves the research scientists' ability to test and evaluate sensor systems against missile threats.

Background Directorate engineers have used smokey surface-to-air missile (SAM) training rockets during testing for several years, primarily as a low-cost simulator for missile-warning sensor testing in both static firings and free-flight launches. The large cleared area required for free-flight tests limited the sites available to accomplish this testing, mainly to expensive test ranges.

Open test ranges are also usually low-clutter environments. However, to thoroughly test the missile-warning sensor's capability, scientists need to examine how the sensor picks out missiles in a high-clutter, urban-type environment.

Directorate scientists determined that by launching a smokey SAM along a cable, they could control the flight and reduce the safety footprint. They further examined ways to assemble the apparatus onto a mobile trailer with a telescoping tower where it could be transported, set up, and fired in any high-clutter urban environment.

Directorate engineers recently demonstrated this concept at Wright-Patterson Air Force Base, Ohio. They used a crane to raise the cable to about 70 ft, with the other end of the 1/8 in., 2,000 ft aircraft cable attached to a pickup truck. The engineers drove the anchor truck forward to pull tension on the cable until the cable was a sufficient height off the ground. The rockets traveled 1,500 to 1,800 ft.

Sensors Directorate Successfully Tests DIAL System

Payoff The Differential Absorption Ladar (DIAL) system detects and measures concentrations of gasses, such as environmental contaminants and chemical agents in the atmosphere, and may be useful operating in the differential scatter mode for bio-aerosol discrimination. This lightweight, small, and flight-capable system selects the minimum number of wavelengths to provide the maximum probability of identifying a chemical or group of chemicals in a complex chemical environment.

Accomplishment The Sensors Directorate's Multi-Function Electro-Optical Branch successfully tested Lidar II, a frequency-agile DIAL system designed and assembled by LaSen, Inc. Lidar II is the second-generation device based on the environmental laser mapping system—a DIAL-based, high-speed, multi-chemical mapping system. Directorate researchers successfully tested this sensor on the ground and on a helicopter platform, with detection limits of <1.5 parts per million (ppm).

Background An Air Force Small Business Innovation Research program funded the initial effort to construct a midwave active laser chemical remote system with potential application as a base remediation sensor. LaSen, Inc. designed Lidar I, a 100 lb sensor with detection limits of <5 ppm at ranges up to 2.0 km in a topographic reflector mode, to map volatile organics (methane, toluene, benzene, etc.) associated with Air Force base environmental cleanups, dumpsites, and underground diesel fuel leaks.

Lidar II is a compact (<40 lbs) version of Lidar I, engineered to operate from a helicopter during flight. This new device is less than half the size and weight of Lidar I, with improvements in receiver design performance.

Initial flights proved that the vibration and temperature fluctuations encountered during flight operations did not affect performance of the system. Subsequent flights demonstrated the sensor's ability to detect, from the air, natural gas leaks at pipeline valve stations.

Directorate researchers are currently upgrading the system to include a video tracker and Global Positioning System/Inertial Navigation System to confirm and geo-reference actual sampling locations on the ground. They will further demonstrate sensor capabilities in a number of blind tests against underground pipeline tests during subsequent flights and investigate the sensor's potential to detect and identify hard targets on the ground, based on spectral differences in material reflectivity.

New Technology Provides Powerful Security Protection for Wireless Communications

Payoff The Sensors Directorate sponsored new technology developed by Robert Gold Comm Systems, Inc. (RGCS) under a Phase II Fast Track Small Business Innovation Research program. This technology provides powerful security protection for wireless computer networks, cell phones, and other radio communications. Benefits include highly secure communications with the overhead of encryption and selective addressability of receivers, individually or in groups.

Accomplishment Dr. Gold developed a self-synchronizing and selective addressing algorithm based on times-of-arrival (TOA) measurements of a frequency-hopping radio system. These algorithms allow a monitor to synchronize to a frequency-hopping radio in a network by making relatively brief observations of the TOAs on a single frequency.

RGCS designed the algorithms for integration into spread-spectrum, frequency-hopping systems widely used for wireless communications such as wireless fidelity computer networks, cellular phones, and two-way radios used by the military, police, firefighters, ambulances, and commercial fleets.

Background Although very convenient for users, wireless communication is extremely vulnerable to eavesdropping. For example, hackers frequently access wireless computer networks (laptop computers linking to the network).

Encrypting the data increases the security of these networks, but encryption is complex, inconvenient, time consuming for users, and adds a significant amount of overhead information that reduces data throughput. In frequency-hopping (spread-spectrum) networks now in wide use, users protect the data by sending it in brief spurts, with the transmitter and receiver skipping in a synchronized pattern among hundreds of frequencies. An intruder without knowledge of the synchronization pattern would just hear static.

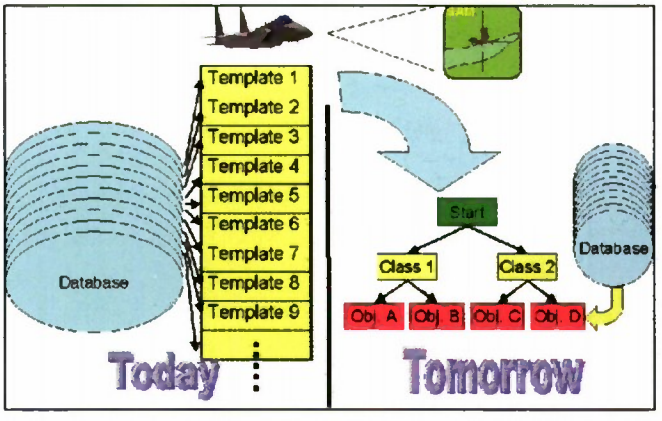
A major vulnerability of many spread-spectrum networks involves compromising the network security by intercepting unprotected information. Originators must send the sync pattern information to authorized receivers, often unprotected.

The Gold algorithms support code-division multiple access, frequency-hopping multiple access, and ultra-wideband spread-spectrum communication systems. They are designed for incorporation into enhanced versions of existing products, most of which already include circuitry that manufacturers can adapt to implement the technology.

Algorithm Decreases Computational Time to Perform Combat Identification

Payoff The Sensors Directorate Automatic Target Recognition (ATR) Team has invented a revolutionary detection and recognition process that matches potential battlefield targets to known targets in Air Force databases in a fast, automated process.

Accomplishment By understanding the fundamental relationship between objects and images and constructing a metric or measurement for comparing objects to images, the ATR Team created an algorithm that dramatically decreases the amount of computational time necessary to perform combat identification (CID). CID is the process of attaining an accurate characterization of detected objects in the joint battlespace to the extent that high confidence, timely application of military options and weapons resources can occur. A computer will watch all video cameras, radars, and other Air Force sensor platforms, aiding the pilot or intelligence analyst by letting them concentrate on the task at hand.



Object-image relations (OIRs) indicate when an object and image are consistent. OIRs help to answer questions about which objects could have produced a specific image. An object-image metric indicates how to measure the distance between images, the distance between objects, and the distance between an object and an image. This metric will affect both the overall ATR algorithm approach as well as the implementation of many components of the algorithm.

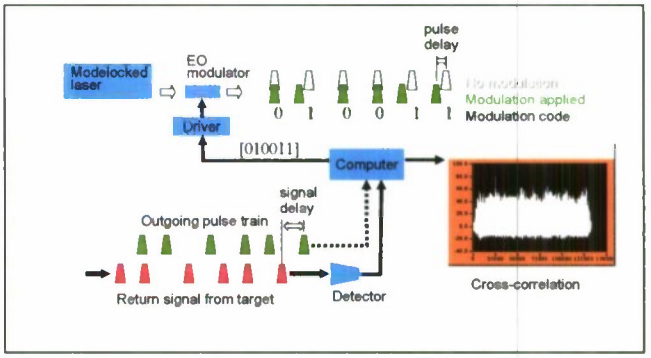
Background The new process avoids item-by-item searches through huge databases in order to find a match for a potential target. Past systems comprised very large databases of pictures and objects that were created, maintained, and searched sequentially for potential matches. The new system will hold the same amount of information as the original database but will be dramatically smaller.

Laser Sensing Capability Enhances Target Ranging and Identification

Payoff A new technique, based upon pulse modulation of a mode-locked laser source, enhances target identification and ranging capability with a smaller laser that will support transition of laser sensing capability to tactical aircraft and unmanned air vehicles. This technique easily provides a resolution of better than 25 cm and eliminates the need for high-energy pulses that are difficult to generate and can damage optics.

Accomplishment The Sensors Directorate's Electro-Optical Countermeasures Technology Branch at Wright-Patterson Air Force Base, Ohio, recently demonstrated a novel technique for target ranging and identification based upon pulse modulation of a mode-locked laser source. The mode-locked laser is a compact, rugged, room-temperature source well suited to multifunctional use.

Directorate engineers used a passively mode-locked, 0.5-watt (W) neodymium laser with electro-optic modulation and a 1 GHz bandwidth detector to determine range-to-target and target depth information in the laboratory with a resolution of better than 25 cm. The engineers simultaneously ranged multiple targets with the same 25 cm resolution.



The 40 ps laser pulsewidth translates into high peak power at the target, and the MHz-level repetition rate permits signal averaging over many pulse trains, yielding accurate results at signal-to-noise ratios below 0.1. Modeling suggests laser average power requirements remain a challenge for airborne laser radar applications, with upwards of 100 W likely needed for extension of this technique to ranges over 10 km. Directorate engineers expect ongoing advances in both laser sources and detectors to boost overall system throughput to allow realization of its potential.

Background The mode-locked target identification (ID) approach exploits the technique of pulse position modulation, long used in radio frequency applications and more recently applied to optical communications. The mode-locked target ID approach directs the mode-locked laser output at the target in pulse trains of fixed length, modulated with a known pseudo-random pattern where it delays some pulses by a small fraction of the pulse period and transmits others without delay.

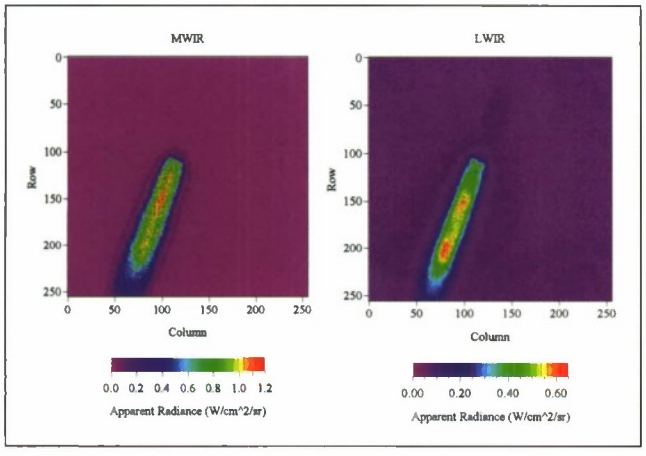
In the absence of modulation, each pulse looks like the next, but the known modulation pattern enables the detection system to recognize a specific pulse train upon its return. The mode-locked target ID approach determines range-to-target by measuring the pulse train's round trip time and obtains the target depth information from the degree to which the pulses are smeared out in time.

The mode-locked target ID approach performs comparison of the scattered return signal with the known outgoing pattern by means of a mathematical cross-correlation, then averages many pulse trains to pull the signal out of the noise. The approach can use multiple range measurements to obtain target velocity information.

Improved Multiwaveband Infrared Arrays

Payoff The Space Vehicles Directorate's Improved Multiwaveband Infrared Array (IMIRA) program's long wavelength infrared (LWIR) dual band focal plane arrays (FPA) have wavelength cutoffs approaching the difficult 12 micron region. This region is where the mercury cadmium telluride energy gap is relatively narrow, making high performance harder to achieve.

These LWIR FPAs also allow for the demonstration of a novel hyperspectral concept for which a target interferogram, rather than a spectrum, is created and dispersed across one axis of the array. Such a novel hyperspectral sensor benefits greatly from the high percentage (99%+) of operable pixels in the 256 x 256 pixel arrays, since inoperable pixels lead to deviations in the sampling of the interferogram and lowered fidelity of the recovered spectrum.



Accomplishment The directorate's IMIRA program demonstrated superb LWIR FPA performance as part of a progressive effort to develop two- and three-waveband capabilities. The range of application of this technology includes space hyperspectral concepts as well as the more traditional imaging sensor, which benefits from the improved target to background discrimination of dualband phenomenology. In either case, savings in volume, mass, and cryogenic cooling is obtainable, relative to the more traditional approaches involving two single-waveband FPAs and beam-splitting optics.

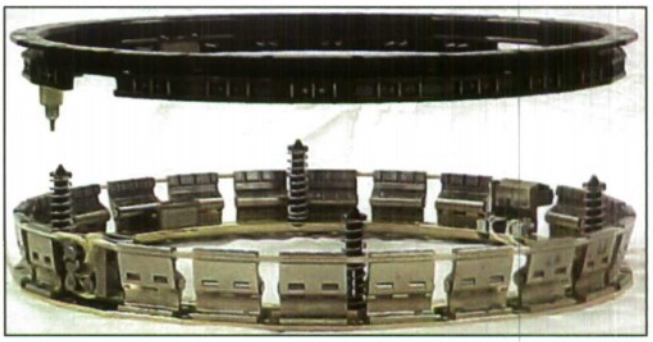
Background The directorate awarded the IMIRA program to DRS Infrared Technologies in Dallas, Texas, in support of the Category 2B Advanced Technology Demonstration of the same name and also as a vehicle for executing customer and research initiative efforts for dualband and longer LWIR cutoff wavelengths, respectively. Directorate researchers evaluated the FPAs delivered under IMIRA in the directorate's characterization facility and verified the manufacturer's performance claims.

Lightband Separation System

Payoff Planetary Systems Corporation (PSC) of Silver Spring, Maryland, developed a system called Lightband, under a Small Business Innovation Research (SBIR) contract with the Space Vehicles Directorate, to provide a low-cost, low-mass, non-pyrotechnic separation system for small spacecraft. Directorate engineers flight-demonstrated the Lightband system on the Kodiak Star Mission in Kodiak, Alaska. The Department of Defense will use the Lightband system in over 10 spacecraft missions including the Space Test program's CAPE small satellite launch system, XSS-11, and the University Nanosat program.

Accomplishment PSC developed and demonstrated a low-shock separation system for use with small satellites. Recent activities improved and expanded the initial design. As a result, the Lightband separation system has become the baseline for many future Air Force and National Aeronautics and Space Administration missions.

Background Existing pyrotechnic clamp-band separation systems are not suited for small satellite applications; their high-shock separation event is too close to the sensitive electronics on a small satellite. The PSC SBIR effort demonstrated a new class of non-pyrotechnic, low-shock separation systems for small satellite applications.



The standard Lightband system uses a tensioned line and hinged leaf retaining latches to join the Lightband upper and lower rings. When the latches are released, a set of separation springs push the rings apart with the desired velocity.

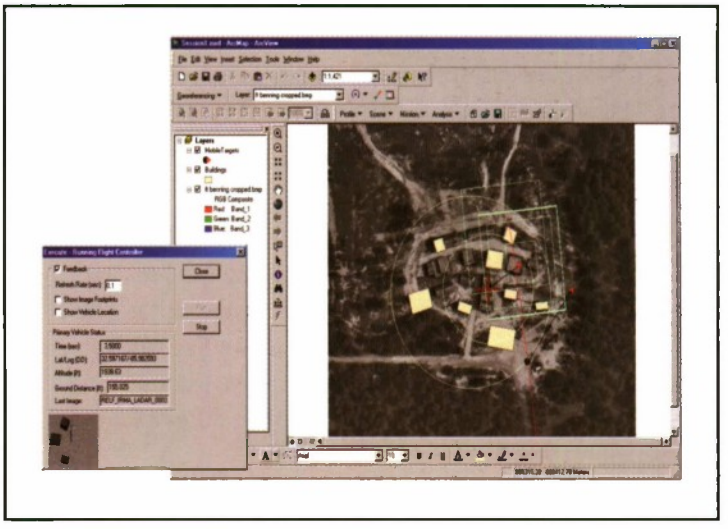
PSC added, through the use of simple design features, the benefits of low mass and low cost. Typical side-by-side comparisons with traditional bolt pyrotechnic separation systems result in a shock load reduction with less total and flyaway mass at approximately half the cost.

In addition, as part of an ongoing enhancement to the Lightband separation system, PSC is developing a motorized activation mechanism. Once completed, this will allow for virtually unlimited testing of the actual flight hardware with no consumable parts—a feature that is currently not available in any spacecraft separation systems.

Space Vehicles Directorate Delivers ISMET Software

Payoff The Space Vehicles Directorate's Integrated Sensor Modeling and Effectiveness Tool (ISMET) software package allows users to simulate advanced vehicle technology target scenes, sensor target acquisition, and effectiveness/lethality analyses.

Accomplishment Ballistic Missile Technology, working with Applied Research Associates, recently received the directorate's ISMET user's manual and software. Infrared, ladar, and synthetic aperture radar sensor models; ladar automatic target recognition (ATR); as well as ground-fixed and ground-mobile target lethality are available for the user. The terminal stage flight dynamics of the vehicle is included to search and acquire the target.



The main software runs on Windows® personal computers. However, directorate engineers designed the tool to run over a network and link to sensor models and ATR software located on other platforms since some of the tools are UNIX® operating system based. Users can change the sensor or scene's characteristics to help determine the required sensor characteristics for the vehicle, target, and scenes of interest.

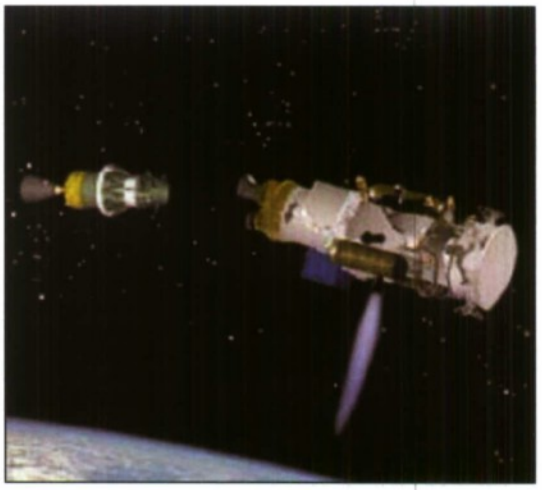
Background The ISMET allows trade studies on sensor target acquisition and weapon effectiveness for advanced vehicle technology. The directorate developed the tool using commercial geographic information system software.

ISMET integrates several existing government and commercial off-the-shelf sensor modeling, ATR, and weapon effectiveness/lethality tools into a single cohesive product. Future plans for the tool include addition of more sensor models and ATR software, better flight dynamics, and more realistic scenes with clutter and terrain.

XSS-10 Microsatellite Demonstration Program

Payoff The successful completion of a miniature, 68 lb satellite's experimental mission earlier this year was an important first step in the development of a technology that promises to dramatically decrease launch costs and extend the capabilities of space vehicles. The XSS-10 microsatellite, recently launched as a secondary payload with Global Positioning System Mission IIR-8, achieved all primary objectives and transitioned important lessons learned to XSS-11 and other future microsatellite initiatives.

Accomplishment The Space Vehicles Directorate's XSS-10 demonstration program was the first on-orbit flight demonstration of an autonomous microsatellite used to track and inspect a remote space object. Using the second stage of a Delta II rocket as its remote space object, the microsatellite acquired, photographed, and maneuvered to five different positions around the Delta II. XSS-10 relayed real-time photographs from each position as it maneuvered through space without support from ground personnel.



XSS-10 also demonstrated critical new technologies including lithium polymer batteries, a miniature propulsion system, and an integrated visual camera system. The XSS-10 had capabilities similar to larger satellites, but its 3 ft long by 18 in. circumference required developers to shrink its communication system from 12.5 to 2 lbs and reduce its power needs to one-tenth that of previous model requirements.

The team was successful in completing the XSS-10 mission objectives including inspections, powering the spacecraft on and off, and communicating with the vehicle's computer via its own ground-based control center rather than a central control center. The scientific results of the XSS-10 mission provided a critical first step towards autonomous satellite operations.

Background This demonstration marks the first in a series of future microsatellites for important missions. XSS-10 is a building block for future space operations and may lead to rapid, responsive space systems that enhance space situational awareness. Microsatellites bring affordable new capabilities to revolutionize space missions through reduced costs for development and launch.

High-Performance Solar Cells

Payoff The high-efficiency solar cell Dual Use Science and Technology (DUS&T) program has developed single crystal solar cells with higher efficiencies and lower dollar-per-watt costs than any previous solar cells. These cells are baselined on all US military spacecraft now in the acquisition cycle.

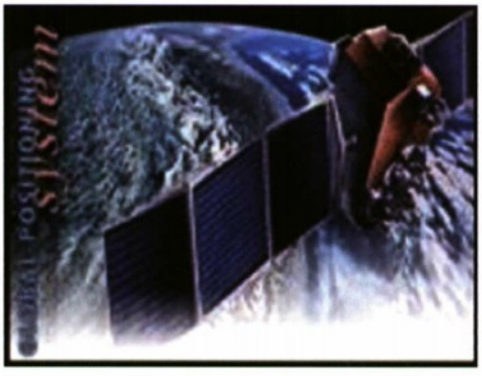
Accomplishment The Space Vehicles Directorate, Defense Advanced Research Projects Agency, Spectrolab, and EMCORE team performed work from fiscal year (FY) 99-03 to develop the highest possible efficiency space solar cells. The EMCORE start-up company bid successfully on the DUS&T program and, within a year, provided a competitive product. This re-established the historical dual sources of domestic solar cells, with the associated risk and cost-reduction benefits.

By mid-FY02, both Spectrolab and EMCORE were offering 27.5% production cells and 29-30% best-cell efficiencies. In addition to these performance improvements, better production processes resulted in a 20% reduction in dollars/watt cost of the cells.

These solar cell products are, by far, the best in the world, completely dominating the domestic military, civilian, and commercial markets as well as being selected for many foreign spacecraft. Their rapid insertion into current US military satellite programs attests to their mission-enabling qualities.

For example, the Advanced Extremely High Frequency and Wideband Gapfiller systems, the follow-on programs to the Military Strategic and Tactical Relay Satellite, along with certain classified programs, are spacecraft that were required to transition to the Evolved Expendable Launch Vehicle class of launchers from the Titan IV used by their predecessors. The high-performance solar cells developed by this DUS&T program enabled that transition without a loss in available power that would have otherwise resulted from the necessary decrease in solar array area.

Background When this program began, the state of the art in multijunction solar cells was 24% efficiency in production lots and approximately 25.5% best-cell efficiency. A Manufacturing Technology program funded Spectrolab and TECSTAR to develop these first triple-junction solar cells. The directorate worked jointly with Sandia National Laboratory to identify further improvements for adjustment of the subcell bandgaps. The directorate initiated the DUS&T program with the goal of achieving 35% efficiency cells through development of new materials with more optimal bandgaps and compositional tailoring of the existing materials.



AFRL Provides Key SCA Characterization Conclusions and Revised SCA Screening Protocol for SBIRS High Program

Payoff Assessing performance levels of sensor chip assemblies (SCAs) in the presence of ionizing radiation provides key information on SCA performance, pointing the way towards understanding failures observed in a significant percentage of SCA assets.

Accomplishment The Space Vehicles Directorate's Infrared Radiation Effects Laboratory (IRREL) characterization facility conducted a characterization campaign to assess performance levels of scanning SCAs in the presence of ionizing radiation. They extracted key information on SCA performance from the data sets for the Space-Based Infrared System (SBIRS) High program.

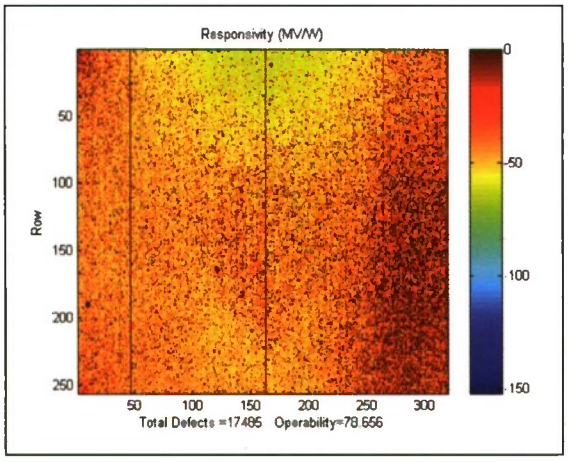
This increased level of understanding allows the development of a screening process wherein the "go/no go" decision on ionizing radiation survivability is determined in the laboratory without performing actual radiation testing. As a result of these efforts, the fabrication did not require additional lots of SCAs, thereby saving the directorate's systems program office the costs and schedule delays associated with such fabrication runs.

Background The directorate constituted the IRREL in 1987 to address challenging issues of characterizing the performance of high-sensitivity, lower (space) background focal plane arrays (FPAs) under development for the Strategic Defense Initiative Office (now the Missile Defense Agency). The IRREL characterization facility provides a broad range of capabilities, including operating temperatures (4 Kelvin and upwards), background levels (10^9 photons sec^{-1} cm^{-2} and higher), ionizing radiation environments (Cobalt-60 gammas, protons, neutrons, X-rays), and infrared (IR) wavelengths (visible to 30 microns), for all visible and IR FPA (detector array and cryogenic multiplexer) types.

The execution of the IRREL mission required reconfigurable cryogenic Dewars in a timely fashion to meet various electrical requirements of diverse SCAs and FPAs, and an FPA drive and data acquisition system with very low levels of system noise. Portability of the test system for use at remote radiation source locations and low levels of radioactivity after exposure were also key requirements. The personnel performing these tests have more than 90 years combined experience that is unrivaled anywhere in the Department of Defense.

320 x 256 Pixel, Dual-LWIR Waveband FPA Development

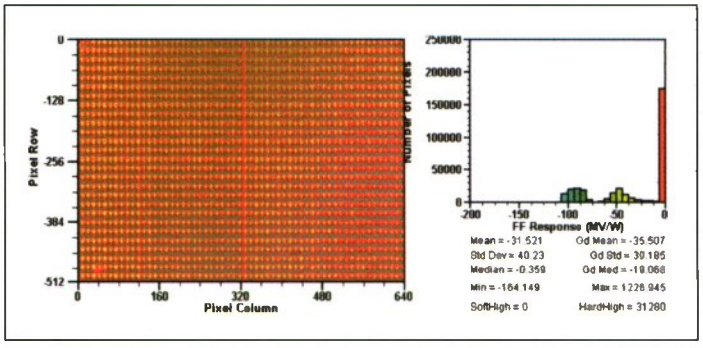
Payoff Dualband focal plane arrays (FPAs) allow for systems applications with savings in volume, mass, and cryogenic cooling, relative to the more traditional approaches involving two single waveband FPAs and beam-splitting optics.



Accomplishment The Space Vehicles Directorate evaluated dualband FPAs developed recently as part of Lot 4 for the Missile Defense Agency/Advanced Sensors (MDA/AS) technology program that show the better FPAs achieve good imagery in both wavebands, with values of pixel response operability in the 90% regime. The shorter waveband (with cut-off wavelength near 8 microns at the 60 Kelvin operational temperature) also exhibits similarly high values in sensitivity operability.

Sensitivity operability is indicative of both pixel response (and noise) uniformity with respect to the FPA mean and becomes increasingly challenging for the longer wavebands of the dualband technologies. A derivative of the technology forms the basis of risk reduction for the Navy Standard Missile 3, Sea-based Midcourse Seeker.

Background MDA/AS provided funding for the directorate's Improved Multi-waveband IR Array (IMIRA) program to develop high-sensitivity, dualband FPAs. The directorate awarded the IMIRA program to DRS Infrared Technologies of Dallas, Texas, as a vehicle for executing research initiative efforts for dualband and longer long-wavelength infrared cutoff wavelengths.



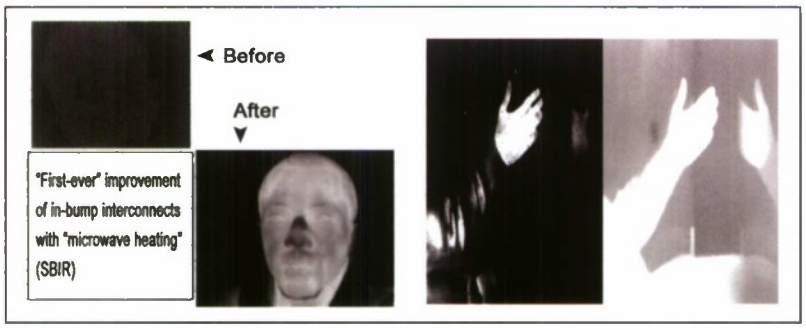
Directorate researchers evaluated the FPAs delivered by DRS Infrared Technologies under the IMIRA program in the directorate's characterization facility, largely verifying the performance claims of the manufacturer. DRS Infrared Technologies developed the high-density, vertically interconnected photodiode (HDVIP) process for single waveband FPAs in response to the Defense Advanced Research Projects Agency's Infrared FPA's Flexible Manufacturing program.

The processing begins with tellurium-rich, liquid-phase epitaxial growth of p-type detector material diced and epoxied onto cryogenic multiplexers. DRS Infrared Technologies makes interconnects to the multiplexer pads with the etching of vias, followed by their metallization (with this step representing a substantial deviation from the indium bump interconnection used by most other infrared FPA manufacturers). At the time of the via etching process, DRS Infrared Technologies converts the axial region surrounding the via from p- to n-type, thereby forming the photodiode.

The advantages of the HDVIP process for dualband applications include high values of optically active area for all wavebands and exact collocation of pixels for each band, high cryogenic reliability, and reduced probability of a pixel outage in one band affecting its spatial counterpart.

New Dualband Focal Plane Array Interconnect Technology for Jet Propulsion Laboratory Quantum Well Infrared Photodetector Technology

Payoff A dualband Quantum Well Infrared Photodetector (QWIP) focal plane array (FPA) (with band centers near 9 and 14 microns) provides for simultaneous dualband imaging. When operated in an integrated camera assembly, the image quality is sufficiently high to see both temperature variations on an individual's hand as well as the radiation from the hand reflected from a metallic optics table. The technology shows great promise in allowing future hybridization using more closely spaced interconnects needed for smaller pixel pitches and multiple wavebands and using metals more robust than indium.



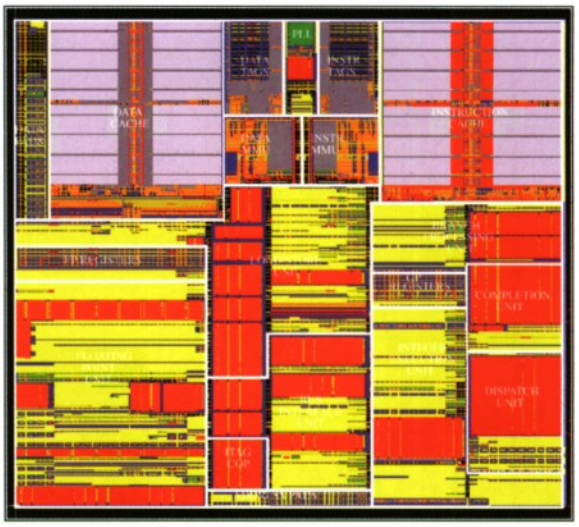
Accomplishment Ongoing Small Business Innovation Research (SBIR) at Microwave Bonding Inc. (MBI), monitored by the Space Vehicles Directorate, demonstrates the feasibility of a new hybridization approach for QWIP detector arrays and their associated cryogenic multiplexers. Working closely with Jet Propulsion Laboratory (JPL) QWIP personnel, MBI has demonstrated the first-ever hybridization of an infrared detector array with its cryogenic multiplexer through the fusing of indium interconnects with microwave energy. MBI localizes the microwave energy deposition to the indium bumps, preventing elevated temperatures from damaging the detector array structures.

Background QWIP FPA development at JPL has been under way for several years, with some programs having joint technical oversight with the directorate. Interconnect technology advances, made possible under the directorate's SBIR, will allow future JPL devices to achieve larger FPA dimensions and multi-waveband capability.

PowerPC™ Processors Fly On Air Force Missions

Payoff As spacecraft perform increasingly complex tasks, more onboard processing power is required. AFRL's latest generation of space processors, based on PowerPC, is becoming the architecture of choice for major Air Force and civil satellites.

Accomplishment AFRL's Space Vehicles Directorate set out in 1998 to develop a space microprocessor with 10 times the throughput of current state-of-the-art spacecraft computers. During the next year, two projects, based on PowerPC architectures, were started. These projects were aimed at both the military market and expected commercial telecom applications. Based on the commercial expectations, both projects were heavily cost-shared by the development contractors chosen.



During the next 2 years, both projects achieved technical successes with the Honeywell RHPPC™ passing verification test suite for the Motorola 603e and the BAE Systems RAD750™ demonstrating equivalence to the IBM PowerPC 750. Both processors have been delivered to flight programs. These programs range from small AFRL experiments like XSS-11, to the Air Force's biggest operational programs like MILSATCOM and GPS-III, which will soon be flying in space. Even though the commercial prospects have been postponed following the delay of systems like Teledesic and Iridium Next, both contractors continued their cost sharing and delivered prototype units within cost and schedule baselines.

Background Outside of the protection offered by the earth's atmosphere and magnetic field, satellite electronics must be adapted to the space radiation environment using both circuit layout and special processing techniques. The size and complexity of these chips drove designers to use the most aggressive foundry facilities available. Designers also had to harden new structures such as phase lock loops that had never before been integrated into hardened chips. This project also pioneered the use of special circuit design techniques at a commercial foundry to achieve radiation tolerance for most space missions at reduced cost.

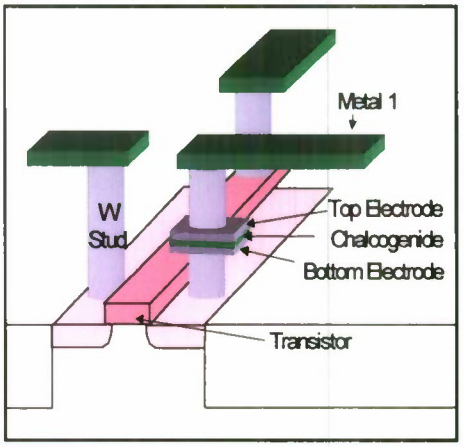
AFRL Demonstrates New Nonvolatile Memory Technology

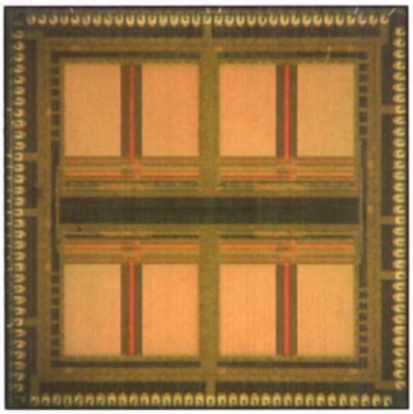
Payoff The Space Vehicles Directorate's Space Electronics and Protection Branch recently announced the "first-pass success" of a 64 kbit nonvolatile memory array. This chalcogenide-based random access memory (C-RAM) is an electrically nonvolatile, solid-state memory with significant advantages over other nonvolatile memory types. Most military satellites are highly dependent upon nonvolatile memory.

This C-RAM solution offers the only known manufacturable route to radiation-hardened, nonvolatile memory well beyond the 1Mbit level. The higher densities have the advantage of reduced power and weight.

Accomplishment The directorate and its contractors, BAE SYSTEMS and Ovonyx, Inc., designed, fabricated, and tested test chips to demonstrate full integration of a chalcogenide-based memory element into a radiation-hardened complementary metal oxide semiconductor (CMOS) process.

Electrical test results on the first packaged parts indicate full functionality of the 64 kbit memory arrays—unprecedented for such new and unique material integration. Test results also confirmed that the insertion of a chalcogenide manufacturing flow had no effect on measured CMOS transistor parametrics and did not change the total dose response of the base technology.





Background While chalcogenide refers to any alloy containing a majority of a Group VI element (sulfur, selenium, and tellurium), the chalcogenide alloy in this application is a carefully crafted combination of germanium, antimony, and tellurium. This alloy can change between two room-temperature phases—a highly ordered polycrystalline phase and a disordered amorphous phase—by appropriate heating and cooling.

There are both optical and electrical differences between the phases. The polycrystalline phase has about 14% higher reflectance and 2-6 orders of magnitude greater electrical conductivity than the amorphous phase.

Manufacturers of the nonvolatile memory chip use conventional semiconductor memory fabrication methods to deposit a tiny volume of chalcogenide material for each bit location. The phase of the chalcogenide is then changed by electrically heating and cooling the material at a controlled rate. The power required is a function of volume; directorate researchers demonstrated currents as low as 10μA at 5V per bit, making the memory as good or better than other memory technologies for low-power applications.

The nonvolatile memory chip senses the state of the bit (one or zero) from the very large resistance difference. Since the information is stored in the phase of the material at each bit location, no power is required to maintain the data on the chip. Also, the material itself is intrinsically highly resistant to radiation from natural space or nuclear environments, so that simply starting with a radiation-hardened semiconductor process may develop radiation-hard memory chips.

Low-Shock Separation System Dramatically Reduces Satellite Failures

Payoff The shock of separation of satellites from the launch system (normally a rocket) causes many failures, requiring development of a satellite low-shock separation system. The Lightband system is 25% lighter, 50% smaller, 40% cheaper, and generates <5% of the shock of existing conventional pyrotechnic separation systems. The Lightband provides a capability that reduces on-orbit failures, reduces the cost of design and redesign, and reduces launch costs. This technology could save spacecraft programs several million dollars in life-cycle costs per spacecraft.

Accomplishment Using technology explored under the Small Business Innovation Research (SBIR) program, the Space Vehicles Directorate successfully developed and transitioned the country's next-generation, small spacecraft separation system called the Lightband. Operating with limited SBIR funding, a directorate team developed, designed, tested, and successfully flew the world's first reusable, non-discrete point, low-shock, non-pyrotechnic separation system.

This Lightband system successfully separated the National Aeronautics and Space Administration's (NASA) Starshine-3 primary satellite from Lockheed Martin's Athena I launch vehicle on the first orbital launch out of Kodiak, Alaska. For the Starshine-3 spacecraft, the low-shock separation system reduced the shock-induced loading from 8,000 g-force (typical pyrotechnic separation system) to 300 g's.

Background During the past decade, NASA lost billions of dollars due to satellite malfunctions, resulting in total or partial mission failure. These malfunctions are often directly attributable to vibration loads during launch and satellite separation from the rocket.

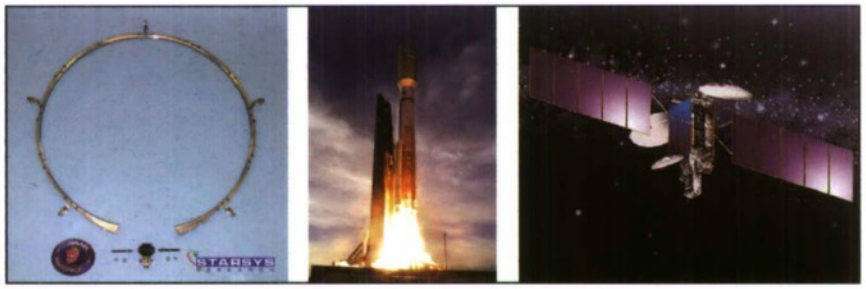
Low-shock separation systems are an enabling technology for small (<100 kg) Department of Defense satellites and for the launching of fragile spacecraft components such as advanced optical systems. Small satellites are particularly susceptible to shock-related failure because of the close proximity of sensors and instruments to the shock source, necessitating a low-shock separation system.

The Air Force required a low-risk small satellite launch system that was compatible with existing systems. Due to the program's success, this separation system is baselined into AFRL's University Nanosatellite program, the Technology Satellite of the 21st Century, Experimental Small Satellite-11, the Space and Missile Center's Space Test Satellite, Multiple Space Vehicle 05 (the first evolved expendable launch vehicle secondary payload adapter flight), the Naval Postgraduate School satellite, and the university's "CubeSat."

Low-Shock Clamp-Band Satellite Separation System

Payoff The Space Vehicles Directorate and Starsys Research Corporation developed a low-shock satellite release technology to separate spacecraft from a launch vehicle with a clamp-band system while imparting very low shock loads to the spacecraft. A Starsys Research and Saab-Ericsson Space commercial system using the technology claimed the first-flight heritage when it released the Rainbow-1 satellite from an Atlas V rocket.

Accomplishment Under a Small Business Innovation Research contract with the directorate, Starsys Research developed a clamp-band opening device that uses the patented Fast Acting Shockless Separation Nut (FASSN) technology to restrain the clamp-band tension bolts with a double helix, flywheel nut. A pyro-compatible pulse releases the flywheel nut, which spins up and ejects the tension bolts.



The strain energy in the clamp band is then converted to rotational energy in the flywheel nut, allowing the two mating halves of the structure interface to separate with extremely low shock. The successful use of this system in the Atlas V/Rainbow-1 mission confirms its commercial and military potential.

Background These new low-shock release mechanisms can support heavier payloads while imparting shock loads on the order of tens of g's, as opposed to thousands, when compared to classical spacecraft release mechanisms with pyrotechnic-based technology. Because they can be reset and reused, these mechanisms will also decrease life-cycle costs.

According to Mr. Scott Tibbitts, the president of Starsys Research, the low-shock release mechanism will change the way spacecrafts are released from launch vehicles. Shock has always been a problem for spacecraft designers. In a conventional release system, shock is created when the energy in a highly tensioned bolt is instantaneously released.

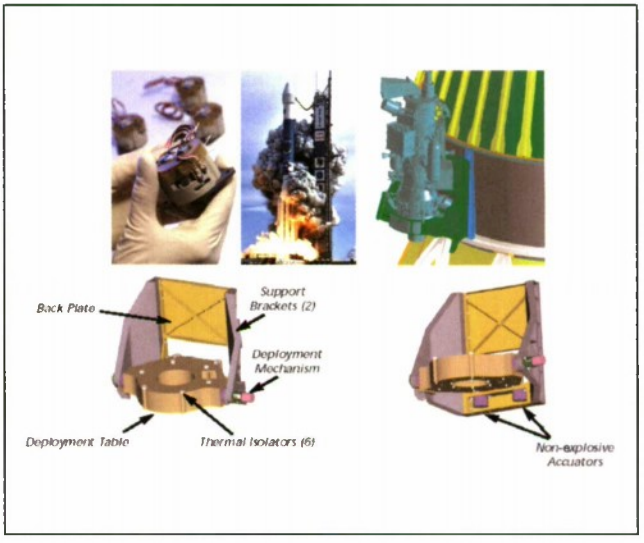
Sensitive spacecraft electronics must be built to withstand this release shock, which adds significantly to the cost of the spacecraft. In contrast, the FASSN technology provides an instantaneous shock-free release. Over the next several years, Starsys Research and Saab-Ericsson Space expect this revolutionary device to become the industry standard.

Qwknut Low-Shock Separation Device

Payoff Starsys Research Corporation Qwknut low-shock release devices were flown as part of the Delta-II/GPS 2R-8 mission. Scientists used them to deploy the Swales Aerospace Sconce Secondary Payload Platform to release the XSS-10 satellite.

The Starsys Research Qwknut system eliminates pyrotechnic safety concerns, is lightweight (under half a pound), has a 50% reduction in mass over current systems, and performs low-shock separation. A typical shock level for separation is under 150 g's, an order of magnitude lower than the thousands of g's imparted by traditional pyrotechnic release bolts.

Accomplishment The Space Vehicles Directorate and Starsys Research developed the Qwknut low-shock release technology under a Small Business Innovation Research contract. Swales Aerospace developed the Sconce Payload Platform for XSS-10 as an interface between the XSS-10 microsatellite and the Delta-II 2nd Stage, procuring Starsys Research Qwknuts for use as part of the system. Two Qwknuts were installed on the Sconce to hold the deployment table vertical for flight through the vibration-intense ascent. On-orbit and upon receiving an initiation command from the 2nd stage, the XSS-10 experiment "fired" the Qwknuts (in parallel) and rotated the deployment table outward where it was released to begin its mission.



Background The Starsys Research Qwknut is a fast-acting separation nut for release of loads up to 3,000 lbf. The Qwknut may be reset in under a minute by pushing an integral reset lever, allowing mission engineers to functionally test the same hardware to be flown. Its extremely fast release time, less than 35 milliseconds, is possible through redundant shape memory alloy triggers. The device responds to a standard pyrotechnic firing pulse, enabling retrofit for existing systems.

Technology Transfer

IDASS Chosen for Space Situational Awareness Test Bed

Payoff The Directed Energy Directorate's Intelligence Data Analysis System for Spacecraft (IDASS) software provides visualization and analysis tools to fuse sensed data and space object models to aid assessment of space object health and status. IDASS supports the workflow of surveillance system operators with efficient data management and familiar data presentations.

IDASS also supplies the needs of researchers with generalized data representations and flexible processing. The software supports simulated three-dimensional viewing to enhance space situational awareness (SSA) by providing an improved picture of the mission payload status and on-orbit damage assessments of both friendly and potentially hostile space objects.

Accomplishment The directorate's Satellite Assessment Center (SatAC) recently transitioned a mature SSA software technology into an operational test bed environment at Air Force Space Command (AFSPC). The 14th Air Force (AF) requested AFSPC to include this technology in the test bed to provide a more useful, fused space common operational picture (Space COP).

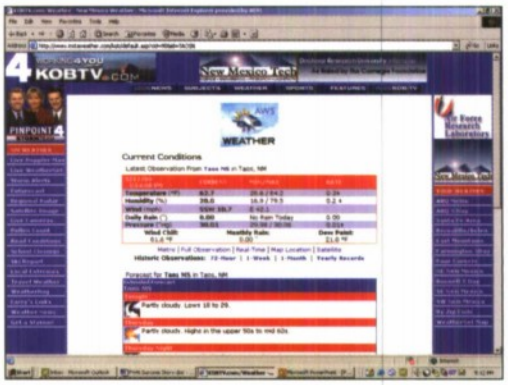
The SatAC worked for 5 years to develop a revolutionary SSA workstation to fuse 21st century technological information from diverse sources into a more formidable Space COP. The 14th AF recognized this accomplishment and solicited AFSPC's support in inserting this software into a highly visible and challenging test bed environment with the hopes of greatly augmenting the space warfighters' information and insight into the space battlespace.

Background The directorate's SatAC, an AFRL Center of Excellence in space object assessment technologies, developed IDASS from the ground up in order to fuse diverse types of satellite information from various stove-piped sources. The directorate successfully demonstrated IDASS at the Joint Expeditionary Forces Experiment 1999 and 2000 and has a growing user base throughout the space intelligence community.

The IDASS software runs on Intel®-based workstations under the Microsoft® Windows® NT/2000 operating system, Silicon Graphics, Inc. workstation computers under the IRIX® 6.5 operating system, and Sun™ UltraSPARC® workstations under the Solaris™ operating system.

Phillips Research Site Establishes New Mexico-Wide Weather Monitoring Network with Pinpoint WeatherNet Project

Payoff The AFRL Phillip's Research Site (Directed Energy and Space Vehicles Directorates), in collaboration with local television channel KOB-TV4, is involved in the Pinpoint WeatherNet project establishing a statewide weather monitoring network. The weather stations comprising this network are located at over 50 schools throughout the state of New Mexico.



As part of the KOB-TV4 news format, this technology transfer partnership between AFRL and its partnership intermediary, New Mexico Tech University, is highlighted during the on-air weather portion of all news segments. The value of this airtime for AFRL and New Mexico Tech University is greater than $6.2M in advertising and promotional dollars.

Accomplishment KOB-TV4, in a partnership with AFRL since 1994 under a Cooperative Research and Development Agreement (CRADA), collaborates on meteorological monitoring and forecasting. Recently, the Pinpoint WeatherNet project became part of a national partnership with the National Weather Service (NWS).

The NWS uses AFRL-provided technology as part of Homeland Security, providing the capability for real-time and localized prediction of the path and velocity of airborne hazardous materials, possibly released by a terrorist group or the result of a natural or accidental disaster. As a result, the Federal Laboratory Consortium (FLC) awarded KOB-TV4 with their 2002 Mid-Continent Regional Partnership Award.

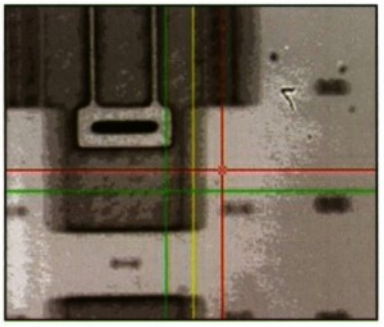
KOB-TV4 prominently highlights AFRL and its other technology transfer partners on its Web site. This Web site generates more than 200,000 hits per month and features the ability to download free Eyewitness News 4 WeatherBug software. This software provides the user with real-time access to data from the weather stations located at the schools. In February 2003, the KOB-TV4 Web site recorded the 10,000th download of this software. *The New York Times* also recognized the national WeatherBug site as among the top ten most visited sites by 12-17 year olds.

Background The KOB-TV4 CRADA is a cornerstone of the AFRL Technology Transfer for Education (TTE) program for students in grades K-12. Since its inception, the AFRL TTE Office has been responsible for 190 Education Partnership Agreements with public and private education institutions. Over 60,000 students from more than 200 schools in New Mexico have benefited from the AFRL TTE program to date.

The AFRL TTE program has received the following awards and acknowledgements: Team Kirtland Award for the Air Force Materiel Command Director's Excellence Award for Community Relations; FLC Award for Excellence in Technology Transfer; Commendation from the entire New Mexico Congressional Delegation; legislative memorial of appreciation for education outreach in New Mexico; General Ronald Yates Team Award for Excellence in Technology Transfer; Phillips Laboratory Mission Support Team Award; and over 2,500 letters of appreciation from students, teachers, parents, principals, and legislators. The Air Force and Department of Defense view this program as a national model of technology transfer for education.

MEMS Technology Design Evaluation Test Bed

Payoff An Information Directorate-developed microelectromechanical systems (MEMS) test bed technology is enabling the development of a new generation of low-power, rugged smart sensors and actuators that integrate mechanical, optical, fluidic, and electronic devices on a single chip. This unique new MEMS test bed is capable of rapid, accurate characterization of MEMS prototypes and products.

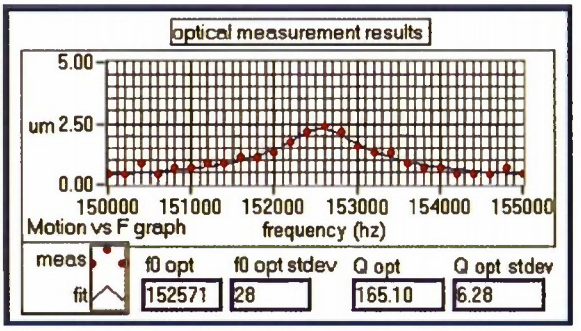


Accomplishment Interscience, Inc. of Troy, New York, developed the MEMSPEC™ product by incorporating a directorate-developed software that contains a patented blur synthesis matching image-processing technique. This instrument can measure both horizontal and vertical displacements with nanometer resolutions in a vacuum or controlled atmospheric environment. The directorate's method enables characterization of MEMS motions at significantly higher frequencies than prior art.

Background This MEMS technology evolved from MEMS program work co-sponsored by the directorate and the Defense Advanced Research Projects Agency/Microsystems Technology Office. The directorate was the agent for this program and contributed in-house work focused on the design, evaluation, and improvement of MEMS resonators.

Interscience developed the MEMSPEC instrument as the first commercial MEMS tester. Previously, this instrument was capable of only coarse (1 μm), slow (150 kHz) horizontal measurement capability, and prior methods used in other instruments were constrained to measuring the motions of MEMS below about 200 kHz.

Use of the new AFRL-developed measurement method removes that frequency limit. Directorate researchers expect the availability of the new instrument to speed the refinement of future generations of high-frequency MEMS systems.



Space Shuttle Releases Two Pico Satellites

Payoff Scientists and engineers at the Information Directorate, using funding from the Defense Advanced Research Projects Agency of Arlington, Virginia, developed the microelectromechanical systems (MEMS)-based pico satellite (PICOSAT) inspector (MEPSI) experiment. MEPSI is a significant step forward in the development of an onboard autonomous inspection capability.

The miniature self-inspection system provides decision makers with a rapid feedback capability for detection and response to spacecraft anomalies for maintaining ultimate satellite longevity. Directorate engineers can develop the miniature self-inspection system for a particular space system or for carrying aboard virtually any host vehicle.

Accomplishment In December 2002, the Space Shuttle Endeavor, enroute from the International Space Station, successfully released two PICOSATs from a specialized spring-loaded launcher assembly mounted on the sidewall of the space shuttle. They weighed slightly less than 2 lbs each.

The PICOSAT is the smallest functional satellite in the world and the smallest satellite payload ever carried on the space shuttle. PICOSATs will eventually orbit near a spacecraft to monitor for maintenance and failure detection or perhaps to serve as a protection against natural or man-made threats to the spacecraft.

These small satellites will independently monitor the status of the spacecraft and communicate that data directly to earth. The shuttle deployment was the latest in a series of experiments that will lead to demonstrating these taskable miniaturized autonomous spacecraft companions.

Background Objectives of the mission include demonstration of a launcher assembly approved for use in the shuttle cargo bay, establishment of communications and data exchange between the two PICOSATs and the ground station, exercise of onboard MEMS inertial measurement system, and improved transmitting power. Directorate researchers envision MEPSI to enhance satellite command and control operations by providing active, onboard imaging capability to assess spacecraft damage, monitor launch and deployment sequences, and augment servicing operations.

SoRDS: A Platform for Voice/Video/ Network Radio

Payoff The demand for smarter communications led to software reconfigurable radios, and the need for more robust data led to new compression algorithms. Sending more data over the same communication link requires a more integrated communication system with data throughput, link parameters, and communications parameters, all tied together and controlled as a unified system.

The Information Directorate created the Software Radio Development System (SoRDS) to support test and evaluation of communications techniques dealing with voice, video, and networking applications. SoRDS' modular architecture consists of a signal processing system, adaptive computing system, and radio frequency (RF) transmit/receive system.

Accomplishment The directorate's Information Grid Connectivity Branch teamed with PAR-Rome Research Corporation to design, develop, and implement a wireless test bed, incorporating reprogrammable software and reconfigurable hardware. SoRDS, recently used to establish a wireless video link, allows evaluation and comparison of various video compression techniques and algorithms.

SoRDS is a portable platform that enables rapid development and demonstration of wireless communication applications. The full SoRDS package includes the Beowulf cluster computer system (a multiprocessor, high-performance computer where each processor is connected by high-speed Ethernet), plus a network switch module, an input/output (I/O) chassis (including data and audio I/O and the RF module), and a host computer providing a graphical user interface and system control.

Background The future of US military communications is the software-based Joint Tactical Radio System (JTRS). The SoRDS test bed provides a means to design, develop, and test communication techniques in a flexible, state-of-the-art laboratory test bed before insertion into the JTRS.

SoRDS offers waveform designers the ability to develop techniques that may be too advanced or in need of advanced components that are not available in present JTRS-capable systems. Waveforms in the queue for implementation on SoRDS include high-data rate waveforms, wideband waveforms, low probability of intercept/low probability of detection/antijam waveforms, and other advanced communication techniques.

Information Directorate's WebTAS Technology Aids in Shuttle Probe

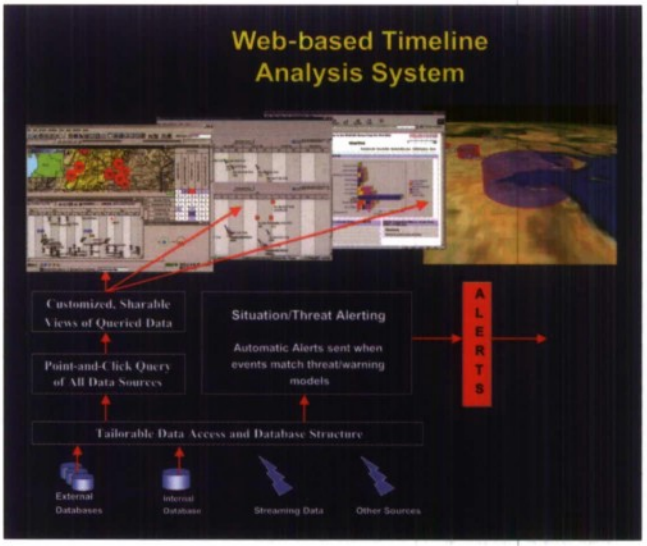
Payoff The Information Directorate-developed, Web-based Timeline Analysis System (WebTAS) allows users to rapidly connect to diverse data sources and combines the data in multiple analytical/visualization tools, with the goal of providing alerts/warnings of developing situations. For example, the WebTAS query tool allows users to build ad-hoc queries with a simple point-and-click interface. WebTAS can display the results in tables, timelines, maps, graphs, histogrids, and Web browsers.

Accomplishment The Air Force Space Command's (AFSPC's) Space Analysis Division Team, part of the Department of Defense (DoD) Columbia Investigation Support Team, needed to pinpoint exactly when the ill-fated Space Shuttle Columbia began to break apart on its return to earth 1 February 2003. The team is using WebTAS to correlate, validate, and visualize multiple databases of DoD sensors and related information from a wide variety of data from different orbital analysis tools to visualize the dynamic nature of Orbiter events across the mission timeline.

AFSPC's Space Analysis Division officials indicated the Columbia project might be the first of several useful applications for WebTAS within the center. The directorate installed WebTAS at the AFSPC Space Analysis Division's Colorado Springs, Colorado facility. AFRL Commander, Major General Paul D. Nielsen, offered WebTAS to members of the Air Force investigative board assisting the National Aeronautics and Space Administration in the Columbia investigation.

Background WebTAS, a set of analytical tools, allows users to site configure, connect to, and query across multiple databases and other data sources. WebTAS combines data queried across multiple sources in Map, Timeline, Graph, and other displays for analysis.

WebTAS can also set up criteria to aggregate activities over time and space and automatically generate e-mail alerts of unfolding situations. WebTAS is operational at several sites in support of the Global War On Terrorism, Operation IRAQI FREEDOM, Homeland Security/Defense, Air Operations Planning, Special Operations/Special Forces, and other mission areas.



Autonomous Negotiating Team's Software a Transition Success

Payoff The Autonomous Negotiating Team's (ANTs) software improves warfighter capabilities in the areas of flight and maintenance scheduling. ANTs intelligent software agents have internal problem-solving abilities for the scheduling components, which allow them to continuously collect specific information and determine when to obtain new information to remain current in support of decision makers.

Agent technology has the potential to assist users with informational changes and uncertainty associated with strategy and tactics for battlefield command and control as well as peacetime crisis management situations. Negotiation techniques allow the agents to coordinate between the operations and maintenance systems for optimized solutions.

Accomplishment The Information Directorate's Information Awareness and Understanding Branch, the lead technical agent for the Defense Advanced Research Projects Agency (DARPA) ANTs program, recently conducted the final demonstration of the ANTs software. The ANTs scheduling tools were successfully wed during Operation IRAQI FREEDOM.

Background The objective of the ANTs program is to provide technology that enables the development of information systems that autonomously negotiate the allocation of resources to tasks in real-time, distributed systems. The scheduling tools are currently in use at Marine Air Group 13 for four squadrons of Harrier jets. The Marine Corps plans to use ANTs for the entire Marine Corps pending Marine Air Board approval.

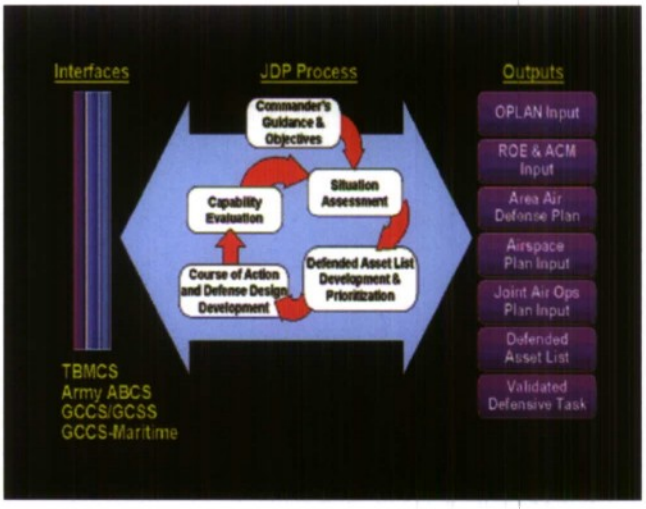
The directorate signed a Technology Transfer Agreement to provide the ANTs scheduling software to the Joint Strike Fighter program through the prime contractor, Lockheed Martin. The Navy is funding the ANTs contractors through the Future Naval Capabilities program to expand the tools available to additional aircraft types.

AFRL's Integrated Flight Management Advanced Technology Demonstration (ATD) is currently using ANTs scheduling algorithms on Air Mobility Command scheduling problems. The directorate is also integrating the ANTs technology with the Human Effectiveness Directorate's Logistics Control and Information Support ATD, where an initial prototype will solve C-130 maintenance scheduling problems at Air Force Special Operations Command. DARPA and AFRL are continuing to pursue numerous transition avenues for the ANTs scheduling tools.

Joint Defensive Planner Transitioned

Payoff The Joint Defensive Planner (JDP) is the first automated tool that supports operational users during the defensive planning process and provides the necessary analysis tools to compare various defensive designs. The results are better, faster campaign planning inside the enemy's decision-making process and an increased pace of command and control for a higher operations tempo. JDP is a Theater Battle Management Core System mission application as well as a Global Command and Control System segment that supports planning for joint service and coalition forces' active defense against aircraft (manned and unmanned), cruise missiles, and ballistic missiles in a theater of operations.

Accomplishment The Information Directorate manages the JDP program that assists those individuals responsible for planning, evaluating, and implementing theater air and missile defense (TAMD). JDP is capable of supporting in-garrison, long-term deliberate planning, short-term contingency planning, in-theater plan refinement, and continuous plan repair. JDP provides service interoperability through collaboration with an Army planning system Air and Missile Defense Workstation (AMDWS) and other external systems through the use of Enterprise Java Beans™ (EJB).



Through this technology, JDP exposes the objects necessary for remote access by all external systems such as AMDWS. EJB allows the JDP object to be deployed anywhere within the network, reused within other applications running on disparate platforms, and managed from a remote console. EJB hides the complexities of making the JDP objects persistent, finding them over the network, securing them, isolating them from sharing conflicts, protecting them from failures, managing their lifecycle, and ensuring their scalability and availability.

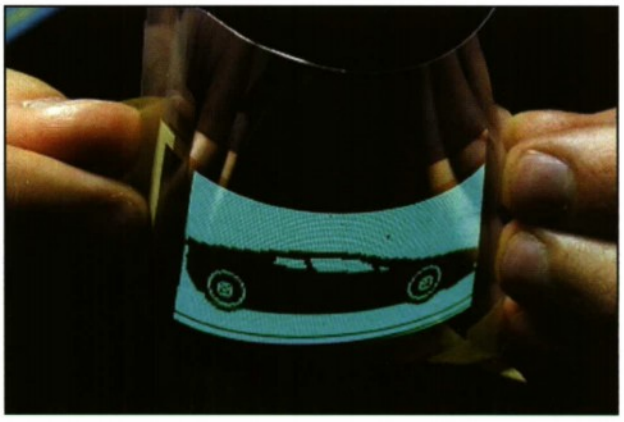
Background The Missile Defense Agency and the Air Force jointly funded the JDP research and development program. The objective was to develop a single, joint area air and missile defense plan to support the Combatant Commander, Joint Force Air Component Commander, and Area Air Defense Commander's battlestaffs across all phases of a campaign. JDP assists the planners on these staffs in utilizing limited defensive resources tasked to counter projected enemy courses of action against rank-ordered strategic and operational assets.

JDP, through the use of the Alternative Options Generator, is able to automatically develop up to four different defense designs for consideration by the TAMD planner. The real-world situation is transformed into a mathematical framework of selected sets. The first set consists of the elements to be covered (defended assets); the second set consists of the pairings of threats to defended assets (enemy courses of action); and the third set consists of defense options of an active defense system together with the threat incidences it can counter through defensive tasks. The JDP distributed architecture permits it to make defense designs available to external high-fidelity simulation systems for detailed analysis that can then be used to update the defense design.

Human Effectiveness Directorate Transfers Revolutionary Display Technology to Industry

Payoff The Human Effectiveness Directorate created key technology for a breakthrough electronic display and transferred it to an industrial consortium led by the Universal Display Corporation (UDC) in Ewing, New Jersey.

Accomplishment Organic light-emitting devices (OLEDs) are a new class of displays with properties that make them highly attractive for a broad array of military and commercial uses. OLEDs are thin, flat, and lightweight; emit bright light with little power; are readable at very wide viewing angles; and are flexible and transparent.



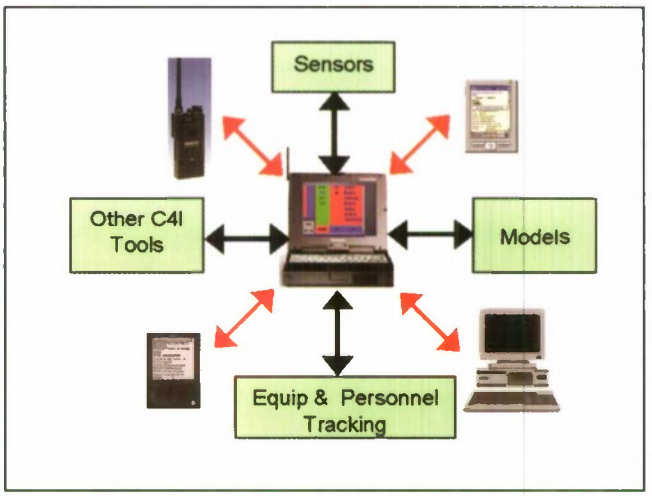
The directorate-managed, Defense Advanced Research Projects Agency (DARPA)-funded High-Definition System (HDS) program helped create materials, devices, and fabrication processes essential to OLED production. UDC will produce prototypes for evaluation in military avionics by L3 Communications in Marietta, Georgia, and will establish economic viability via partnerships with several companies pursuing consumer electronic applications.

Background Princeton University, the University of Southern California, Hughes Research Laboratory, and UDC performed the project, which was possible through a grant as part of the HDS program. DARPA provided $5.5M to fund the HDS program, which focused on creating a variety of affordable display technologies capable of displaying digital high-definition television.

FASAT Technologies Support Homeland Defense

Payoff The Human Effectiveness Directorate-sponsored Fast Access Situational Awareness Toolkit (FASAT) allows organizations to monitor, track, and communicate information that directly affects operations by providing the means to deliver the right data to the right people at the right time, anywhere, and on any device. Thus, distributed team members can make decisions more quickly, more intilligently, and more efficiently. FASAT technologies support homeland defense capabilities by enhancing the probabilities of saving lives, time, and money.

Accomplishment FASAT is a Web-based enterprise solution for monitoring, managing, and mitigating incidents through a unique two-way alert notification, response, and graphical tracking capability. The capstone of FASAT technologies is a new commercialized product called IncidentPortal. IncidentPortal meets the requirements of the Pentagon's security system and is a candidate for deployment in fiscal year 2004.



Background Directorate researchers worked with *mobile*FOUNDATIONS engineers to develop the FASAT technologies through directorate-sponsored Small Business Innovation Research Phase I and Phase II contract awards. FASAT's software development combines state-of-the-art advanced automation, situational awareness tools, collaboration tools, and wireless technologies into a seamless environment for distributed operations to occur in a manner that maintains user situation awareness.

The creativeness and quality of FASAT technologies came to the attention of the Pentagon's Security Office while attending a demonstration where *mobile*FOUNDATIONS' engineers used IncidentPortal for nationwide counterterrorism activity. The directorate subsequently invited Mr. Jeff Fox, *mobile*FOUNDATIONS' Chief Executive Officer, to demonstrate FASAT's IncidentPortal at the Pentagon's annual Chemical, Biological, Radiological, and Nuclear (CBRN) Response Drill. The success of FASAT technologies during the 2002 Pentagon CBRN Response Drill resulted in IncidentPortal's consideration for deployment into the Pentagon's security system.

CART Transitions Advanced Human Modeling Architecture

Payoff The Human Effectiveness Directorate created the Combat Automation Requirements Test bed (CART) to assess the effects of alternative crew system interfaces using modeling and simulation (M&S). Now Air Force and Department of Defense (DoD) analysts, engineers, and researchers can rapidly and inexpensively create and tailor interoperable operator models for specific project simulation objectives.

Accomplishment The CART Team successfully developed and demonstrated a state-of-the-art modeling architecture capable of realistically representing warfighter decision making, performance, and tactics. The directorate recently transitioned this modeling architecture and graphical user interfaces, developed under the CART program, to over 60 model developers across all of DoD, industry, and academia in the form of Improved Performance Research Integration Tool (IMPRINT) version 6.40c. This technology transition culminates more than 4 years of research, development, and demonstration using real-world Air Force missions.

Background M&S tools used today in the military typically contain limited crew behaviors that are insensitive to emerging missions, breakthrough technologies, or new crew system interface concepts. The results are studies and analyses that could provide erroneous conclusions regarding a system's effectiveness and survivability.

The CART software represents the next logical step in operator modeling tools. The directorate's team leveraged IMPRINT—a manpower and personnel analysis tool developed by the Army Research Lab—and enhanced the underlying architecture to include goal orientation and distributed simulation protocols. Goal orientation provided a better representation of how crews shift their task loads across different goal states—from attacking targets to avoiding threats.

The team added an interface to the DoD-mandated, high-level architecture to connect realistic operator models by using CART software and wargame simulations that drive modeled crew behavior. This capability can save Air Force program offices, operational researchers, and studies and analysis shops valuable time and money in conducting their simulations, while greatly improving the credibility and realism of their results.

The CART Team assessed the efficacy of this technology on two different occasions by using highly complex crew models. The first test compared actual pilots to pilot models when attacking mobile time-critical targets.

The second test verified that nine crewmembers worked together as a team within an air operations center to find, track, and destroy time-sensitive targets. These critical experiments verified the feasibility of the architecture's capability to emulate warfighter behavior, which led the way to software transition. Next, the CART Team will be applying this technology to major command-sponsored simulations to help reduce the cost, time, and effort of integrating Air Force operator representations in geographically dispersed exercises.

Microlasers Illuminate Phase II SBIR

Payoff A recently developed color helmet-mounted display (HMD) produces images bright enough for aircrew members to see them clearly during daytime flight. The ability to present color symbology on HMDs enhances information transmission to pilots.

The microlaser HMD will mitigate risk in the Multi-Spectral Helmet-Mounted Display 6.3 program if its color, active-matrix, organic light-emitting diode display is unavailable or cannot meet daytime luminance requirements. Further, the microlaser system can illuminate other, non-HMD cockpit liquid crystal displays (LCDs).

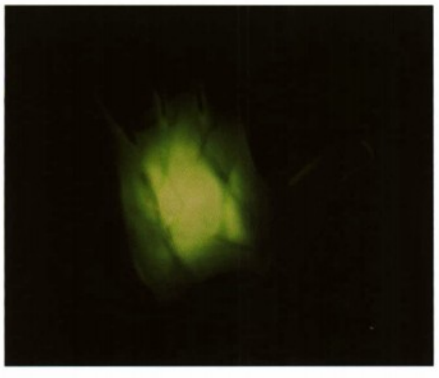
Accomplishment A Small Business Innovation Research (SBIR) collaboration between the Human Effectiveness Directorate's Visual Display Systems Branch and several contractors, developed a breadboard LCD HMD lit by a compact microlaser system. This color HMD is the first in the world that produces images bright enough for pilots to see clearly during daytime flight and provides a new option for programs like the Joint Strike Fighter, which currently calls for replacing the heads-up display with an HMD.

Background The microlaser HMD is rooted in the technological expertise of scientists and engineers (S&Es) within the directorate's Visual Display Systems Branch. During the Phase I SBIR, the S&Es and contractors demonstrated the feasibility and advantages of using solid-state microlasers to illuminate LCD-based HMDs. During Phase II, the team produced and integrated the microlaser system, fiber-optic input and output assemblies, compatible HMD optics, and an LCD, and then tested the system.

Life-Saving Vein-Viewing Technology Delivered to Medical Community

Payoff Manufacturing the vein viewer device will provide both the Air Force and the medical community with a solution to the need for a reliable, accurate, and inexpensive point-of-care device for viewing a patient's veins rapidly and accurately, in conditions where the lighting is less than optimal. On the battlefield, in hospitals, and at the scene of accidents, prompt intravenous (IV) administration has the potential of saving countless lives.

During the course of this project, Materials and Manufacturing Directorate scientists and engineers developed contacts and working relationships with researchers in the medical imaging community, the venture capital community, and the inventor/ entrepreneurial communities in Ohio. These contacts help the directorate learn of new inventions and solutions, for transfer to the Air Force community, to solve expensive or difficult problems at minimum cost or disruption to traditional business practices.



Accomplishment Directorate scientists invented, developed, patented, and licensed a vein viewing device that can see beneath the skin and through body sections to show the vasculature (the network of blood veins in the body) in a broad range of lighting conditions. The device dramatically shortens the time between occurrence of a wound and the IV administration of life-sustaining fluids—a factor that could save the lives of severely wounded soldiers as well as auto accident victims and trauma victims.

Due to the technology's potential for a broad range of civilian medical uses, the directorate established a Cooperative Research and Development Agreement with InfraRed Imaging Systems, Inc. of Columbus, Ohio. They will manufacture and market the technology to the medical industry and expand the technology to solve other critical medical challenges.

Background The vein viewer device, which uses night vision goggles (NVGs) equipped with special filters developed by the Air Force, sees infrared light as it passes through a patient's body. Directorate scientists used a television remote control infrared light source and standard military NVGs to clearly detect the partial absorption of infrared light by blood in veins.

This device provides users with a clear view of the network of veins in fingers, hands, lower arms, and feet. Research showed that the capability to view veins is due to the absorption of infrared light by deoxygenated hemoglobin traveling in veins, while bone, muscle, and other tissue transmit or scatter the infrared light rather than absorbing it. Additional experiments proved that a needle beneath the skin would also be visible because metal blocks infrared light.

Directorate scientists demonstrated a prototype device at Wright-Patterson Medical Center, Cincinnati Children's Hospital Medical Center, and Columbus Children's Hospital, all in Ohio. Physicians involved in the demonstrations suggested the technology could be used effectively to alleviate a great deal of suffering by patients including infants, the elderly, and patients who must undergo painful medical procedures requiring repeated access to veins such as chemotherapy or dialysis.

High-Resolution Digital Flat Panel X-ray Detector and Software Transitioned to OC-ALC

Payoff The transition of the high-resolution digital flat panel detector system provides Oklahoma City Air Logistics Center (OC-ALC) personnel with improved nondestructive inspection (NDI) tools for evaluating complex aircraft engine components. Digital radiography (DR) technology offers higher resolution detection capability that users can enhance with software imaging tools to improve an inspector's ability to find anomalies in the captured image. Technicians will use these images to precisely locate and diagnose the defect before initiating the repair process.

DR technology increases the probability of defect detection due to its enhanced resolution and sensitivity over the previous intensifier detector system. Digital X-ray flat panel detector systems can achieve this higher resolution because image intensifier systems have significant blurring due to X-ray scattering, whereas digital flat panel detector systems significantly reduce this X-ray scatter due to the detector elements' compact design.

Accomplishment Researchers from the Materials and Manufacturing Directorate transitioned a new high-resolution digital flat panel X-ray detector system and its respective image processing software to the OC-ALC Engine Tank and Cooler Inspection Facility for real-time radiographic inspections of TF33, F100, and F110 engine oil tanks and coolers used on C-141, B-52, F-15, and F-16 aircraft. This system provides image archiving capability, enhanced performance, improved productivity and, best of all, higher resolution and sensitivity over the previous image intensifier detector system.

Background Inspectors use X-ray radiography inspection extensively throughout the life cycle of the aircraft. Aircraft manufacturers use this type of NDI during component manufacturing and during aircraft structural assembly to evaluate the integrity of welded joints for porosity and voids.

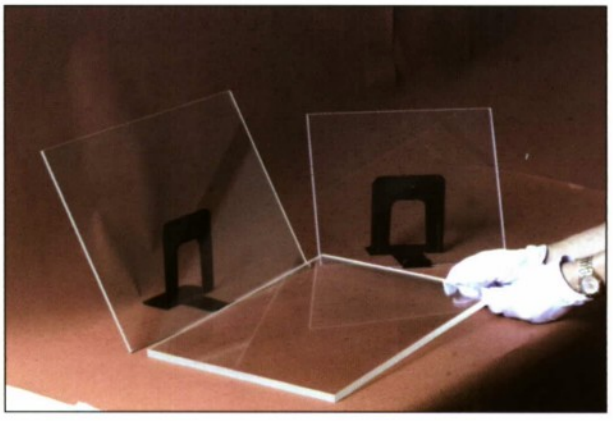
Depot workers use X-ray inspection during the maintenance of aging aircraft to inspect internal structures and honeycomb material for core damage, internal moisture, corrosion, and to evaluate internal geometries in turbine engine components for cracking and weld anomalies. NDI inspections are useful because they eliminate the need for unnecessary maintenance and aircraft disassembly, which are time-intensive and can potentially create additional damage and problems in aging Air Force systems.

The directorate's Nondestructive Evaluation Branch recently contracted with Marietta X-Ray, Inc. (MXRI) to evaluate and assess the performance of various commercial off-the-shelf hardware and software systems from several X-ray detector platforms using aircraft components. MXRI of Marietta, Georgia, chose the General Electric DXR-250RT flat panel detector system and the General Electric Radworks 5.1 imaging software to best meet the inspection requirements of the Engine Tank and Cooler Facility at OC-ALC.

The system's transition marks the completion of the first phase of the Digital Radiography Insertion Program (DRIP) that focuses on specific Air Force depot applications for DR to improve overall depot NDI production capabilities and productivity. The Aeronautical Systems Center's Aeronautical Enterprise Program Office and OC-ALC's NDI production unit manage the DRIP program.

ALON™ Material Successfully Scaled up for Military and Commercial Applications

Payoff Polycrystalline aluminum oxynitride, known commercially as ALON, offers performance and scaling not otherwise possible for large, lightweight, infrared (IR) transparencies. This new technology could play a significant role in the development of affordable, transparent armor including windows for military aircraft, where trimming life-cycle costs could save millions while providing greater protection for flight crews.



Other primary military applications include forward-looking infrared windows, missile domes, underwater sensors, and personnel protection. Promising commercial applications include supermarket scanner windows, semiconductor equipment components, vehicle transparent armor, various types of lighting, and scratchproof lenses.

Accomplishment Engineers at the Materials and Manufacturing Directorate, working with Raytheon Electronic Systems, completed an advanced development effort to evaluate forming techniques and optimize fabrication processes for a tough, lightweight, transparent ceramic material that offers outstanding potential for both military systems and commercial products. ALON addresses a wide range of technological interests throughout the Department of Defense and other federal agencies as well as private industry.

As part of the advanced development effort, the engineers fabricated several 14 in. x 20 in. ALON plates for flight testing, ballistics testing, and transparent armor applications. Their efforts demonstrate that ALON has excellent mechanical and optical properties and provides a number of advantages when compared to conventional transparent armor including dramatic life-cycle cost savings.

Background ALON, a polycrystalline ceramic material comprised primarily of aluminum oxynitride, is a very durable optical material with a high degree of transparency from the ultraviolet through the mid-IR wavelengths. ALON is equivalent to sapphire in terms of optical quality, low density, high strength, and high durability, but it is also an isotrophic ceramic, making it scalable by conventional powder-processing methods.

ALON has a number of significant advantages, as previously mentioned, over conventional materials currently used to make windows for reconnaissance aircraft, missile domes, protection shields and lenses, and other products that support the warfighter. A potential market for its use already exists in supermarket scanner windows, which are manufactured in quantities of tens of thousands of units per year. Field testing is under way for this technology transfer.

ALON demonstrated outstanding ballistic impact resistance for safeguarding motor vehicle occupants. As a result of these findings, engineers are evaluating ALON for possible insertion into ground-based transparent armor. Raytheon Electronic Systems at Lexington Laboratories, Lexington, Massachusetts, owns the patent. However, Surmet Corporation of Burlington, Massachusetts, recently acquired ALON from Raytheon and is manufacturing the ceramic for commercial and military applications.

ManTech's AMU Program Drives Down Costs, Weight, and Size in Vital Defense Satellite Program

Payoff The Affordable Millimeter Wave Units (AMU) program has shown a 90% reduction in hardware, a 65% reduction in parts cost, a 50% reduction in board size and weight, and a module yield of greater than 95% in 19 GHz boards with 37 modules and 64 connectors. The production improvements provided through the AMU program will produce significant cost avoidances for critical Air Force satellite programs. It will make the difference in availability of specific systems and military capabilities to the warfighter.

Accomplishment The Manufacturing Technology (ManTech) Division of the Materials and Manufacturing Directorate, under a cost-sharing contract with Northrop Grumman, applied new forms of automated packaging radio frequency (RF) modules and millimeter wave units that drive down the cost, while also decreasing the size and weight of each unit. The AMU program now allows a rapid and highly repeatable automated assembly of module and board-level AMUs, with minimal labor and no hand tuning.

Background Microwave and millimeter wave units for defense satellites are extremely expensive—sometimes totaling more than 20% of the cost of a satellite. Typical applications use these units in high quantities, although they are very expensive individually—as much as $50,000 per pound.

Defense satellite systems scheduled over the next few years will include more microwave hardware than ever before. Phased arrays will use thousands of microwave modules per satellite, and some satellite constellations will consist of as many as 20-30 satellites. Without less expensive microwave hardware, some of these key Air Force mission systems are unaffordable.

AMU's objectives were to sharply reduce the assembly and test costs of satellite microwave units by as much as 60% as well as reduce the size and weight of each unit by at least 10%. Early results indicate that this technology will typically meet and surpass all objectives. Under the new automated process, AMU's modules and units require no hand tuning due to precise assembly procedures and an optimum RF design. The new AMUs also include more printed components that further reduce cost.

The AMU program successfully demonstrated hardware designed specifically for three major defense satellite system programs. For near-term space systems, such as the Transformational Satellite, the Space-Based Infrared System Low, and the Advanced Extremely High Frequency (AEHF) systems, researchers estimate AMU technologies will save 50-80% of the cost of tens of thousands of modules, which previously would have cost several thousand dollars apiece. For example, the AEHF is now in development, and it has adopted and inserted AMU technologies in more than 100 RF board assemblies and nearly 10,000 RF modules.

Composite Patch Vacuum-Mold Repair System Transferred to Commercial Industry

Payoff Vacuum-mold repair system (VMRS) technology dramatically reduces the time required to undertake multiple contour, metal aircraft structure repairs at field locations. The process uses a quick, reusable mold for transferring the contour of an equivalent undamaged metal structure and laying-up of a graphite-epoxy composite patch.

The new system also incorporates an integral heating device and other equipment that, when packaged together, provide a complete composite repair kit. VMRS can replicate the contour of a damaged aircraft part in less than 10 minutes versus several hours required by current splash molds, which are not reusable. As a result, technicians are able to complete their repairs and return the aircraft to flying status much faster.

Accomplishment The VMRS, a revolutionary composite patch repair system developed by the Air Vehicles Directorate (formerly the Flight Dynamics Laboratory) and built by Lockheed Martin Corporation, reduces the amount of time required to complete metal aircraft structure repairs at field locations. The Materials and Manufacturing Directorate's Materials Integrity Branch refined the VMRS technology, demonstrating promising results during extensive testing before transferring the technology to commercial industry. Airtech Advanced Materials Group obtained a license to produce and sell this new technology, which they have entitled the Impression Master®.

Background Prior to the development of vacuum-mold repair, the most effective way to repair metal aircraft structures depleted from excessive wear and fatigue or damaged in combat was to fly the aircraft to a maintenance depot or complete the repairs at a field location using conventional splash-mold techniques. Splash-mold techniques, using plastic or ceramic curing compounds, are effective in repairing multiple contour structures; however, they are also costly and time-consuming, since they require one-time use molds.

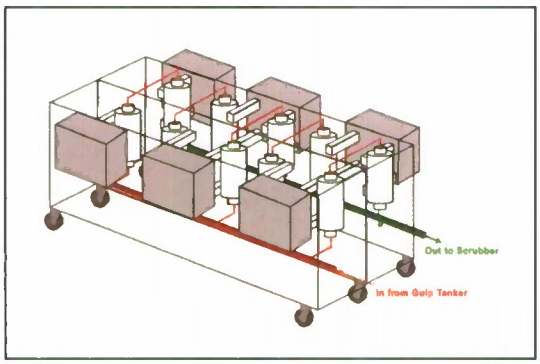
Splash-mold techniques require large quantities of repair materials to complete several repairs. They also necessitate an unacceptably long downtime of an equivalent undamaged aircraft while the mold is curing.

Another disadvantage of splash-mold techniques is that the composite material handling and processing methods employed require cold storage of materials using "clean room" equipment that is bulky, heavy, expensive, and requires extensive training and experience. Transport of aircraft to maintenance depots for metal aircraft structure repair is very expensive and often creates logistics problems, since maintenance workers work the repairs in around periodic maintenance already scheduled or in progress.

VMRS employs a mechanically hardened tooling technique that uses a sealed rubber bag containing lightweight granular filler. Once positioned over the damage location of an equivalent aircraft, the maintenance technician draws a vacuum within the bag, which causes the rubber skin to constrict on the filler, locking it in a firm arrangement and replicating the surface geometry of the damage location.

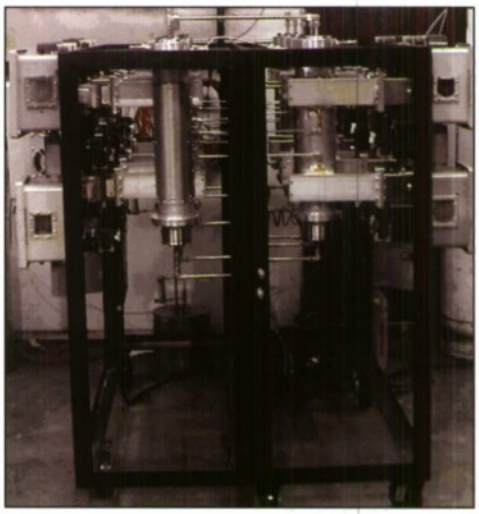
Microwave Reactor Technology Demonstrates Success at Eliminating Hazardous Materials from Spacecraft

Payoff Full-scale laboratory testing of prototype versions of the microwave reactor revealed that the technology was greater than 99% efficient in the destruction of waste oxidizers and fuels. Testing also demonstrated that the reactor system does not generate any of the additional hazardous waste by-products associated with current treatment systems and methods. Successful implementation of the microwave reactor destruction system is expected to eliminate one of the largest waste streams at Cape Canaveral Air Force Station, Florida; Kennedy Space Center complex, Florida; and Vandenberg Air Force Base, California.



Accomplishment A team of scientists and engineers, including experts from the Materials and Manufacturing Directorate, developed a prototype technology capable of reducing or eliminating hazardous waste generated during the treatment of oxidizers and fuels used during operation of Air Force and National Aeronautics and Space Administration launch vehicles. During the collaboration between AFRL's Pollution Prevention Research and Development Team, Air Force Materiel Command's Pollution Prevention Integrated Product Team, Science Applications International Corporation (SAIC), and CHA Corporation, the team developed, tested, and validated the highly effective microwave reactor's capability to eliminate waste.

Background AFRL conducted a research and development requirements survey for Air Force Space Command (AFSPC) to identify processes where hazardous materials could be reduced or eliminated. AFSPC identified eliminating hazardous waste by-products generated by spacecraft as a top priority.



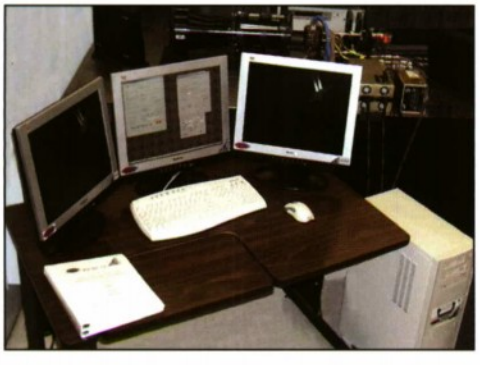
The current treatment, a dual extraction method that uses a vacuum sweep, air stripping, and catalytic oxidation, is used for hazardous waste site remediation. Catalytic oxidation requires a significant amount of supplemental fuel, and it also produces secondary air pollutants including nitrogen oxides and dioxins. Using this treatment, hydrazine fuels and an oxidizer (dinitrogen tetroxide) used in spacecraft and launch vehicles still generate more than 300,000 lbs of hazardous waste by-product annually.

Under a contract between the directorate and SAIC, CHA Corporation was subcontracted to demonstrate and validate a technology to treat the oxidizer and fuels while significantly reducing or eliminating the hazardous waste by-product. CHA Corporation used microwave energy to treat and destroy the waste oxidizer and fuels without producing any hazardous waste by-products. AFSPC began efforts to design, develop, and test a production-scale microwave reactor unit.

KHILS Facility Transitions Infrared Scene Projection Systems

Payoff The ability to evaluate the performance of infrared-guided munition seekers with dynamic imagery at multiple Department of Defense facilities will greatly enhance the development of future munitions while reducing the cost of test and evaluation.

Accomplishment The Munitions Directorate is transferring a new generation of infrared scene projector systems to a number of government facilities. These devices are key components necessary to provide accurate dynamic imagery for missile seeker, hardware-in-the-loop testing. These systems enable greatly improved operation of both the Honeywell and Santa Barbara Infrared, Inc. emitter arrays under development at the directorate's Kinetic Kill Vehicle Hardware-in-the-Loop Simulator (KHILS) Facility for the last decade.



Background KHILS teamed with seven agencies on the project to fund the development, design, and fabrication of the custom electronics called the personal computer-based array control electronics (PACE). The team included the Missile Defense Agency's Ground-based Midcourse Defense Team, the Air Force's Electronic Warfare Evaluation Simulator Facility and Guided Weapons Evaluation Facility, the Sensors Directorate's Dynamic Infrared Missile Evaluator Facility, the Naval Air Warfare Center's Aircraft Division, the Defense Investigative Agency's Missile and Space Intelligence Center, and the US Army's Space and Missile Defense Command upgrade at Arnold Engineering Development Center's Decade Facility.

Over 20 projection systems are in varying stages of fabrication. Many of these systems include both emitter arrays from residual directorate contracts with Honeywell and the new PACE electronic drive systems. Besides transition to government facilities, the directorate recently transferred PACE systems to industry in support of contracts developing next-generation emitter arrays.

YBCO-Coated Conductor Gets Go-Ahead for Full Development

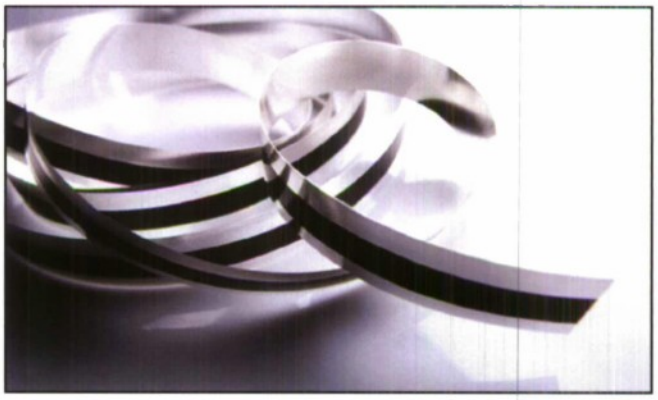
Payoff A novel flat wire conductor, prepared by coating a metal substrate with yttrium barium copper oxide (YBCO), produces a significantly higher current-carrying capacity over conventional copper wire. It is the next-generation, high-temperature superconducting wire necessary for the development of Air Force directed energy weapons and the Navy's Electric Warships & Combat Vehicles programs. System components benefiting from the conductor include power generators, high-frequency source magnets, transformers, and motors.

Liquid cryogens are not used to cool the superconductors because highly reliable commercial refrigerators are available to provide the necessary cooling. Specific commercial advantages include three to five times more power capacity than conventional power cables and elimination of cooling oil in transformers to reduce fire and environmental hazards. Superconducting motors and generators will be much more efficient and less expensive than their conventional counterparts.

Accomplishment Mr. Pete Aldridge, Under Secretary of Defense, recently gave final approval for full development of YBCO-coated conductors under Title III of the Defense Production Act. The Department of Energy Office of Power Technologies and the Department of Defense (DoD) Defense Production Act–Title III Office are currently setting aside $12 million in federal funds to combine with $12 million in industrial funding to ensure availability of YBCO-coated conductors in long-length sections.

The Title III approval sets in motion private sector production capabilities to support manufacturing of the YBCO-coated conductor. Propulsion Directorate scientists are actively involved in furthering development of YBCO-coated conductors.

Background The need for compact, lightweight, high-power generators and magnets is critical to new defense applications. DoD needed a superconductor that operates at higher temperatures to reduce the cooling requirement of conventional machines or cryogenic refrigerators for low-temperature superconductors, which are 10 to 100 times larger. The new high- temperature superconducting technology competes with both conventional and low-temperature superconducting rotating machines.



By simply substituting the YBCO-coated conductor technology for today's conventional copper/iron core technology or low-temperature superconductor technology, high-speed, high-temperature superconducting generators can produce megawatts of electrical power while weighing up to 80% less. These size and weight reductions enable high-power-dependent weapon systems on air or mobile platforms, opening the door to airborne applications such as directed energy weapons.

Tremendous benefits also exist for commercial applications. Establishing an industrial manufacturing capability for the YBCO-coated conductor will lead to commercialization in electric power applications such as transformers, transmission cables, motors, and generators.

Propulsion Directorate Makes Major Advances in Capacitor Technology

Payoff A Propulsion Directorate-led team recently produced the biggest improvement in decades in electrical and thermal properties of capacitor dielectrics. The Diamond-Like Carbon (DLC) Capacitor Team successfully optimized DLC plasma deposition parameters to produce capacitors with energy density and temperature capability three times the current state of the art. These improvements are crucial for airborne applications of directed energy weapons (DEW) because they offer considerable savings in system weight as well as superior performance.

Team members appearing from left to right in the photo are Mr. Kosai Hiroyuki, from K Systems; Mr. Jacob Diemer and Ms. Sandra Fries-Carr, both from the directorate's Power Division; Mr. Vic McNier, from the University of Dayton Research Institute; and Mr. Richard Wu, from K Systems.

Accomplishment In addition to tripling the energy density and temperature capabilities of current capacitors, the team recently demonstrated continuous and uniform deposition of DLC over a large area by manufacturing a 25 ft length of the DLC capacitor film. As a result, the Army and Navy committed funding to develop capacitor films for their own pulsed-power weapon applications.

Furthermore, an extensive collaborative effort exists with the Army and Navy to create an aggressive DLC Technology Transfer program with the goal of having a commercial product available by 2005. Scaling-up this technology will enable compact pulsed-power systems for pulsed high-power microwave applications. Both the aerospace and the DEW community identified this as a critical enabling technology.

Background Capacitors are a critical component in nearly every military and commercial high-performance system. Military and commercial aircraft manufacturers, power supply manufacturers, the medical industry, and power utilities use high-temperature, high-energy-density capacitors.

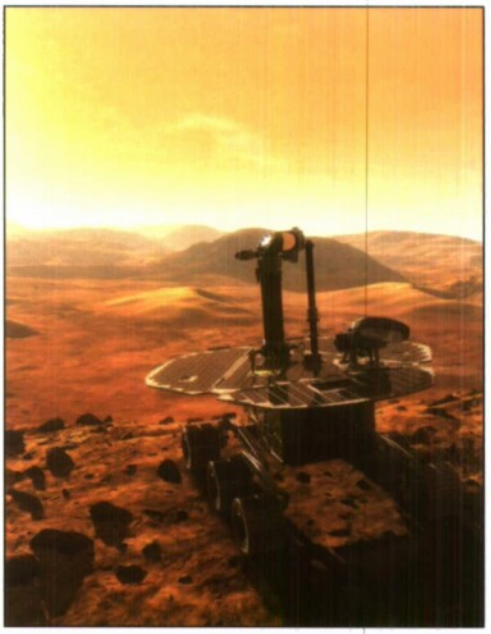
The objective of the Diamond Thin Film Capacitor Development program was to fabricate DLC film capacitors for high-temperature and high-voltage applications that were superior to state-of-the-art devices. DLC has unique properties such as high dielectric strength, very high resistivity, high-temperature stability, high thermal conductivity, exceptional mechanical strength, and chemical inertness. These properties make it attractive for use in advanced power management and distribution systems where engineers expect temperatures above 300°C (approximately 570°F).

Propulsion Directorate Develops Lithium-Ion Battery to Power Mars Rovers

Payoff Lithium ion technology offers a three- to four-fold increase in gravimetric (watt-hours/kg) and volumetric (watt-hours/liter) energy densities and produces voltages in excess of three times the value of typical nickel-based battery systems such as nickel cadmium and nickel hydrogen. These advantages make lithium ion an attractive choice for energy storage systems where weight, volume, power, and mission duration are critical issues.

Accomplishment The Propulsion Directorate will complete another milestone in its development and transition of high-energy-density, rechargeable lithium-ion (Li-Ion) batteries when the National Aeronautics and Space Administration's (NASA's) Mars Exploration Rovers "Spirit" and "Opportunity" power up their solar array power subsystem for the first time on the red planet in January 2004. The world will see their success when the rovers begin collecting geological science data as part of NASA's Mars Exploration Rover project.

The deployed solar array power subsystem onboard the rover is driven by two 8 Amp-Hr Li-Ion batteries. Directorate scientists and engineers developed the technology, while the Jet Propulsion Laboratory (JPL) and Lithion, a division of Yardney Technical Products, developed the batteries. These jointly developed batteries will keep the rover "alive" at night and provide additional power during intensive daytime operations.



Background Since its initiation, the Li-Ion program has attracted the attention and support of major aerospace firms and other Department of Defense components. The Air Force and NASA Glenn/JPL combined expertise and resources to address the many energy storage requirements facing future space missions.

The joint effort resulted in four contracts with major military battery developers, which address numerous mission applications. Battery developers will design, fabricate, and test cells and batteries for military and NASA low-earth-orbiting and geosynchronous satellites, advanced high-voltage aircraft applications, and unmanned air vehicles.

Revolution in National Radar Cross Section Measurement Standardization by Signature Technology Office

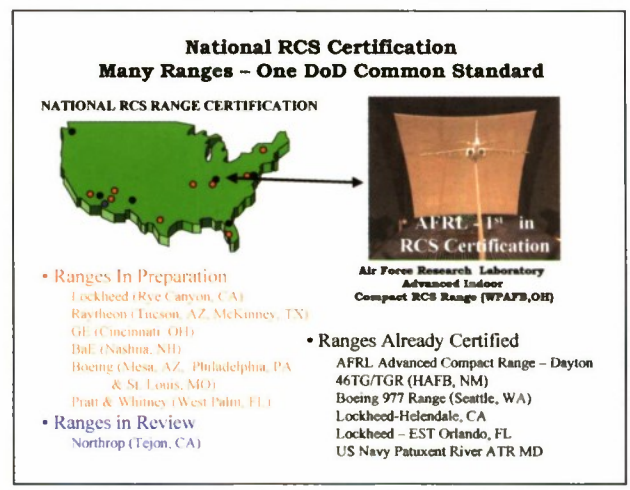
Payoff Working in collaboration with the Department of Defense (DoD) Range Commanders Council, the US Navy and Army, the National Institute of Standards and Technology, the National Aeronautics and Space Administration, and academia, the Sensors Directorate's Signature Technology Office developed and implemented the first national calibration and measurement standardization process for DoD and industrial radar cross section (RCS) measurement facilities.

Based on the commercial American National Standards Institute (ANSI)-Z540 standard and demonstrated initially on the directorate's Advanced Compact Range, 6 of the approximately 20 major RCS test and evaluation sites in the US adopted this standard. The remaining sites are working for compliance by 2004.

Accomplishment The directorate established baseline parameters for concrete and quantifiable calibration and measurement procedures for RCS facilities in the US, Canada, and the United Kingdom. This rigorous and methodical approach for establishing standard measurement processes helps commercial and DoD facilities deliver quantifiable and repeatable RCS data for a number of developmental weapon system programs, thereby reducing the risk and cost of inserting low-observable technology into common weapon systems.

Background Prior to the implementation of the ANSI-Z-540 standard, minimal communication existed between national RCS facilities regarding quality of measurement. Since RCS measurements are a product of extremely complex electromechanical systems containing complex hardware and software subsystems, solving system-level problems was difficult without a standard to measure them and a forum to exchange ideas.

The directorate conceived a national certification program because it not only developed a standard in cooperation with its industry peers, but it also implemented a peer review system that assured the standard would be fairly and uniformly enforced. The certification process has three phases and normally takes 6 months to a year to complete depending on the quality of documentation maintained by the facility.



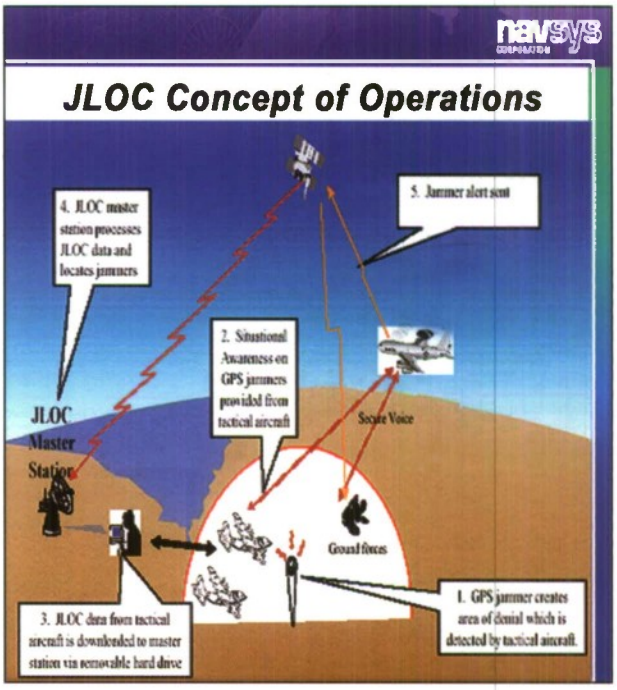
The directorate-developed standard, adopted as RCC Standard 804-01, calls for a 5-year migration plan. It will require US government and industrial RCS ranges to comply with the standard for DoD contractors performing RCS measurements for the directorate.

GPS Jammer Detection Location System

Payoff The Sensors Directorate managed a Small Business Innovation Research Phase III project with NAVSYS Corporation of Colorado Springs, Colorado, to develop a Global Positioning System (GPS) jammer location (JLOC) system. The JLOC system's architecture is a method of accurately locating interference sources in a timely and efficient fashion. This qualifies the GPS system to be used for safety of life-critical applications. It also provides a solution that offers situational awareness on navigation warfare threats in a tactical environment.

Accomplishment The directorate's research and development efforts, along with NAVSYS, resulted in significant technological advancements and product development. The GPS JLOC system architecture solves interference problems through a network-centric approach where data is collected from conventional GPS user equipment acting as jammer sensors. Current GPS user equipment generates diagnostic data on the quality of the received GPS signals. This data is relayed to a JLOC master station where it is processed to deduce the location of the jammer or interference source.

Background GPS performs a crucial role in enhancing national defense. Due to low broadcast signal architecture, the GPS signal is particularly susceptible to intentional and unintentional interference. Under such circumstances, detecting and locating the interference in a timely manner would greatly minimize this risk. This also is significant in light of the growing interest by certain countries to explore low-cost, low-power methods of disrupting the GPS signal.



GPS interference also is a significant concern to the Federal Aviation Administration (FAA), as the air transportation system is becoming increasingly reliant on the use of GPS. Before GPS can be approved for use in approach and landing, any GPS interference sources in the vicinity of an airport must be located and disabled. Currently, there is no cost-effective method for the FAA to detect and locate these sources.

In addition, the JLOC system architecture will support the civil need for an interference detection and location system. Civilian users are increasingly dependent on GPS for navigation (including aircraft landing), power grid synchronization, and communications synchronization (including the cellular phone system). It is critical that researchers and engineers develop receivers to promptly identify and locate GPS jammers, which may pose potential disruptions to these operations.

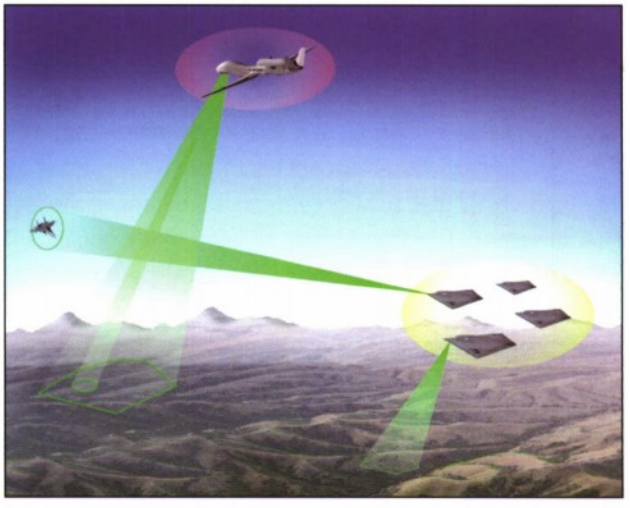
AFRL Develops Airspace Operations Sensing Requirements for UAV and Transfers Technology to Civilian Users

Payoff The Air Vehicles Directorate has transferred unmanned air vehicle (UAV) sensing system requirements for airspace operations to civilian users and UAV developers, providing design goals on which to base future sensing subsystem designs and filling a glaring omission in UAV technology planning. The directorate is developing technologies that enable future UAVs to coexist as safely as manned aircraft in both military and civilian airspace.

Using these requirements ensures that UAVs will detect possible conflicts, such as midair collisions and runway excursions, so users can take the appropriate action to avoid the conflict. The technology transferred forms a worldwide baseline for the UAV community.

Accomplishment Working with engineers from Northrop Grumman Corporation, AFRL engineers established, iterated, and finalized sensing system performance requirements for the broad range of future US Air Force missions. Throughout the process, directorate engineers noted that many mission elements are similar to civilian airspace operations tasks, and that the requirements were directly applicable to civilian UAV technology.

The engineers also noted that no compendium or report existed that defined and expressed these requirements. To transfer this technology, the directorate coordinated report writing with the American Institute for Aeronautics and Astronautics focal point for UAV airspace integration, transitioning the groundbreaking report in time for presentation at the UAV airspace integration meeting. The far-reaching insight of the directorate's research is directly impacting the airspace operations sensing systems for current and future UAVs.



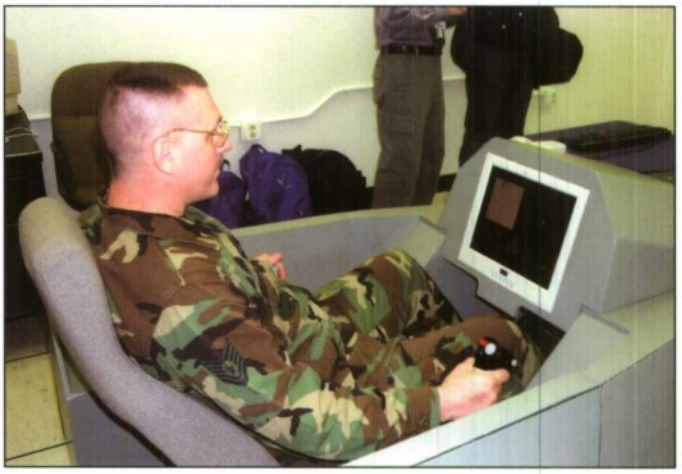
Background In order to share airspace with manned aircraft, UAVs must detect conflict situations effectively as manned aircraft. Because this is not currently the case, the Air Force segregates UAVs from manned airspace—placing a significant restriction on UAV operational usefulness.

To eliminate this segregation, UAVs need to sense the presence of other aircraft in their operating environment. For this reason, directorate researchers identified a need to replicate the human see-and-avoid capability onboard UAVs for acceptance into the National Air Space. Not all aircraft have air traffic transponders, so UAVs cannot rely on those alone. UAVs must use onboard sensors to detect aircraft and fuse that with available transponder information to give UAVs and UAV operators situational awareness of the airspace around the vehicle to ensure that unmanned aircraft are as safe as our manned aircraft.

Air Vehicles Directorate Helps Recruiting Squadron

Payoff The 345th Recruiting Squadron from Scott Air Force Base (AFB), Illinois, has a new tool—a flight simulator nicknamed the Draco Simulator Interceptor Experience (SIX)—to help them in their mission of recruiting and retention. Simple to set up by as few as two people and easily transportable, the simulator is intended for use at various recruiting events where people with an interest in the Air Force can experience what it is like to fly an Air Force jet.

Accomplishment A team of six engineers and co-op students from the Air Vehicles Directorate worked for 5 months designing and building a fully mobile flight simulator from the ground up, utilizing old parts from around the directorate. The directorate even produced the software in-house, which helped to make the total cost of the unit less than one-fifth that of a comparable commercially produced item.



The directorate presented the Draco SIX to the 345th Recruiting Squadron to help educate potential Air Force recruits in a style that is more appealing to today's youth. With this in mind, the Draco SIX has an active schedule planned as the centerpiece at several events in the upcoming months. In exchange for the simulator, the recruiting squadron has agreed to show an AFRL video before running the simulator to illustrate the opportunities available in the laboratory.

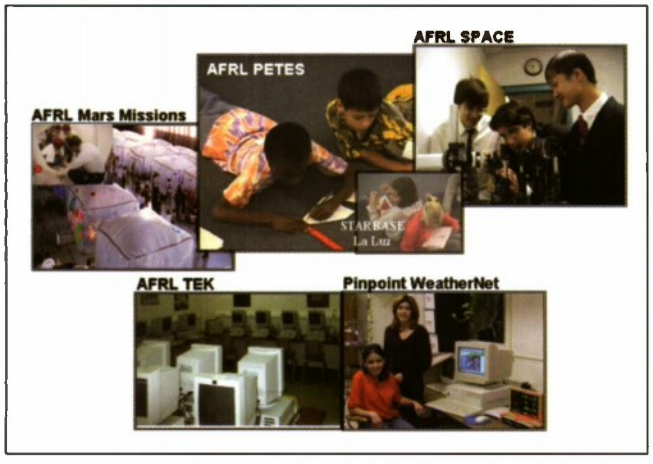
Background The 345th Recruiting Squadron asked the directorate for help creating a hands-on tool they could take with them to schools, festivals, and other venues to attract people interested in aviation. Along with three directorate engineers, the production team also consisted of students from a co-op program that recently resumed after 15 years of inactivity. Mr. Gary Hellmann, the Control Simulation and Assessment branch chief and a former co-op student himself, wanted to challenge the current class of co-op students to best utilize their potential.

The simulator was first unveiled during TechFest 2003 at Sinclair Community College, Dayton, Ohio, where it received very positive feedback from 200 people who tested it. Thanks to the success of the first project, the directorate plans to build a second simulator for the Educational Outreach program at Wright-Patterson AFB, Ohio.

Technology Transfer for Education Program

Payoff Of all the technology transfer activities, education outreach most directly impacts and benefits those who are the future—today's students. The Office of Technology Transfer for Education (TTE) program, located at the AFRL Phillips Research Site, brings the technology and expertise of Air Force scientists and engineers into classrooms throughout the state of New Mexico and beyond.

Over 60,000 students from more than 200 schools in New Mexico have benefited from TTE program efforts to date. Currently, TTE has 163 Education Partnership Agreements (EPA) processed or pending and 18 Cooperative Research and Development Agreements (CRADA) processed or pending with local school districts.



Accomplishment The Space Vehicles and Directed Energy Directorates' TTE program received a 2001 Federal Laboratory Consortium Award for Excellence in Technology Transfer. One of the most coveted awards in the tech transfer field, this award recognizes individuals within federal labs (and their industry partners) who have done outstanding work in transferring federally developed technologies.

The TTE has a proven track record of effective leveraging with outside sources. The Pinpoint WeatherNet project CRADA with KOB-TV4 generated over $6.2 million of promotional airtime. More than 13% of mentors supporting the AFRL TTE program are from the private sector.

The TTE team fulfills four out of five congressional mandates for technology transfer. The Office of the Secretary of Defense and the Secretary of the Air Force acknowledged TTE's activities as a model for all of the Department of Defense and highlighted TTE in testimony to Congress in 2000 and 2001.

In 2002, the TTE managed the Space Rocks! kids festival for the 2002 World Space Congress. In 2000 and 2001, the TTE received commendations from the entire New Mexico Congressional Delegation. Also in 2001, the TTE received the Legislative Memorial of Appreciation for Education Outreach in New Mexico.

Background The TTE program consists of five technology-based education outreach projects. These projects include the AFRL Mars Missions project for 5th graders, a classroom-based simulation adapted from the Challenger Center for Space Science Education's Marsville® project.

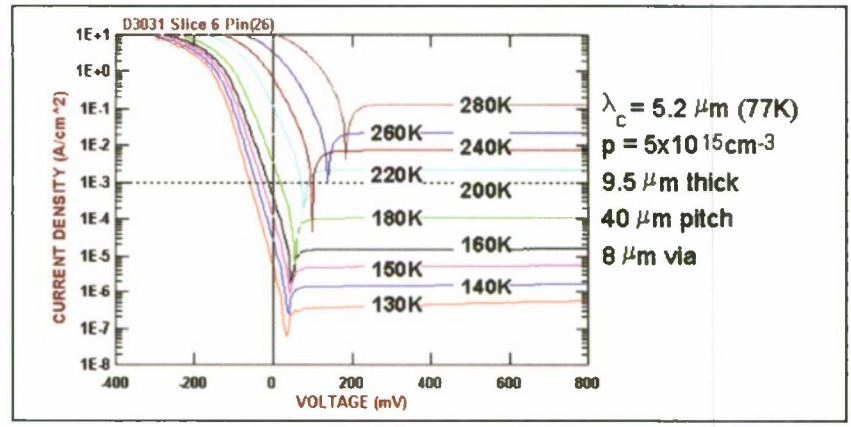
Another project, the AFRL Providing Engineering and Technology Experiences for Students project, bridges the transition from elementary to middle school and middle school to high school by fostering student mentorship in AFRL technologies. The Pinpoint WeatherNet project is a CRADA with KOB-TV4, which provides high-quality weather stations and on-line curriculum for New Mexico middle schools.

The AFRL Students Planning and Conducting Engineering project helps high school student teams design and conduct year-long, real-world research and development projects. The AFRL Technology Equipment for Kids project includes an EPA between the directorates and New Mexico Technet, Inc., which ensures students receive educationally useful, AFRL-donated technology tools.

AFRL HotStar

Payoff Higher-operating-temperature, staring focal plane arrays (FPAs) is a program to develop medium waveband infrared (MWIR) FPAs, which meet the stringent requirements of space-based missile warning programs, with cooling at higher operating temperatures provided by passive space radiators.

Accomplishment The Space Vehicles Directorate awarded the HotStar program to DRS Infrared Technologies of Dallas, Texas, as a vehicle for developing higher-operating-temperature MWIR FPAs. DRS Infrared Technologies delivered standard (copper-doped) FPAs under HotStar to the directorate to evaluate in the directorate's characterization facility for level of performance and to establish a technology baseline prior to improving the technology.



As part of the solution to meeting these stringent performance requirements, achieved in the past only with cryogenic (sub-100 Kelvin) operating temperatures, a revision (at DRS Infrared Technologies) in the standard doping process replaces copper with gold atoms to achieve the p-type doping side of the photodiode junctions. The lower dark currents associated with the new doping approach allow HotStar to meet its performance objectives and also benefit Navy programs that have adapted the gold-doping technology for ship-based defense technology.

Background DRS Infrared Technologies developed the high-density, vertically interconnected photodiode (HDVIP) process for single waveband FPAs in response to the Defense Advanced Research Projects Agency's Infrared Focal Plane Array's Flexible Manufacturing program. The processing begins with tellurium-rich, liquid-phase epitaxial growth of p-type detector material diced and epoxied onto cryogenic multiplexers.

DRS Infrared Technologies makes interconnects to the multiplexer pads with the etching of vias, followed by their metallization (with this step representing a substantial deviation from the indium bump interconnection used by most other infrared FPA manufacturers). At the time of the via etching process, DRS Infrared Technologies converts the axial region surrounding the via from p- to n-type, thereby forming the photodiode. Another advantage of the HDVIP process for the HotStar application is its compatibility with microlensing approaches to reduce the ratio of photodiode junction to pixel optical areas.

Awards and Recognition

Continued on next page

Awards and Recognition

Dr. Bruce W. Suter Wins Arthur S. Fleming Award

Payoff Dr. Bruce W. Suter, a principal researcher in the Information Directorate, sponsored by the Air Force Office of Scientific Research, received the 2002 Arthur S. Fleming Award for achievements in both technical and managerial issues. Dr. Suter was one of 12 outstanding public servants working in the federal government to receive this award in 2002.

Accomplishment Dr. Suter, the directorate's principal researcher in information signal processing technology, consistently pushes the fundamental principles of science through extensive personal study and collaboration with his peer group. Dr. Suter's peer group includes 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.

Background Dr. Suter was instrumental in the establishment of the directorate's Center for Integrated Transmission and Exploitation (CITE) and currently serves as director and principal researcher of CITE. CITE is an organization whose goal is to explore the system-level issues involved by simultaneously considering both communications and exploitation.

Dr. Suter also serves as a technical consultant in the area of data compression for the Air Expeditionary Force Battlelab. He recently completed a very extensive wavelet-based video compression consulting activity entitled "Global Information Compression Methodology and Implementation for Enhanced Command Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance System Integration."

Dr. Suter has authored an advanced technical monograph, *Multirate and Wavelet Signal Processing* (Academic Press 1998), together with over 100 conference and journal publications, demonstrating exceptional ability and superior performance continuously in his career. His publications include papers on multirate and wavelet signal processing, numerical linear algebra, transform theory (Fourier, Hankel, Radon Wavelet), neural networks, parallel processing, and computer arithmetic.

Dr. Suter received a US patent for the fastest fast Fourier transform implementation ever devised. The Air Force Materiel Command (AFMC) recognized Dr. Suter in 2001 for his work in the technology transfer of his patent by honoring him with one of the highest awards of the AFMC–the 2000 General Ronald W. Yates Award for Excellence in Technology Transfer.

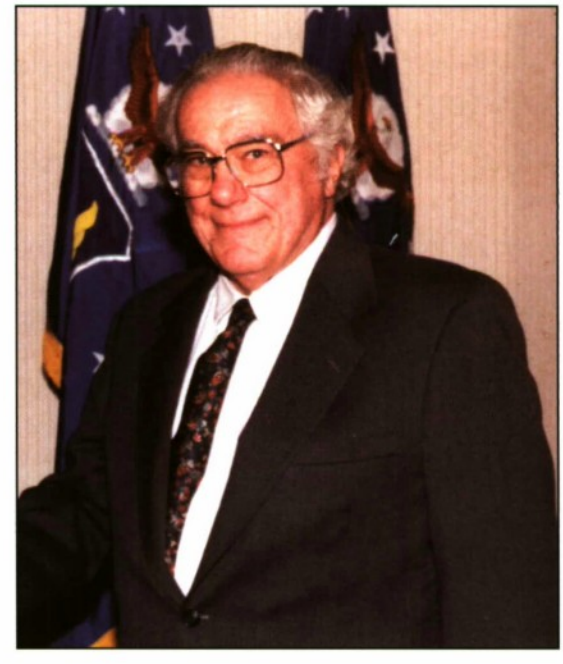
The Arthur S. Fleming Award program, established in 1948 by the Downtown Jaycees, educates the public about the contributions young civil servants make to America. To date, just 400 people have received this honor. Past Fleming honorees include Senator Daniel Patrick Moynihan (1965); Elizabeth Hanford Dole (1971); and Dr. Anthony Fauci, Director of the National Institute for Allergies and Infectious Diseases (1979).

Dr. Edmond M. Dewan Receives the Harold Brown Award

Payoff Dr. Edmond M. Dewan recently received the prestigious Harold Brown Award for creating the template used to determine atomospheric weather conditions. The Harold Brown Award was named for Dr. Harold Brown, a renowned nuclear engineer, mathematician, public servant, and the former Secretary of Defense under President Jimmy Carter. Dr. Brown was also a former Secretary of the Air Force.

Accomplishment Dr. Dewan, a researcher with the Space Vehicles Directorate's Spacecraft Technology Division, whose work is funded by the Air Force Office of Scientific Research, created an optical turbulence model that converts vertical profiles of atmospheric winds and temperature into vertical profiles of the optical turbulence parameter. The Airborne Laser (ABL) Missile Defense System Program Office selected the Dewan Model for incorporation into the Atmospheric Decision Aid (ADA) to operate with the ABL Missile Defense System.

Background Dr. Dewan's model is especially significant to the Air Force because of its impact on the ABL theatre missile defense system scheduled for deployment this decade. The effectiveness of this system is 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 Air Force designed the ABL system 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. In a worst case scenario, turbulence could make the ABL inoperative.

The Air Force positions the ABL relative to the target in a manner to avoid as much turbulence as possible, using an 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.

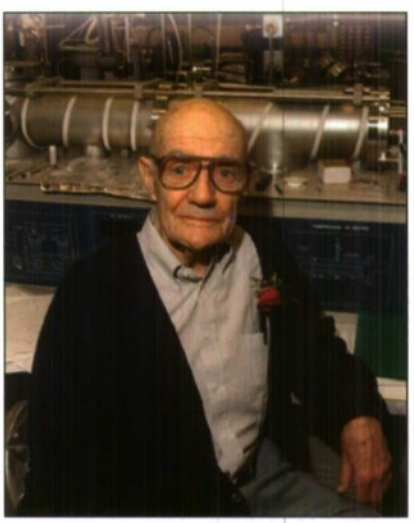
The Air Force used Dr. Dewan's model, in conjunction with meteorological balloon observations in the Persian Gulf and Korean Peninsula, to reveal a peak of optical turbulence associated with subtropical jets. Dr. Dewan's model and its future improved versions show promise crucial to future Air Force optical turbulence prediction systems for many years to come as the Air Force develops new high-energy laser systems. Dr. Dewan has published 111 scientific papers, given more than 145 presentations, and recently received the Guenter Loeser Memorial Award for lifetime achievement.

AFOSR Helps Fund Two 2002 Nobel Laureates

Payoff Building on its legacy of funding Nobel Prize-winning scientists, the Air Force Office of Scientific Research (AFOSR) recently added two additional laureates, Dr. Daniel Kahneman (pictured left) and Dr. John Fenn (pictured right), to its list of distinguished researchers. For the past 50 years, AFOSR has identified a significant number of researchers who have gone on to win Nobel Prizes in their respective fields. With the addition of Drs. Fenn and Kahneman to that list, AFOSR has enhanced a legacy of Nobel Prize-winning research that results in world-class scientific contributions that support the Air Force's mission of supremacy in the air and on the battlefield.

Accomplishment Dr. Kahneman, of Princeton University, is one of the winners of the Nobel Prize in economic sciences and Dr. John Fenn, of Virginia Commonwealth University, shared the Nobel Prize in chemistry. AFOSR has sponsored 48 Nobel Prize researchers since 1955; 45 were funded before they received the prize.

Background AFOSR began funding Dr. Kahneman in 1971 when the Life Sciences Directorate supported his groundbreaking work on human perception, attention, and decision making. Dr. Kahneman studied the determinants of human choice in risky situations with psychologist Amos Twersky.



Dr. Kahneman and Mr. Twersky's research shows that a person's decisions depend on how the person frames or describes the decision problem, and this dependence results in decisions that deviate in predictable ways from the rational choice strategy. This research directly supported one of the long-standing goals of the directorate for advancement in improved human performance.

Dr. John Fenn also began his relationship with AFOSR in the early 1970s when AFOSR funded his work on molecules seeded in atomic beams. AFOSR continued to support Dr. Fenn during the 1980s, while he worked at Yale University, with several contracts dealing with molecular collision processes.

Dr. Fenn used these studies and other associated systems to research fundamental chemical reaction dynamics, which substantiated the Nobel Prize for chemistry for Herschbach, Lee, and Polanyi in 1986. Dr. Fenn received the 2002 Nobel Prize in chemistry for his work in electrospray mass spectroscopy that grew out of his experience and expertise from earlier molecular research.

Dr. Lyle H. Schwartz Receives Honorary Membership to ASM International

Payoff The American Society for Metals, commonly referred to as ASM International, is the society for materials engineering and scientists, which boasts nearly 40,000 members from 100 countries and selects just one honorary member each year. Honorary membership in ASM International recognizes distinguished service to the materials science and engineering profession, to ASM International, and to the progress of mankind. Honorary membership is among the most prestigious awards of the society.

Accomplishment ASM International selected Dr. Lyle H. Schwartz, the director of the Air Force Office of Scientific Research (AFOSR), for honorary membership to ASM International. ASM recognized Dr. Schwartz for his innovative and effective leadership in planning, prioritizing, and administering materials research and development within the federal government and industrial/government partnerships. The society also honored Dr. Schwartz for his outstanding work in X-ray and neutron diffraction, Mossbauer spectroscopy, and for his service to ASM International.

Background As AFOSR's director, Dr. Schwartz leads a staff of more than 150 scientists, engineers, and support personnel in Arlington, Virginia, and two foreign technology offices in London and Tokyo. Dr. Schwartz, who received his doctorate of philosophy in materials science from Northwestern University, helps AFRL maintain the technological superiority of the Air Force.

Dr. Miguel Visbal Receives ASC Outstanding Engineer and Scientist Award

Payoff The Affiliate Societies Council (ASC) of the Engineering and Science Foundation recently recognized Dr. Miguel Visbal, a principal research engineer in the Air Vehicles Directorate, for scientific achievements in the computational simulation of unsteady aerodynamics, aeroelasticity, aeroacoustics, and electromagnetics. His selection enhances AFRL's reputation as a world leader in aerospace research and recognizes the skill and professionalism of directorate scientists and engineers.

Accomplishment The ASC of the Engineering and Science Foundation recognized Dr. Visbal as one of the recipients of the 2003 Outstanding Engineers and Scientists Award. The ASC presented the award at the 44th Annual Awards Banquet during Engineers and Scientists Week in Dayton, Ohio. Dr. Visbal was one of four awardees that received special recognition for his ingenious contributions in the Research category.

Background The ASC of the Engineering and Science Foundation consists of members from nearly 50 professional science and engineering organizations whose combined membership in Dayton exceeds 15,000. The mission of the ASC includes continuing professional education, career guidance, outreach for technology and knowledge sharing in the community, and administrative services for affiliated groups. Each year during Dayton's Engineers and Scientists Week, the ASC honors outstanding contributors in the areas of Research, Technical Leadership, Education, and Engineering Design and Development.

Dr. Visbal is the team leader for Multidisciplinary Computational Research in the directorate's Computational Sciences Center of Excellence. During his career, he obtained and published significant first-ever results for the fundamental physics that dictate unsteady, separated aerodynamic flows including vortex breakdown and dynamic stall.

Dr. Visbal recently conducted pioneering research in the formulation of accurate, high-order numerical schemes for computational fluid dynamics. Researchers are using his developments in the computational simulation of fluid-structure interactions, turbulence, and magneto-gas dynamics.

Dr. Visbal is a recognized contributor in his field as evidenced by his membership on international committees and review teams. The National Aeronautics and Space Administration (NASA) invited him to serve on a NASA Peer Review Panel, and he also served as a general chairman during an international conference. He is a reviewer for numerous international journals and served as a National Science Foundation consultant as well as an adjunct faculty member at the Air Force Institute of Technology, Wright State University, and Ohio Aerospace Institute.

Dr. Visbal's basic research team receives nearly $1M annually from the Air Force Office of Scientific Research (AFOSR) as well as hundreds of thousands of computer processor hours from the Department of Defense High-Performance Computing Modernization program resources. His team received renewal status as a prestigious AFOSR Star Team for the period 2002-2004.

Dr. David Moorhouse Receives Senior Scientist Appointment

Payoff In a ceremony officiated by Major General Paul Nielsen, Dr. David Moorhouse was recently appointed senior scientist and named chief of the Multidisciplinary Technologies Center (MDTC). Dr. Moorhouse's previous position was senior research engineer at the MDTC. The center will greatly benefit from Dr. Moorhouse's extensive experience in vehicle design and system integration, which are major parts of the center's mission.

Accomplishment The MDTC is one of the Air Vehicles Directorate's centers of excellence. As chief of the MDTC, Dr. Moorhouse will lead the center in its mission to identify, develop, and improve critical, military-specific air vehicle technology design tools, methods, and processes to support innovative and affordable military aerospace vehicle development. The mission supports the Air Force by quickly identifying innovative, viable aerospace vehicle concepts.

Background The MDTC's research covers five different areas. In all five areas, the focus is to exploit the synergistic interactions of multiple technologies to yield system benefits in support of innovative, fully integrated vehicles.

The first area, Efficient Design and Analysis Tools, is developing physics-based modeling tools and processes for design, analysis, and increased analytical certification of aerospace vehicles. Second, Uncertainty Quantification is developing rules and tools for understanding variability in system properties and the operating environment on air vehicle response. Third, Adaptive Structures is developing structural design with integration of mechanization and actuation for beneficial shape changes. Fourth, Energy-Based Method focuses on a multidisciplinary design framework for system-level optimization. The fifth area, A New Thrust, centers on flight experimentation to validate scientific methods with realistic data.

During his distinguished career, Dr. Moorhouse authored 65 journal articles, papers, and technical reports. His awards include the following: Dr. Courtland D. Perkins In-House Engineering Award, Directorate Engineer of the Year, Air Force High-Value Invention/Suggestion Award, Air Force Systems Command Science and Technology Achievement Award, *Aviation Week and Space Technology* Laurels Award, Fellow of the Royal Aeronautical Society, Associate Fellow of the American Institute for Aeronautics and Astronautics, Invited Member of the Aerospace Engineering School Advisory Council for Georgia Tech, and Invited Member of the PhD Committee at Technical University of Delft, The Netherlands.

Ms. Charlotte Gerhart Receives AFMC Junior Civilian Engineer Award

Payoff The Air Force Materiel Command (AFMC) awarded Ms. Charlotte Gerhart, of the Space Vehicles Directorate, the Junior Civilian Engineer Award, which recognizes individuals with less than 10 years of engineering experience for technical contributions to the sustainment, testing, and advancement of Air Force weapons systems. AFMC will also forward the winner in this category as a nominee for the Air Force Outstanding Engineer Awards.

Accomplishment Ms. Charlotte Gerhart received the AFMC Junior Civilian Engineer Award for program manager of the year for her work on the Vibro Acoustic Launch Protection Experiment (VALPE) and other research projects. Her efforts will save the Air Force hundreds of millions of dollars during the next decade.

Background The VALPE project, launched on two Terrier Improved Orion sounding rockets, consisted of five separate experiments that demonstrated vibration isolation, acoustic mitigation, and energy recovery. These technologies are key to decreasing design requirements and improving overall reliability for future space missions.

In addition to coordinating the VALPE Team, Ms. Gerhart is a recognized expert in the area of spacecraft thermal management and continues to direct and coordinate research, design, and analysis in that field. Keeping all components of a satellite within their individual temperature limits is critical for operation and is difficult in the harsh environment of space.

Ms. Gerhart is also responsible for overseeing the development of novel technologies that will eventually result in the capability to perform autonomous on-orbit servicing of satellites. The ability to refuel, repair, and upgrade satellites on orbit has the potential to revolutionize the way the Air Force and the Department of Defense currently use satellites, much the way mid-air refueling has changed aircraft operations.

AFRL Names Seven New Fellows

Payoff The AFRL Fellows program recognizes and rewards the laboratory's most outstanding in-house scientists and engineers for their accomplishments and technical excellence in support of our nation's air and space forces. Each Fellow receives a special $100,000 grant for the first 2 years following selection. The grant serves to assist in further self-development and additional research.

Accomplishment AFRL recently selected the following as AFRL Fellows (pictured left to right): Mr. Wayne Bonser, Information Directorate, Rome Research Site, Rome, New York; Dr. Gail Brown, Materials and Manufacturing Directorate, Wright-Patterson Air Force Base (AFB), Ohio; Dr. Raymond Gordnier, Air Vehicles Directorate, Wright-Patterson AFB, Ohio; Dr. Kirk Hackett, Directed Energy Directorate, Kirtland AFB, New Mexico; Mr. William McQuay, Information Directorate, Wright-Patterson AFB, Ohio; Dr. Robert Pugh, Space Vehicles Directorate, Kirtland AFB, New Mexico; and Dr. Jeffrey Zabinski, Materials and Manufacturing Directorate, Wright Patterson AFB, Ohio.

Mr. Bonser contributed to the development, leadership, and transition of commercial and military software radio technology. Dr. Brown is a leader in cutting-edge research on superlattice materials. Her accomplishments have made a tremendous impact on programs for new infrared detector materials. Dr. Gordnier is an expert in multidisciplinary computational sciences whose research in unsteady aerodynamics and fluid-structure interactions are critical to the understanding of air vehicle performance and sustainment.

Dr. Hackett, a leader in the areas of high-power microwaves and non-lethal weapons development, performed research crucial to the development of Active Denial Technology. Mr. McQuay has a distinguished record of contributions in modeling and simulation technologies going back to the early days of computer-based simulation of electronic phenomena through today's use of simulation to support operational decision makers. Dr. Pugh has a record of distinguished contributions in the research and development of space electronics, resulting in affordable, leading-edge, radiation-hardened electronics that are used in over 90% of the Department of Defense satellites. Dr. Zabinski has pioneered research discoveries that have shifted the paradigms of lubrication and coating technology at AFRL, nationally, and abroad.

Background Military and civilian scientists and engineers, comprising about 55% of AFRL's workforce, are eligible for selection as an AFRL Fellow. Eligible participants must be assigned to AFRL for the past 3 consecutive years and have at least 7 years of active federal service. Participants must perform the recognized work at the laboratory or one of its predecessors.

Ultrashort Laser Bioeffects Team Named AFOSR Star Team

Payoff The Air Force Office of Scientific Research (AFOSR) recently selected the Advanced Ultrashort Laser Bioeffects Team, of the Human Effectiveness Directorate, as an AFOSR Star Team. This is the second 2-year term for this team's selection as an AFOSR Star Team. Star Team status substantiates the directorate as a world leader in helping the Air Force evaluate the mission impact of escalating laser threats, and it affirms the directorate's reputation as a world-class center for laser-tissue interaction research.

Accomplishment The directorate's Advanced Ultrashort Laser Bioeffects Team, recently selected as an AFOSR Star Team, will provide information that will play an important role in establishing new national, international, and military laser safety standards used for the development of appropriate concepts-of-operation for laser weapons.

Background Over the past decade, the directorate conducted basic research to determine the threshold levels at which ocular exposures to short-pulsed (sub-nanoseconds in duration) laser light will produce retinal damage. The research team identified three new mechanisms for retinal damage from laser exposure.

The team performed other basic research and developed biological databases to demonstrate that nonlinear physical mechanisms are generally responsible for producing lesions on retinas exposed to these extremely short pulses of laser light. Information obtained from this research played an important role in establishing new national, international, and military laser safety standards used for the development of appropriate concepts-of-operation for laser weapons. The biological databases developed provide the foundation for validating future models of ocular damage from new generations of military lasers.

Dr. Benjamin Rockwell Named Laser Institute of America Fellow

Payoff The Laser Institute of America (LIA) recently selected Dr. Benjamin Rockwell, a senior research biophysicist with the Human Effectiveness Directorate, as a Fellow at the International Congress on the Applications of Lasers and Electro-Optics in Scottsdale, Arizona. Dr. Rockwell's selection as a Fellow strengthens the directorate's reputation as a world-class center for laser-tissue interaction research and as a world leader in determining the safety of laser threats.

The LIA is a professional membership society dedicated to promoting lasers, laser applications, and safety worldwide, serving the industrial, medical, research, and military communities. The LIA recognizes those members, who make seminal contributions to the fields of laser applications and safety with the distinction of Fellow.

Accomplishment Dr. Rockwell investigated laser damage to the retina, conducting groundbreaking experimentation on the nonlinear optical phenomena that are responsible for the lowest energies ever to damage retinal tissues. These nonlinear effects occur when ultrashort laser pulses (shorter in duration than one nanosecond) impinge the retina.

This research included the lowest single-pulse damage of the retina, measurement of the nonlinear optical properties of the eye, and determination of three new damage mechanisms of the retina from laser exposure. These damage mechanisms are not only important for determining safe exposure levels and weapons effectiveness, but may also help in developing new treatments of retinal diseases such as macular degeneration.

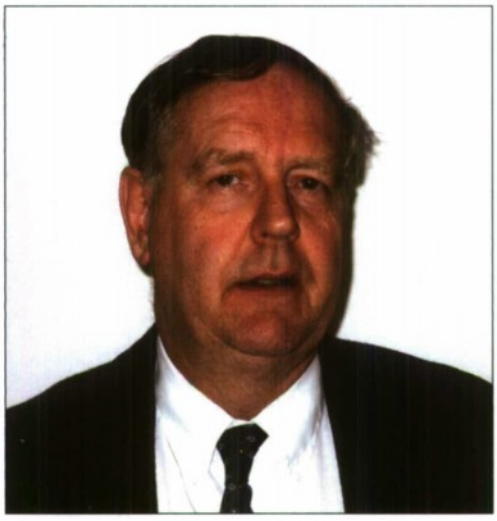
Background Dr. Rockwell served for 3 years as a senior member of the LIA and was elected in 2001 to serve a 3-year term on both the board of directors and the executive board. During his tenure at AFRL, Dr. Rockwell published a book chapter, 31 journal articles, and 72 proceedings articles. He served on many conference committees and has one patent.

Dr. Rockwell also serves as the Secretary of the American National Standards Institute's Z136 Committee, the National Laser Safety Committee, and as US delegate to and on the Technical Area Group for Laser Bioeffects for the International Electrotechnical Commission. His research team defines the safe exposure levels for ultrashort laser pulses and the resulting protective requirements for personnel protection.

Dr. Daniel W. Repperger Wins Distinguished John Paul Stapp Award

Payoff The Aerospace Medical Association gives the John Paul Stapp Award annually to individuals in recognition of their outstanding contributions in the field of aerospace biomechanics and to promote progress in protection from injury resulting from ejection, vibration, or impact.

Accomplishment The Aerospace Medical Association recently presented the John Paul Stapp Award to Dr. Daniel W. Repperger, an AFRL Fellow from the Human Effectiveness Directorate's Human Interface Technology Branch. Dr. Repperger has made fundamental contributions to aerospace biomechanics and human protection for more than 30 years. The results have been innovative technology and new knowledge regarding human performance in high-g, high-turbulence, and weightless environments.



Background Dr. Repperger originally developed patented technology in 1985 for a force-reflecting "haptic" control stick that can assist and help protect a pilot in a high-turbulence environment. The control stick uses virtual force to augment the pilot's neuromuscular control, resulting in improved tracking control and disturbance rejection. Because these unique interfaces involve neuromuscular biomechanics and employ control theory methods, their application is essential to the medical rehabilitation of convulsive individuals.

Dr. Repperger's wide range of career achievements exemplifies his leadership in the scientific community. In addition to his duties as an AFRL Fellow, he serves as associate editor for numerous journals and as an adjunct professor at nearby colleges and universities.

As demonstrated by his 12 US patents, 21 Air Force inventions, and 65 journal articles, Dr. Repperger enhanced United States Air Force state-of-the-art technology. His selection for the John Paul Stapp Award highlights the talent, dedication, and professionalism that strengthen the directorate and the aerospace community as a whole.

Dr. James T. Webb Receives AsMA Paul Bert Award for Physiological Research

Payoff The Aerospace Physiology Society of the Aerospace Medical Association (AsMA) established the Paul Bert Award for Physiological Research in 1969 and presents the award annually for outstanding research contributions in the field of aerospace physiology. The AsMA named the award in honor of the famous French physiologist and "Father of Pressure Physiology."

Accomplishment The Aerospace Physiology Society of the AsMA recently awarded Dr. James T. Webb the Paul Bert Award for Physiological Research for his contributions to the field of aerospace physiological research. Dr. Webb, a Fellow of AsMA since May 1994, is the altitude lead scientist with the Human Effectiveness Directorate's Biodynamics and Protection Division Protective Systems Branch.

His method of prebreathe enhancement was instrumental in saving the National Aeronautics and Space Administration (NASA) more than $3 million. It also kept two pilots flying the U-2 high-altitude reconnaissance aircraft, who otherwise would have been reassigned to different airframes at considerable expense to the United States Air Force (USAF).

Background Dr. Webb's career spans over 20 years in high-altitude protection research for civilian, Department of Defense, and North Atlantic Treaty Organization (NATO) aircrews. A recognized expert, Dr. Webb advises Special Operations Forces, NATO, the Air Force Special Operations Command, and the Air Combat Command in matters pertaining to decompression sickness (DCS), exercise-enhanced prebreathe, and unpressurized high-altitude missions.

As one member of a three-man team and coinvestigator for more than 44 studies, his expertise is invaluable in DCS prevention research. Hired in 1987, as a contract scientist with Wyle Laboratories, his extensive knowledge and attention to detail garnered him the position of lead scientist in 1994. During his tenure, he coauthored more than 100 publications and was lead author on 68 publications.

AsMA, considered the international leader in aviation, space, and environmental medicine, applies and advances scientific knowledge to promote and enhance the health, safety, and performance of those involved in aerospace and related activities. From the 1929 organizational meeting of 29 aeromedical examiners, the association has grown to its present strength of more than 3,500 members from 76 countries. The AsMA formed the Aerospace Physiology Society in 1965 and serves physiologists working with crewmembers from the USAF, US Navy, NASA, and NATO.

Dr. Michael Murphy Receives the Air Force Science and Engineering Award

Payoff The Science and Engineering Award recognizes "working-level" Air Force personnel for their outstanding contributions in research, development, or engineering.

Accomplishment The United States Air Force (USAF) presented Dr. Michael R. Murphy, Chief of the Human Effectiveness Directorate's Radio Frequency Radiation Bioeffects Branch, the USAF 2002 Science and Engineering Annual Award for Achievement in areas of exploratory or advanced technology development. Dr. Murphy directed efforts to document human- effects data in support of nonlethal weapons (NLWs) and is the chair of the North Atlantic Treaty Organization's Technology Group on the human effects of nonlethal technologies.

Dr. Murphy provided Air Force capabilities and expertise in support of the Department of Defense (DoD) executive agent for NLWs through the Joint Nonlethal Weapons Directorate (JNLWD). Dr. Murphy led research and risk communication efforts in support of the human effects of a unique microwave-based, antipersonnel, nonlethal weapon called the Active Denial System (ADS).

Dr. Murphy simultaneously enhanced the international service and scientific reputation of the group conducting the ADS research. Due to his technical expertise and support of expanded human-effects research of nonlethal weapons, his group earned the designation and funding as the Joint Nonlethal Human Effects Center of Excellence in the DoD.

Background Dr. Murphy oversaw field studies of ADS effectiveness and development with emphasis on human effects. Using the results of those studies, he initiated a campaign to overcome the potential suspicion, fear, and misunderstanding of DoD's first antipersonnel radio-frequency NLW.

Dr. Murphy developed and executed a plan to communicate human-effects research internationally to support scientific and military acceptability for the program. This plan included presentations on ADS at foreign and domestic venues.

Dr. Michael Haas Receives Fritz J. Russ Bioengineering Award

Payoff The Fritz J. Russ Bioengineering Award recognizes an outstanding individual who has made significant contributions in research, development, teaching, or management for at least 3 years. The selection of Dr. Michael W. Haas is a prime example of the Human Effectiveness Directorate's bioengineering expertise and quality research that supports the Air Force mission and the local community.

Accomplishment Dr. Michael W. Haas, a Human Effectiveness Directorate engineer, received the Fritz J. Russ Bioengineering Award during the annual banquet of the Institute of Electrical and Electronics Engineers of Dayton, Ohio. Dr. Haas' work in the Human Interface Technology Branch of the Crew System Interface Division represents a unique combination of bioengineering, systems engineering, and exceptional management for the advancement of bioengineering and Air Force objectives.

Background Dr. Haas' accomplishments epitomize the guiding principle of his work—to understand the biological and psychological opportunities and constraints that underlie the optimal integration of humans and machines and then to develop the technology to capitalize on that understanding. One example is his application of synthetic spatial audio technology to enhance the perception of multichannel communication. Dr. Haas' work in this area virtually assures the transition of spatial audio technology to the Airborne Warning and Control System (AWACS) Block 40/45 communication system and to several ground-based tactical control facilities.

Dr. Haas made similarly exceptional contributions in his basic research program. His work enabled numerous improvements in flight control, navigation, and targeting by tailoring cockpit display modalities to the momentary sensory and attentional capacity of the users.

Additionally, Dr. Haas provided exceptional management leadership. His Virtual Air Commanders Team was invited to participate directly in a series of interface evaluations that played a major role in the design of the Block 40/45 crew stations. His leadership yielded increased funding and led to new research and development opportunities.

Dr. Haas' contributions extend throughout the United States Air Force and into the local community. By leveraging area university resources, he generated several hundred thousand dollars in cost savings for the Air Force while providing a unique mentoring environment for graduate students.

Dr. Ajit K. Roy Honored as ASME Fellow

Payoff The American Society of Mechanical Engineering (ASME) recently selected Dr. Ajit K. Roy, of the Materials and Manufacturing Directorate, as an ASME Fellow for his leadership, technical contributions, and research in composite materials. His work in a wide variety of composite technologies has advanced the state of the art.

Accomplishment Dr. Roy received the award in recognition of over 20 years of groundbreaking research in advanced analytical modeling and test method development for organic matrix composite materials. His selection as an ASME Fellow recognizes his individual achievement and contributions and enhances the directorate's reputation as a world leader in materials and materials testing-related research and development.

Background Dr. Roy, a researcher in the directorate's Structural Materials Branch, is responsible for conducting and managing basic research activities in mechanics of composite materials, particularly in the area of novel material forms and analytical tools for failure analysis of composite materials. He is responsible for managing a technology portfolio to develop advanced composite materials technology in organic matrix composites and complex materials forms.

Dr. Roy served as the Department of Defense focal point for carbon-foam technology. Carbon foam is a tailorable, ultra-lightweight, and high- temperature multifunctional material.

Dr. Roy's staff developed an analytical/numerical tool to perform stress analysis of three-dimensionally reinforced composites. This software provides the first comprehensive fracture mechanics methodology for failure analysis of textile composites by explicitly modeling the complex and curved interface surface stress and displacement continuity of intricate textile reinforcements.

Dr. Roy also initiated and led an integrated analytical and experimental program on predicting three-dimensional, thermo-elastic behavior of thick laminated composites and carbon-carbon composites. His development of unique test methods for characterizing matrix-dominated properties is key to enhancing performance of carbon-carbon composites.

Dr. Roy has published over 75 papers in peer-reviewed journals and proceedings and coauthored two chapters in a composite design book. He received a best paper award from the American Institute of Aeronautics and Astronautics for his work on wave attenuation in periodic structures.

Dr. Edmund Moore Honored as Black Engineer of the Year

Payoff Selection for the Black Engineer of the Year Award (BEYA) is a highly sought after and prestigious honor given to black engineers recognized as front-runners and leaders in the engineering, science, and technology career fields. During the last 17 years, the BEYA selection panel selected only 8% of more than 3,000 nominations for awards.

Accomplishment A panel of representatives from industry, government, and national organizations recently selected Dr. Edmund Moore, a Materials and Manufacturing Directorate engineer, to receive a 2003 BEYA for his career achievements, personal accomplishments, and commitment to helping others succeed in the engineering, science, and technology career fields. Dr. Moore, a basic research program manager, materials research scientist, and assistant to the director for the directorate's collaboration program with historically black colleges and universities (HBCU), will receive the award in the Special Recognition category during the 17th Annual BEYA Conference in Baltimore, Maryland.

Dr. Moore's career accomplishments and leadership, particularly during the nomination period, provided profound, long-term contributions to the placement of African-Americans and other minorities in the Air Force's most challenging scientific research and development areas.

Background Dr. Moore began his career with the directorate in 1991, attending the University of Florida for both a master's degree and a doctorate in materials science and engineering while on staff. He previously earned undergraduate degrees in mathematics and physics from Florida Agricultural and Mechanical University and his first master's degree in materials science and engineering from the Massachusetts Institute of Technology.

Previously, Dr. Moore assumed the added responsibility of implementing a program to increase the quantity of technical work, of interest to the directorate, performed by HBCUs, while increasing the number of African-Americans and other minority scientists in the directorate. Dr. Moore continues to organize, implement, and manage the directorate's collaboration program with HBCUs and minority institutions.

Dr. Moore will soon assume responsibility for the System Support Division's quick reaction evaluation contract—a high-visibility, 6-year $20 million basic research program that includes corrosion support, electrical and structural materials, materials testing and evaluation, rain erosion, failure analysis, nondestructive inspection, composite testing, and electrical static discharge research and development activities at the directorate. In addition, he will assume materials research duties in the areas of carbon foam technology, ceramics, and ceramic coatings.

Dr. Gail Brown Earns Air Force Basic Research Award for Superlattice Materials Research

Payoff Dr. Gail J. Brown's research resulted in significant advancements in the fundamental physics, design, parameters, and growth processes for Type-II superlattice materials. Her achievements and selection for the Air Force Basic Research Award advance the Materials and Manufacturing Directorate's reputation as a world leader in materials research and development and recognize AFRL's efforts in supporting Air Force operational requirements. Dr. Brown's work supporting the warfighter could lead to several millions of dollars in savings for the Air Force and Department of Defense.

Accomplishment Dr. Gail J. Brown, a research leader and principal research physicist in the directorate's Survivability and Sensor Materials Division, Sensor Materials Branch, recently earned the Air Force Basic Research Award for cutting-edge research on superlattice materials for next-generation infrared sensing. The award also recognizes Dr. Brown for exemplary leadership in coordinating the research project from computational modeling and growth of the superlattice materials to initial device testing of the new materials' system.

Background A number of Air Force weapon systems incorporate infrared (IR) detector arrays operating in the long and very long wave infrared (VLWIR) wavelengths. For space-based sensors, the issues of sensor system weight, power, and reliability are critical factors as well as the increasing demands for more capability and higher performance.

Dr. Brown specializes in the development of materials for improving the performance of sensors on advanced IR systems. The international IR technical community recognizes Dr. Brown as a leading expert and advocate for this science and its application to Air Force needs in space. She performed and led the defining research in the science of semiconductor superlattice materials for IR sensing, with a special focus on application to space-based VLWIR sensors.

Dr. Brown's research concentrates on the design, assessment, and demonstration of new semiconducting materials capable of outperforming industry standards. Her pioneering research on semiconductor superlattices helped make them available for Air Force IR detector applications. Dr. Brown led a team of researchers, composed of government, university, and industry researchers, to cover every aspect of superlattice materials' research from computational modeling to atomic layer-by-layer growth of the material to electrical and optical characterization.

The comprehensive, fundamental research accomplished by Dr. Brown and her colleagues demonstrated the viability of superlattices and showed that these advanced materials can vastly improve IR-sensitive semiconductor performance. In vital Air Force systems, sensors made with these materials offer greatly improved performance, high uniformity over large areas, and wavelength tunability, while significantly improving satellite launch costs, operational reliability, and life-cycle costs.

CAI Phase 2 Team Earns Defense ManTech Achievement Award for 2002

Payoff The Composites Affordability Initiative (CAI)-developed suite of tools and technologies are reaping benefits across the industry. The Department of Defense (DoD) documented more than $5 million per aircraft in cost avoidance for the F-35 as a direct result of CAI's efforts. Thus far, CAI Phase 2 tools and technologies benefited other military aircraft, such as the unmanned combat air vehicle, the V-22, F-16, F/A-18, F/A-22, and RAH-66, along with engines such as the F110-132, GE90-115, and CF34.

The CAI cost analysis tool, an industry standard, resulted in more accurate affordability trades in one-tenth the time. A single application of a bonded joint analysis tool resulted in more than a $2 million cost avoidance for the Navy's F/A-18 Hornet program.

Accomplishment A team of engineers representing the best and brightest from the Air Force, Navy, and aerospace industry, known as the CAI Phase 2 Team, recently won the prestigious Defense Manufacturing Technology (ManTech) Achievement Award for a variety of successes. Two that stood out were the $200 million in cost avoidance for the initial 2,000 F-35s produced and the more than $2 million in savings in the Navy's F/A-18 Hornet program.

Background The CAI Phase 2 Team includes more than a dozen organizations with over 50 key players nominated for the award. Primary team members include the Air Force Materials and Manufacturing and Air Vehicles Directorates, the Office of Naval Research ManTech Detachment, the Joint Strike Fighter Program Office, Lockheed Martin, Boeing, Northrop Grumman, and Anteon Corporation. Representing Air Force ManTech at the ceremony were Drs. John Russell and Frances Abrams; Mr. Dennis Hager, Deputy Chief of the ManTech Division; and Mr. Paul Hauwiller, Anteon Corporation.

The Office of the Deputy Under Secretary of Defense for Science and Technology and the Joint Defense Manufacturing Technology Panel sponsor the award. Together, they recognize and honor those individuals or groups most responsible for outstanding technical accomplishments in achieving the vision of the DoD's ManTech program. That vision is to "realize a responsive, world-class manufacturing capability to affordably meet the warfighter's needs throughout the defense system life cycle."

CAI Phase 2 was a 54-month technology maturation effort funded by a 50/50 cost-share arrangement with industry. The CAI Team did not focus on a single technology, but focused on elevating the state of the art in design and manufacturing across the entire aerospace industrial base for composite structures.

Unprecedented cooperation and exchange of pre-competitive data throughout the aerospace industry has had a tremendous impact on accelerating the advancement of technology across the industrial base. The collaborative nature eliminated the historical difficulties encountered in transferring technology to other contractors.

Award-Winning Polymer Physicist Selected to Attend Leading Engineers Symposium

Payoff The National Academy of Engineering's (NAE) Symposium introduces the nation's top young engineers to each other, challenges them to think about developments and problems at the frontiers of areas different from their own, and facilitates collaborative work and the transfer of new techniques and approaches across various fields. The program also helps establish contacts among the next generation of leaders in engineering.

Dr. Timothy J. Bunning, an award-winning polymer physicist with the Materials and Manufacturing Directorate, contributes to the collective knowledge of the directorate. His appointment enhances AFRL's reputation as a world leader in materials research and development and highlights the talent, dedication, and professionalism of the men and women who work there.

Accomplishment Dr. Bunning was one of 80 leading young engineers in the United States selected to attend the NAE's 8th Annual Frontiers of Engineering Symposium at the academy's Arnold and Mabel Beckman Center in Irvine, California. This 3-day symposium covered a wide range of topics including chemical engineering, human factors engineering, nuclear energy, and quantum information technology.

The symposium brought together engineers ages 30 to 45, who are performing leading-edge engineering research and technical work. Fellow engineers or organizations nominated participants from industry, academia, and government.

Background Dr. Bunning, recognized internationally for significant contributions in a variety of polymer-based optical materials areas, conducts research in polymer-dispersed liquid crystals, polymeric side-chain liquid crystals, laser-resistant polymers, and active and passive polymer photonic structures. A primary focal point of his research is increasing understanding of the very complex nature of nanoscale structure development in holographic polymer-dispersed liquid crystals—polymer-based optical elements that have broad-based applications potential in a number of topical areas such as display and telecommunications technology.

Working with his colleagues in the directorate's Survivability and Sensor Materials Division, Dr. Bunning successfully demonstrated the one-step fabrication of electrically switchable reflection and transmission holograms using holographic photopolymerization. His research efforts increased the understanding of the complex, dynamic balance between polymerization kinetics, diffusion, and phase separation using high-resolution electron microscopy techniques and real-time X-ray and light-scattering measurements. His efforts help advance the development of comprehensive structure/property relationships for a relatively new class of materials.

Dr. Bunning is a recipient of the 2001 Federal Laboratory Consortium Award for Excellence in Technology Transfer and the John H. Dillon Medal, presented each year by the 40,000-member American Physical Society for outstanding contributions to science and national security. He leads a research and development effort aimed at developing new responsive materials and approaches for optical sensing, laser beam control, and filtering applications. The research he performs directly supports the Air Force and the Department of Defense and, in some instances, benefits commercial industry.

Metals Processing Group Led by Dr. Lee Semiatin Earns Coveted Star Team Award

Payoff Dr. Lee Semiatin's leadership of the Materials and Manufacturing Directorate's Metals Processing Group led to a number of improvements in existing processes and the successful development of several new processes for high-temperature alloys. His team's selection for an Air Force Office of Scientific Research (AFOSR) Star Team Award recognizes team and individual achievements, as well as the vital contributions of the directorate, in support of Air Force operational requirements.

Accomplishment The directorate's Metals Processing Group, led by internationally renowned scientist Dr. Semiatin, recently received AFOSR's Star Team Award. The award recognizes teams of researchers who demonstrate world-class status and excellence in their chosen research areas. AFOSR previously recognized Dr. Semiatin's teams as Star Team recipients in 1992, 1995, and 2000.

AFOSR recognized Dr. Semiatin, a senior scientist in the directorate's Metals, Ceramics, and Nondestructive Evaluation Division, and his research team for significant achievements in four major areas: wrought processing of titanium, nickel, and advanced intermetallic alloys; solidification processing of titanium (Ti) including permanent mold casting and laser deposition; advanced modeling techniques for processing; and novel processes for making fine grain, high-strength aerospace alloys including development of innovative processing methods for cryomilled aluminum alloys.

Background AFOSR recognized Dr. Semiatin and his research team for a number of achievements including development of integrated material behavior models for constitutive behavior, deformation mechanisms, and microstructure evolution during hot working of colony microstructure Ti and Ti aluminide alloys (with applications to the breakdown of ingot microstructures); successful development of models for microstructure and texture evolution during solidification processing of Ti; development and implementation of advanced modeling and simulation techniques for deformation and solidification processes including cellular automata, texture models, and phase-field models; and development of workability criteria and validation of a novel method for producing fine-grain, defect-free, aerospace alloys, referred to as the upset/equal-channel angular extrusion (ECAE) technique.

AFOSR also recognized Dr. Semiatin's research team for development of fundamental understanding of workability and methods for extrusion and ECAE of nanophase aluminum alloys for space applications; establishment of workability and demonstration of wrought processing of an advanced molybdenum-silicon-boron alloy for advanced turbine airfoils; increased understanding and successful demonstration of wrought processing of low-cost, laser-deposited Ti forging preforms; and successful development of a fundamental understanding of mold wear during permanent mold casting of Ti (a lower-cost alternative to conventional investment casting and wrought-processing approaches).

Materials Researcher Recognized by Affiliate Societies Council for Outstanding Contributions to Air Force and Industry

Payoff The Affiliate Societies Council of Dayton, Ohio, recognized Dr. Loon-Seng Tan, from the Materials and Manufacturing Directorate, for outstanding contributions in science and engineering for his ideas, leadership, and motivation toward high achievement in materials research required for current and future Air Force systems. His selection enhances AFRL's reputation as a world leader in materials research and development and recognizes the skill and professionalism of directorate scientists and engineers.

Accomplishment The Affiliate Societies Council recognized Dr. Tan, from the directorate's Nonmetallic Materials Division, for contributions supporting both operational and future Air Force systems as well as his expertise in high-temperature synthetic polymer chemistry. His individual efforts and technical leadership working with benzocyclobutene (BCB) and aromatic heterocyclic polymer systems led to numerous successes in the directorate's Polymers Branch and were critical to the transitioning of research breakthroughs for industrial development.

Background Each year, the 15,000-member Affiliate Societies Council recognizes engineers and scientists from throughout the Greater Dayton/Miami Valley area for outstanding technical accomplishments in their research field. Dr. Tan was one of 11 individuals honored at the organization's 44th Annual Awards Banquet in conjunction with National Engineers' Week.

Dr. Tan is a principal research chemist and the directorate's research group leader for polymer synthesis and characterization. In addition to leading and conducting in-house research in structural, opto-electronic and multifunctional materials, he also initiates and monitors research and development contracts complementary to the directorate's in-house research programs.

Dr. Tan's achievements cover a diverse range of scientific and technological areas. He discovered a new addition cure chemistry that led to the development of BCB materials; conceived and demonstrated a chemical route to improve the toughness and use temperature of bismaleimide resins using addition chemistry; and successfully developed a family of new rigid-rod, high-molecular-weight, pseudo-ladder polymers.

Dr. Tan designed and synthesized acid-stable thermoset monomers for use as a matrix resin in molecular composite technology. He also conceived and experimentally proved a route to control the semiconductivity of high-temperature polymers by incorporating triarylamino and diphenylamino functions into rigid-rod backbones.

Dr. Tan's credits include 92 published articles, 65 presentations, and 39 patent actions. He is a leading expert in his field and recognized nationally and internationally for his work. Dr. Tan earned his undergraduate degree in chemistry from Harvey Mudd College, in Claremont, California, in 1976 and received a doctorate degree in inorganic chemistry at Indiana University in 1981. He is a former assistant professor of chemistry at Wright State University in Dayton, Ohio, and a former research scientist for the University of Dayton Research Institute, also in Dayton, Ohio.

High-Temperature Materials Research Team Receives Star Team Award for Outstanding Contributions

Payoff The selection of Dr. Dennis M. Dimiduk's High-Temperature Materials Research Team for an Air Force Office of Scientific Research (AFOSR) Star Team Award recognizes group and individual achievement and highlights the contributions of the Materials and Manufacturing Directorate. The team's selection exemplifies the technical expertise, professionalism, and dedication of the men and women in the directorate and also enhances the directorate's key role as the last remaining domestic center of excellence investing in the development of titanium aluminide (TiAl) base alloys.

Accomplishment AFOSR recently presented a Star Team Award to Dr. Dimiduk and his team for outstanding contributions to the Air Force and Department of Defense (DoD) including 19 published, accepted, or submitted journal articles; 3 invention disclosures and patents; 7 conference proceedings; and 12 invited talks in 2002. The award recognizes teams of researchers and leaders who demonstrate world-class excellence in their chosen areas of research. The combined effort clearly impacts the high-temperature materials science and engineering community at large and directly supports several immediate objectives of the Air Force and DoD.

Background Dr. Dimiduk is an internationally recognized scientist and leader in advanced metals and intermetallic alloys. His contributions include pioneering research that enabled the successful development of a revolutionary class of advanced gamma TiAl for Air Force applications; patenting an ultra-high-strength, fully-lamellar gamma alloy that served as an enabling technology for rotors in the Integrated High Performance Turbine Engine Technology Phase III program; and patenting intermetallic alloys for first-stage turbine airfoils in support of the Versatile Affordable Advanced Turbine Engine studies.

The High-Temperature Materials Research Team played a critically important role in defining the mechanisms controlling the processing-structure-property relationships in gamma TiAl alloys. Their effort focused on developing an understanding and control of nanometer-scale microstructural effects on strengthening and development of advanced high-temperature materials with a unique balance of strength, high-temperature creep resistance, and fracture properties.

This research helps with the design of advanced fracture-critical engine components from these lightweight, revolutionary materials. Continuing research using these new materials could lead to revolutionary levels of turbine engine performance, attainable through expanded utilization of the outstanding properties in rotors, low-pressure turbine blades, and engine casings.

Dr. Dimiduk's team has a profound influence on the design concepts and development of advanced aerospace systems, hypersonic vehicles, and advanced aircraft engines. He has received several high-level awards for his outstanding accomplishments including the 1991 Alan T. Waterman Award for Science. AFOSR has named Dr. Dimiduk a Star Team Leader twice before. He is a recipient of the Outstanding Engineers and Scientists Award presented annually by the Affiliate Societies Council of Dayton, Ohio.

SAMPE Honors ManTech's Dr. Abrams with Fellow Status

Payoff The Society for the Advancement of Materials and Process Engineering (SAMPE) elected Dr. Frances L. Abrams, of the Materials and Manufacturing Directorate, as a Fellow of the society. The Fellow award represents prestigious recognition of a SAMPE member for distinguished contributions in the fields of materials and processes.

Accomplishment SAMPE elected Dr. Abrams a Fellow of the society for her long history of exemplary public service to her country through the application of her knowledge in composite processes that improve, sustain, and decrease manufacturing costs of Air Force weapon systems. SAMPE considers her a role model for many of today's composite technology specialists. Induction of new Fellows takes place during the annual International SAMPE Symposium and Exhibition each May in Long Beach, California.

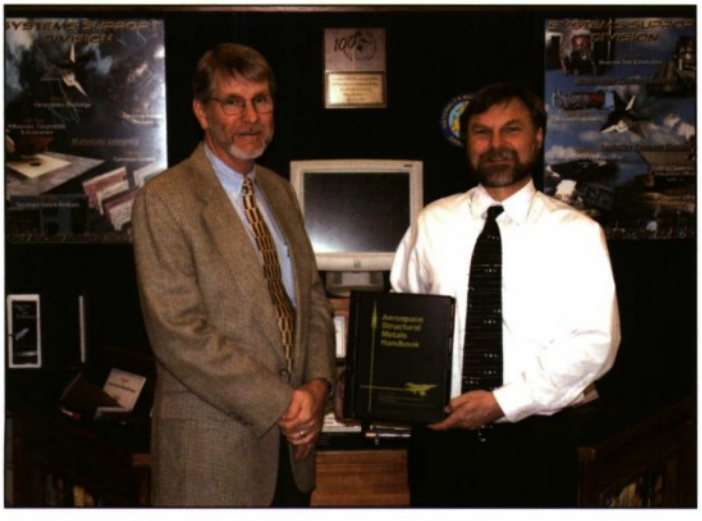
Background Dr. Abrams, a senior engineer for the Manufacturing Technology (ManTech) Division, is one of the leading experts in the world in the processing of advanced composites. Government and industry experts hold Dr. Abrams in high regard for her work in phenolic (a resin) processing as well as advanced ablative (a protective coating) and carbon-carbon propulsion materials and components. She served as a materials and process consultant to numerous Air Force and National Aeronautics and Space Administration systems, solving real-time process control issues.

She planned for, performed research in, and managed many of the leading composite materials and processing initiatives over the past two decades. Currently, Dr. Abrams is the program manager for the Department of Defense and industry's Composites Affordability Initiative's Systems Engineering Team, providing leadership and technical expertise to the Air Force, Navy, and the US airframe industry.

A native of Oregon, Dr. Abrams received her Bachelor of Science Degree in Chemistry from Colorado State University in 1975, a second Bachelor of Science Degree in Chemical Engineering from the University of Dayton (UD) in 1981, and completed her doctorate work in materials engineering from UD in 1995. Dr. Abrams began work with the directorate in 1979 under a co-op program for engineering students at UD and accepted a full-time position as a materials engineer with the laboratory in 1980.

Materials and Manufacturing Directorate Manages Technical Handbook Under Successful CRADA

Payoff The *Aerospace Structural Metals Handbook* (ASMH), produced under a Cooperative Research and Development Agreement (CRADA), provides information and data benefits to the Air Force, Department of Defense, and the aerospace community at no cost to the Air Force. The ASMH serves as a transition tool for emerging materials and facilitates the transfer of technology through timely selection of materials supporting research and development, maintenance and operations, and systems planning. The Air Force uses the annual royalties for laboratory activities complementary to its mission.



Accomplishment The Materials and Manufacturing Directorate successfully managed the production of the ASMH and two other technical publications frequently used throughout the aerospace world for more than a decade. The directorate added a new volume to the ASMH, combined with periodic updates to all three major publications, under a CRADA initiated more than 10 years ago. Managed by the directorate's Systems Support Division, the agreement helps ensure proper selection and understanding of materials used across the entire aerospace spectrum.

Background The ASMH is a unique source for referenced alloy data of special interest to all users of high-performance metals. The handbook permits researchers to select an alloy for a particular application with a working knowledge of typical physical and mechanical properties and, at the same time, allows consideration of the limiting load-carrying factors associated with the service condition or metallurgical history of the alloy. The handbook covers such materials as wrought steel, cast iron, wrought stainless steel, cast steel, cast stainless steel, structural steels, wrought and cast aluminum, copper, brass, bronze, magnesium, and titanium.

Information and data contained in the ASMH assist materials' properties users. Individual chapters on each alloy describe such factors as commercial designations, specifications, composition, heat treatment, physical properties, and environmental effects.

The handbook also provides critical information and data on each alloy's mechanical properties and performance at various temperatures, in formats geared for engineering applications. The directorate also makes revisions quarterly with assistance from the National Aeronautics and Space Administration.

In 1991, the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) at Purdue University, entered into a CRADA with the directorate for the continued technical maintenance, publication, and distribution of the handbook. Since then, the directorate has managed the ASMH program along with two other important publications—the *Structural Alloys Handbook* and the *Composites Failure Analysis Handbook*—all at no cost to the Air Force for principal expenses such as distribution, maintenance, and marketing. The ASMH is available for purchase from CINDAS in either hard copy or compact disc format.

Dr. Charles E. Browning Receives 2002 Presidential Rank Award

Payoff The selection of Dr. Charles E. Browning, of the Materials and Manufacturing Directorate, for the 2002 Presidential Rank Award in the Meritorious Category exemplifies his dedication, professionalism, and contributions to the Air Force and the United States. It recognizes his mission-critical role in support of the warfighter and US national security.

The award also celebrates the directorate's revered status as an internationally recognized center of excellence for materials research and development and manufacturing technology. Only a very small percentage of the Senior Executive Service/Senior Intelligence Executive Service Corps is eligible for this honor each year.

Accomplishment Dr. Browning, Director of the Materials and Manufacturing Directorate, received the 2002 Presidential Rank Award for sustained extraordinary accomplishments and results and for outstanding contributions to the nation and the American people. Dr. Browning was one of only 12 senior executives in the Air Force to earn the award, presented by the Secretary of the Air Force, Dr. James G. Roche, in Washington DC.

Background Each year, the President of the United States recognizes a small group of exceptional senior executives with Presidential Rank Awards. Winners of this prestigious honor are strong leaders, professionals, and scientists who achieve results and consistently demonstrate strength, integrity, and diligence as well as a relentless commitment to excellence in public service.

Award winners are chosen through a rigorous selection process. Agency heads nominate award winners, boards of private citizens evaluate them, and the President approves the winners. The criteria focus is on leadership and results. All recipients receive a framed certificate signed by the President.

The directorate develops materials, processes, and advanced manufacturing technologies for military aircraft, spacecraft, missiles, rockets, and ground-based systems and their structural, electronic, and optical components. Under Dr. Browning's leadership, the directorate directly supports Air Force product centers, logistic centers, and operating commands through expertise in metallic and nonmetallic structural materials; nondestructive inspection; materials used in aerospace propulsion systems; sensor materials; laser-hardened materials; systems support; and advanced manufacturing methods designed to solve system, expeditionary deployment, and operational challenges.

Dr. Browning is responsible for the planning and execution of the Air Force's advanced materials, processes, and manufacturing technology programs that support all elements of Air Force acquisition and sustainment. He is also responsible for interfacing these specific areas throughout the corporate Air Force and Department of Defense, while leading an organization of approximately 530 government employees with a yearly budget of nearly $350 million.

Engineer Selected as One of 50 Most Important Hispanics in Business and Technology

Payoff Ms. Mayra Martinez's dedication and skill have led to improvements in the financial execution of the Materials and Manufacturing Directorate's entire $14 million laboratory operation budget and its marketing and information dissemination efforts. Her efforts directly resulted in program management improvements and paid off with top-notch candidates desiring collaboration and employment opportunities at the directorate.

Her selection for this honor recognizes both individual achievement and the scientific contributions of personnel at AFRL. It also enhances the directorate's reputation as a world leader in materials research and development and highlights the directorate's efforts to support Air Force operational requirements.

Accomplishment The *Hispanic Engineer & Information Technology* magazine recently selected a materials engineer from the directorate as one of the country's most important Hispanic executives in technology and business. The magazine selected Ms. Martinez, a team leader in the Integration and Operations Division, from hundreds of candidates in government, academia, and industry, based on her outstanding management and leadership of directorate laboratory operations, technology transfer, public affairs, marketing, and educational outreach programs.

Background Ms. Martinez earned her undergraduate degree in mechanical engineering from the University of Puerto Rico, and her master's degree in materials engineering from the University of Dayton. In 1988, she began her career with Wright Laboratory, AFRL's predecessor, where she was a project engineer highly involved in the formation, development, and management of technology programs.

Ms. Martinez joined the directorate's Nonmetallic Materials Division's Structural Materials Branch in 1995, lending her significant leadership skills and technical expertise to a variety of programs. In 1996, Ms. Martinez became the program manager for the directorate's Basic Research Development program, where she led the financial execution of a $13 million program and ensured prompt execution of 33 tasks through the Air Force Office of Scientific Research. In this capacity, she managed, tracked, and reported funding execution and financial information to the directorate's director and chief scientist.

In 2000, Ms. Martinez became the team leader for the directorate's Programs Group, where she manages the directorate's laboratory operations, technology transfer, public affairs, marketing, procurement, dual use, small business, and education outreach programs. Ms. Martinez also manages the directorate's Technology Information Center. In addition, she coordinated efforts with the Plans and Programs branch chief to develop new civilian personnel position descriptions, which yielded positive results.

Scientist Earns Air Force Basic Research Award Honorable Mention for Contributions in Conductive Polymer Cladding Research

Payoff Dr. James G. Grote's conductive polymer cladding research, adopted by all nonlinear optic (NLO) polymer device fabricators including industry, universities, and Department of Defense laboratories, rendered these devices viable for both ground and space-based, high-performance Air Force systems, potentially including polymer-based lasers. His research enables the development of not only new devices with world-record operating performance, but also of state-of-the-art NLO polymer materials with diverse applications for both the military and the private sector. Dr. Grote's research could also lead to significant reductions in associated fabrication and manufacturing costs.

Accomplishment Dr. Grote, a senior research scientist at the Materials and Manufacturing Directorate, received an Air Force Basic Research Award Honorable Mention for outstanding contributions in conductive polymer cladding. This award recognizes Dr. Grote, of the directorate's Survivability and Sensor Materials Division, for pioneering work in the theory and materials processing of NLO polymer-based electro-optic (EO) devices, which can support current and future systems.

The award also recognizes Dr. Grote for advancing the fundamental understanding, design, development, assessment, and performance of electronics. His research enables the Air Force to meet its high bandwidth, low operating voltage and performance goals in a relatively short time and advances the potential for NLO polymer-based EO devices becoming the industry standard.

Background Dr. Grote received the coveted Air Force Basic Research Award Honorable Mention for several outstanding accomplishments in the field of opto-electronics and, in particular, his contributions in optical interconnects for multi-chip module integration. His research focuses on high-performance semiconductor, polymer, and ferro-electric-based opto-electronic interconnects and devices as well as optical lithography for interconnect and device fabrication.

Dr. Grote's team investigated the shortfall in actual performance achieved, relative to theoretical performance, for NLO polymer-based EO devices for Air Force systems. NLO polymer-based devices offer numerous attractive advantages over EO devices based on alternative materials.

NLO polymers have low dielectric constants and demonstrate a tolerance to high levels of irradiation for potential use in space-based applications. Also, Dr. Grote and his research team synthesized the NLO polymers with tailorable, high non-linearity to demonstrate the first sub-1 volt operating voltage for an NLO polymer EO device. It was, in fact, the lowest operating voltage reported for any EO device. Potential sub-1 volt device operation is required for integration into Air Force systems and is also useful for commercial applications.

Dr. Grote holds a doctorate degree in electrical engineering from the University of Dayton. He is a former Avionics Directorate Engineer and Scientist of the Year and an adjunct professor in the Electrical and Computer Engineering Department at the University of Dayton as well as an advisor for graduate students there and at the University of Cincinnati. He is a 2002 recipient of the directorate's prestigious Charles J. Cleary Award for Scientific Achievement.

Air Force Honors Senior Materials Engineer for Pioneering Research on Fiber Coatings

Payoff Dr. Randall S. Hay, of the Materials and Manufacturing Directorate, was honored for his efforts to understand the complexities of the fiber coating process and eliminate fiber strength degradation on coatings with advanced chemistries, eliminating a key obstacle to the development of these materials for use in severe operational environments. Subsequent work has proceeded rapidly and shows substantial benefits in terms of real composite properties.

Dr. Hay's discovery of the cause of strength degradation has broad implications in ceramic corrosion in nearly all high-temperature systems. His selection for Honorable Mention helps recognize the contributions of men and women of the AFRL community and enhances the Materials and Manufacturing Directorate's reputation as a world leader in materials research and development.

Accomplishment Dr. Hay, a senior materials research engineer in the Metals, Ceramics, and Nondestructive Evaluation Division recently received an Air Force Basic Research Award Honorable Mention for pioneering research supporting the continued development of fiber-reinforced ceramic matrix composites for critical air and space applications. Dr. Hay identified the mechanisms causing strength degradation of coated fibers (stress corrosion cracking by surface decomposition products of the coating precursors). He and his coworkers then devised a set of experiments to prove these mechanisms existed and found an efficient way to eliminate the problem, while improving high-temperature strength retention.

Background Fiber-reinforced ceramic matrix composites (CMC) provide significant performance and durability benefits through the combination of temperature capability and mechanical integrity for a diverse range of critical Air Force applications. Examples of these applications include turbine and rocket engine components as well as thermal protection materials on currently fielded, developmental, and future air and space platforms. CMC materials have the potential to operate at temperatures in excess of 2,200° F, well above the operating capabilities of most metals.

Dr. Hay's research concentrates on fiber-matrix interface development, with an emphasis on fiber coating processes, characterization, solid-state reactions, sol-gel thin film development and basic interface science, and on identifying interface chemistries that possess the mechanical behavior and capability to withstand very high temperatures under severe conditions. Working with other members of the directorate's Ceramics Research Group, Dr. Hay led a concentrated research effort on oxidation-resistant, fiber-matrix interfaces.

By solving the fiber corrosion problem, Dr. Hay and his colleagues removed a major barrier to the development of future, revolutionary, high-temperature composites for a wide range of Air Force applications. The directorate expects Dr. Hay's improved coating process to apply to other oxide-coating chemistries as well.

Dr. Hay earned undergraduate degrees in chemistry, mechanical engineering, and geomechanics from the University of Rochester, and received his doctorate degree in geophysics from Princeton University. He completed postdoctoral research at the Massachusetts Institute of Technology. Dr. Hay holds several patents related to fiber coating and thin films and has published 55 articles on phase transformations, microstructural development, and fiber coating. He is a 1997 recipient of the directorate's highest scientific honor, the Charles J. Cleary Award, and is an associate editor of the *Journal of the American Ceramic Society*.

Materials Researcher Appointed Senior Scientist for Contributions to Structural Materials Life Prediction

Payoff The senior scientist (ST) position is one of the highest a civilian scientist can achieve and is comparable to the rank of brigadier general. Dr. James Larsen's appointment reflects his dedication to in-house research, his participation in key Materials and Manufacturing Directorate contractual research programs, his important technical leadership on numerous flagship efforts, and his reputation as an expert in materials science and engineering. His selection also enhances AFRL's reputation as a world leader in materials research and development and recognizes the skill and professionalism of directorate scientists and engineers.

Accomplishment The directorate recently appointed Dr. Larsen as ST for structural materials life prediction. The appointment is the result of Dr. Larsen's outstanding technical, professional, and scientific achievements including supporting operational and future Air Force systems as leader of an in-house research group focusing on life prediction and durability of metallic and ceramic materials. His individual in-house research efforts and technical leadership working with monolithic alloys, intermetallics, metal matrix composites, and ceramic matrix composites led to numerous successes in the directorate's Metals, Ceramics, and Nondestructive Evaluation Division including new analytical and computational models for material life prediction.

Background Currently, Dr. Larsen is the directorate's research leader for life prediction and durability of metallic and ceramic materials. In this capacity, Dr. Larsen has full responsibility and authority for the direction and productivity of his research team, which consists of approximately 45 government and contract scientists, engineers, technicians, and graduate and undergraduate students.

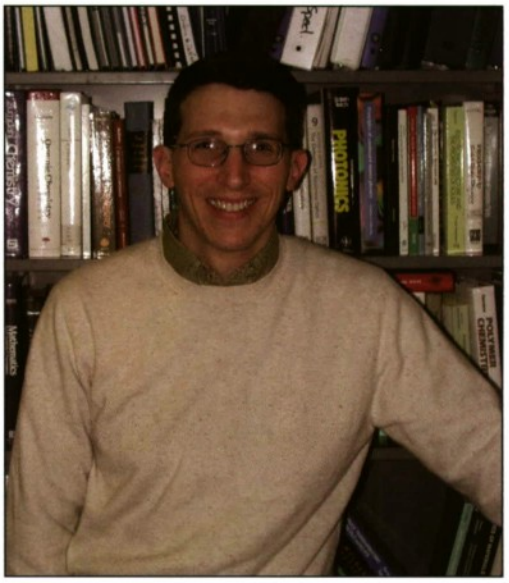
In-house research performed by Dr. Larsen's group addresses the full spectrum of life-prediction problems of current and future aerospace materials. Dr. Larsen conceives and develops goals for the effort and initiates, advocates, and conducts research programs to cover a diverse range of scientific and technological areas.

In his personal research, Dr. Larsen identifies problems, performs experiments, analyzes and interprets data, and develops new analytical and computational models for life predictions. His individual and group research efforts have had a decisive effect on development of the science and technology of mechanical behavior and life prediction of advanced aerospace materials. He has been a major influence on the activities of colleague researchers in government and industry.

Dr. Larsen is a critical participant in the directorate's contractual research program, having provided key technical leadership on numerous contracts. He also served as a key member for various technical teams throughout the directorate as well as the Propulsion and Air Vehicles Directorates. His significant expertise has helped in the areas of materials science, fracture mechanics, mechanical behavior and life prediction of metallic and ceramic matrix composites, and statistical and numerical analysis.

Nanotechnology Research Team Earns AFOSR's Star Team Award

Payoff The selection of Dr. Richard Vaia's Nanostructured Polymers and Nanocomposites Team for an Air Force Office of Scientific Research (AFOSR) Star Team Award recognizes group and individual achievement and highlights the contributions of the Materials and Manufacturing Directorate. Their selection exemplifies the technical expertise, professionalism, and dedication of the men and women of the directorate and enhances the organization's key role as a center of excellence in nanotechnology and materials research and development.



Accomplishment The directorate's Nanostructured Polymers and Nanocomposites Team, led by Dr. Vaia, earned an AFOSR Star Team Award for important contributions to the Air Force and national defense. The award recognizes teams of researchers who demonstrate world-class status and excellence in their chosen areas of research.

AFOSR recognized Dr. Vaia's team for helping to create a fundamental knowledge base required to develop polymer-based nanostructured materials' technologies for a diverse range of Air Force applications. Their research expands the understanding needed to establish predictable structure-processing-property relationships for polymer-based nanostructured materials and also helps demonstrate the feasibility of using these revolutionary materials to address unique military needs.

Background The Star Team Award fosters excellence throughout the research community and highlights the critical role of basic research within the Air Force's broad technology spectrum. AFOSR recognized the Nanostructured Polymers and Nanocomposites Team for advancing the fundamental knowledge base required for the intelligent selection, design, and utilization of nanostructured polymer and nanocomposite materials used to support Air Force objectives. This knowledge base encompasses coordinated efforts in theory and modeling, successful development of cost-effective synthesis and fabrication schemes that users can tailor to match specific needs, clarification of structure-processing relationships, and determination of value-added properties such as shape recovery, random lasing, and self-passivation.

Team members included Dr. Vaia, Dr. Hilmar Koerner, Dr. Rachel Jakubiak, Dr. Fatma Vatansever, Dr. Wansoo Hsu (a visiting scientist and professor from South Korea), Dr. Mark Pender, Dr. Kelly Anderson, Mr. Shane Juhl, Ms. Abigail Cooley, and Mr. Gary Price. Student participants included Mr. Nate Pearce, Mr. Dean Brown, and Mr. Dave Jacobs. Key government collaborators (and their groups) included Dr. Tim Bunning and Dr. Morley Stone, of the directorate's Survivability and Sensor Materials Division; Mr. Max Alexander and Dr. Loon-Seng Tan, of the directorate's Nonmetallic Materials Division; and Dr. Barry Farmer, the directorate's chief scientist.

The potential military utility for nanostructured polymer and nanocomposite materials is vast, ranging from the ground soldier to satellite systems. Potential applications include plastic propellant storage tanks; elastomeric conductive caulks; high-strength, conductive matrix resins for space structures; flexible conductive films for radar substrates; next-generation matrix resins for aircraft; space durable, lightweight films and structures; and reconfigurable space membranes for antennas, solar collectors, and space-based radar.

AFOSR Recognizes Award-Winning Biologist and His Research Team for Contributions to National Defense

Payoff Presented annually, the Air Force Office of Scientific Research (AFOSR) Star Team Award recognizes teams of researchers who have effectively demonstrated, through their track record, world-class status and excellence in their chosen areas of basic research. The Star Team Award recognizes the talent, professionalism, and dedication of the men and women in AFRL and enhances the laboratory's reputation as a leader in research and development.

Accomplishment AFOSR recently selected a directorate team of research scientists, engineers, and technicians led by Dr. Morley O. Stone, a research biologist, to receive a Star Team Award from AFOSR for outstanding contributions to science and national defense. AFOSR recognized Dr. Stone's research team for significant advances in biomimetics and biotechnology, which could have a far-reaching impact on scientific research and applications supporting the Air Force.

Background Dr. Stone is the principal research biologist and biotechnology direction leader in the directorate's Survivability and Sensor Materials Division. The research emphasizes and focuses on how best to combine the revolution in recombinant deoyxribose nucleic acid (DNA) technology with traditional materials science applications in areas such as biomimetics, materials science, bioMEMS, and bioNEMS (micro- and nano-electromechanical systems).

Biomimetics looks at how nature organizes materials or uses biological macromolecules to gain a particular function; for example, how biology senses electromagnetic radiation outside of the visible region. Materials science uses biotechnology to create unique polymeric materials and to better understand processes like biomineralization.

BioMEMS/NEMS consider the interface of biological macromolecules with micro- and nano-fabrication. Biologically derived molecules, for example, serve as catalysts, motors, and/or binding agents. Dr. Stone and his associates explore ways to apply these activities to traditional silicon-based MEMS devices.

Dr. Stone graduated with honors from Wright State University in 1991 with a bachelor's degree in biological sciences, and he earned a doctorate degree in biochemistry from Carnegie Mellon University in 1997. He is a recipient of the Charles J. Cleary Award (the directorate's most prestigious scientific achievement honor) and the Air Force Basic Research Award Honorable Mention.

Dr. Stone won the highly coveted AFRL Commander's Cup in 2002 and was nominated for the Arthur S. Fleming Award for scientific achievement. Dr. Stone is an adjunct professor at The Ohio State University, an advisor to the National Research Council, and was nominated for the Massachussetts Institute of Technology's *Technology Review 100*, recognizing top professionals in the nation. His work appeared in numerous publications, and he is an invited speaker at symposiums and other scientific gatherings nationwide.

Chief Scientist Named ASME Life Fellow

Payoff The American Society of Mechanical Engineers (ASME) recently awarded Dr. Bob Sierakowski, the chief scientist of the Munitions Directorate, with the prestigious honor of ASME Life Fellow. ASME promotes and enhances the technical competency and professional well-being of its members and, through quality programs and activities in mechanical engineering, better enables its practitioners to contribute to the well-being of humankind.

Accomplishment The ASME honored Dr. Sierakowski, a Fellow since 1985, for his long-term contributions to the society including chair of Structures and Materials Committee of the Aerospace Division, chair of the Aerospace Division, and service on the national nominating committee. As the directorate's chief scientist, Dr. Sierakowski advises the director, as well as the commander of AFRL, on research plans and programs in conventional weapon systems and armament basic research. He advises on the relative status of scientific and technical competence within the directorate, the employment of consultants and experts, and the state of technology available from sources outside the directorate.

Dr. Sierakowski functioned in several positions within the engineering community, but his forte is as an educator and consultant/advisor to military organizations. Due to his superior abilities in these areas, the directorate chose him to fill his present position in 1997. The Connecticut native has authored or co-authored more than 150 publications including 3 technical books.

Background Founded in 1880, ASME is a nonprofit educational and technical organization serving a worldwide membership of 125,000. The member-elected Board of Governors and its 5 councils, 44 boards, and hundreds of committees in 13 regions throughout the world perform ASME's work. Four hundred combined sections and student sections serve ASME's worldwide membership.

Munitions Directorate's SBIR Manager Receives Tibbetts Award

Payoff Mr. Richard "Dick" Bixby, the Munitions Directorate's Small Business Innovation Research (SBIR) program manager, recently received the United States Small Business Administration's highest national recognition for research and development in support of the SBIR program. The award, named for Mr. Roland Tibbetts who led the federal effort to create the SBIR program, marks the accomplishments of people and businesses that work with or on behalf of the SBIR program.

Accomplishment As the directorate's SBIR focal point for 10 years, Mr. Bixby provided administrative oversight for more than $100 million in SBIR resources, representing 10 to 12% of the directorate's total budget. Involved in many different activities, he brings a unique vision to the directorate's SBIR program. He understands not only the government's point of view, but also that of businesses, both large and small.

Background Mr. Bixby's leadership in the SBIR program allows the directorate to advance numerous enabling technologies that are important in the development of future munitions systems for the Air Force. These technologies range from material processing, explosives, fuzing, guidance, weapons effectiveness, and seeker development.

The success in developing innovative technology through SBIR projects makes them highly valued within the directorate. These projects are fundamental components of the directorate's mission to develop and transition affordable weapons technology.

Mr. Bixby's efforts helped position the directorate to provide a fully integrated weapons concept with options for enhancing the warhead package lethality based on innovations in material science. Enhancing the lethal package provides a unique national defense capability for systems like the Powered Low-Cost Autonomous Attack System.

Munitions Directorate Scientist Receives Honor for Life's Work

Payoff The Minerals, Metals, and Materials Society (TMS) and the American Institute of Mining and Metallurgical Engineers recently honored Dr. Ronald W. Armstrong, a senior scientist in the Munitions Directorate, for his lifetime achievement by sponsoring a symposium in his honor at the TMS' 132nd Annual Meeting & Exhibition symposium held in San Diego, California.

Accomplishment Dr. Armstrong is responsible for contributing technical leadership to the Air Force basic research mission of sustaining superiority in the science and engineering of energetic and related materials properties and performances. He provides technical reviews, assesses programs, establishes research strategies for new study areas, and performs theoretical and experimental research while interacting with other Air Force and government agencies.

Dr. Armstrong is also a Professor Emeritus in the Department of Mechanical Engineering at the University of Maryland College Park. His lifetime contributions to these and related fields were honored through this recognition.

Background Dr. Armstrong's main efforts relate to energetic material technologies and promoting collaboration with foreign governments/organizations, other services and agencies, universities, and industry, as relevant to the directorate thrusts and long-range goals involving energetic materials and their uses. Dr. Armstrong's research topics include fundamental aspects of the mechanics, physics, and chemistry of high explosives; the mechanical/initiation behavior of nanoparticle systems; and the high-deformation rate/shock behavior of condensed matter.

At TMS symposia, attendees can join more than 4,000 science and engineering professionals, representing more than 70 different countries, who come together for the opportunity to add to their own store of knowledge by capitalizing on the expertise and experience of their colleagues. The symposia features more than 200 sessions with more than 1,900 individual presentations scheduled on topics in precious metal extraction, aluminum processing, high-temperature superconductors, or just about any other materials field or metallurgical discipline.

AFRL Presents Century of Flight Awards at 2003 Dayton Air Show

Payoff Five high school students from the United States edged out more than 170 in a national science fair competition to win prize money and an expense-paid trip to Dayton to attend the 100th Anniversary of Powered Flight celebration for both themselves and a parent. The winners clearly demonstrated great potential to become members of the next generation of scientists and engineers.

(Left ta right: Major General Paul Nielsen, Mr. Ray He, Mr. Eric Mueller, Mr. Stephen Kennedy, Ms. Laura Wong, and Ms. Lauren Hansen)

Accomplishment Major General Paul Nielsen, AFRL Commander, presented Century of Flight Awards at the 2003 Dayton Air Show to Ms. Lauren Hansen of Midway, Utah; Mr. Eric Mueller of Granbury, Texas; Mr. Stephen Kennedy of Indianapolis, Indiana; Ms. Laura Wong of Yardley, Pennsylvania; and Mr. Ray He, of Landisville, Pennsylvania. Ms. Hansen and Mr. Mueller each won $2,000; Mr. Kennedy won $3,000; Ms. Wong won $4,000; and Mr. He won the grand prize of $6,000. AFRL recognized these five students for their outstanding papers based on their research and possible aerospace applications.

Background AFRL, which manages the Air Force Science Fair program, has a long history of involvement in both local and national science fairs. The Centennial of Flight celebration was an opportunity to link science fair participants to the importance of aerospace research. AFRL conducted the contest as a one-time event in 2003 as part of the 100th Anniversary of Powered Flight celebration to highlight Dayton's anniversary activities and help encourage young people to pursue aerospace science.

AFRL gave approximately 800 students, who competed in regional and state science fairs across the United States, the opportunity to submit a 10-page paper based on their science fair research and possible aerospace applications. From that group, 175 stepped forward to meet the challenge.

AFRL required the students to demonstrate the potential positive impact of their research on Air Force capabilities. Scientists from AFRL technology directorates evaluated the entries, and the AFRL Research Council determined the final selection of winners.

Propulsion Directorate Scientist Named ASME Fellow

Payoff The American Society of Mechanical Engineers (ASME) honors its distinguished members with the title of Fellow for promoting the art, science, and practice of mechanical engineering throughout the world. The Fellow grade is the highest elected grade of membership within ASME, the attainment of which recognizes exceptional engineering achievements and contributions to the engineering profession.

Accomplishment The ASME recently named Dr. William M. Roquemore, a senior research scientist for the Propulsion Directorate, an ASME Fellow for 2002. The honor recognizes Dr. Roquemore's significant achievements and contributions to the engineering profession in his role as senior research scientist in the field of air-breathing combustion, diagnostics, and fuels technologies.

Background Dr. Roquemore has nearly 40 years of research to his credit and is a Wright Laboratory Fellow (1989), an AFRL Fellow (1991), and also an American Institute of Aeronautics and Astronautics Fellow (1999). He has published more than 150 research and technical articles that identified technical barriers and then formulated innovative and pioneering approaches to overcome them.

Dr. Roquemore made significant contributions to air-breathing combustion with his work on the revolutionary Trapped Vortex Combustor (TVC), which he coinvented. TVC demonstrates significant improvements in performance while drastically reducing engine emissions.

With this groundbreaking approach to combustor design, the TVC has the potential to expand the flight envelope of Air Force aircraft by reducing lean blowout while significantly reducing oxides of nitrogen and volatile organic compound emissions. The TVC concept won the 2001 Pollution Prevention Program of the Year Award from the Strategic Environmental Research and Development Program Office.

Dr. Roquemore also has patents for a fiber optic device that measures temperature remotely and for materials designed to prepare vertical takeoff and landing sites. His body of work also includes research efforts involving the development and application of laser diagnostic techniques to combustion, thermally stable jet fuels, integrated fuel system technologies, and soot-reducing additives for jet fuel.

Dr. Garscadden Wins 2002 Will Allis Prize

Payoff The Propulsion Directorate's Chief Scientist, Dr. Alan Garscadden, received the 2002 Will Allis Prize for the study of ionized gases. The American Physical Society (APS) bestows this prestigious award, established in 1989, in recognition of outstanding contributions to the study of ionized gases for gaseous electronics phenomena. Dr. Garscadden serves as technical advisor on a wide spectrum of aeronautical research including many facets of propulsion, aerospace power, hypersonics, laser physics, combustion, and plasma phenomena and applications.

Accomplishment The APS recognized Dr. Garscadden for his distinguished career in gaseous electronics, marked by a sustained creativity in linking fundamental processes to the macroscopic properties of gas discharges and plasmas, and for his dedicated role as an advocate for the field of gaseous electronics. He is known for his work in theoretical and experimental basic and applied research in nonequilibrium plasmas and energized gas flows, lasers, laser-based measurements, plasma processing of thin films, optical and mass spectroscopic measurements, electron impact cross sections and their influence on electron transport, and the derivation of collision cross sections from transport data.

Background Dr. Garscadden has authored more than 250 publications and presentations and served on many organizing committees for both national and international meetings and symposiums. He has served on various technical committees and several professional societies, reviewed more than 100 publications, authored several book chapters, and conducted approximately 120 invited lectures and presentations to peer audiences including plenary talks at international meetings. He also served as thesis adviser and adjunct professor for several local and national universities.

The APS represents more than 40,000 members. The society develops and implements effective programs in physics education and outreach to foster the health of the profession through its career and development initiatives. The APS named the award in honor of Dr. William P. Allis, who spent more than 40 years on the Massachusetts Institute of Technology faculty conducting theoretical research on plasmas in magnetic fields and the behavior of partially ionized gases.

Aerospace Propulsion Chief Named Chairman of Interagency Committee

Payoff Mr. Parker L. Buckley, Chief of the Propulsion Directorate's Aerospace Propulsion Office, now heads the executive committee of an interagency propulsion team designed to enhance missile, gun, and space propulsion research, development, and applications across the Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA).

Accomplishment The Joint Army, Navy, NASA, and Air Force (JANNAF) Committee recently named Mr. Buckley as the new chairman of the JANNAF Executive Committee. He will oversee the governing body of JANNAF and its interagency propulsion committee, which exists to promote and facilitate the exchange of technical information; establish standards; and affect coordination of research, exploratory development, and advanced development programs in the areas of missile, gun, and space propulsion.

Mr. Buckley and his team, in the directorate's Aerospace Propulsion Office, work on the development of ramjet and supersonic combustion ramjet (scramjet) technology and integration into combined-cycle engines. Applications of this technology include high-speed weapon systems and low-cost, on-demand access to space.

Background The JANNAF Interagency Propulsion Committee is composed of representatives from DoD and NASA and consists of technical subcommittees and ad hoc committees. JANNAF's work includes propulsion systems based upon chemical or electrical energy release intended for use in missiles, rockets, boosters, spacecraft, satellites, or guns. Technical areas of interest include air-breathing propulsion, combustion, exhaust plumes, propellant development, rocket nozzle technology, safety and environmental protection, and structures and mechanical behavior.

Mr. Buckley received a Bachelor of Science Degree in Aerospace Engineering from the University of Cincinnati in 1972 and a Master of Science Degree in Mechanical Engineering from the University of Dayton in 1981. He flew KC-135 Stratotankers as a reservist in the Ohio Air National Guard for 22 years and flew in Operation DESERT STORM.

Propulsion Directorate Engineer Honored with Top Air Force Award

Payoff The Air Force recently awarded Ms. Kathleen Sargent, a Propulsion Directorate engineer, with the 2002 Air Force Science and Engineering Award for Manufacturing Technology. She was recognized for her exceptional work in the development of turbine engine composite components and materials as well as the successful demonstration of a new design concept—a metal matrix composite (MMC) remote ring compressor rotor.

Accomplishment Ms. Sargent was responsible for bringing the design concept of the remote ring rotor to fruition by creating and leading a government and industry panel to address the shortcomings of this technology area. As a result of her efforts, the directorate devised a new method for fabricating the rings and successfully demonstrated the feasibility of the remote ring compressor rotor concept.

This concept, which allows the use of two MMC rings at the bore without embedding them into the monolithic rotor material, has a number of advantages over the state of the art. Among these advantages are dramatic increases in material strength and temperature capability, reduced weight, and a major fabrication simplification that reduces production and maintenance costs by more than 10%. This technology is vital to meeting the Phase III goals of the Integrated High-Performance Turbine Engine Technology (IHPTET) program.

Background The IHPTET program is an ongoing national program aimed at doubling the US military's 1988 propulsion capability. IHPTET is successfully completing its second of three phases toward achieving very aggressive goals.

To date, through coordinated Department of Defense and industry effort, IHPTET has validated numerous revolutionary propulsion technologies that provide durable performance with low production and maintenance costs for the US military's newest fighter systems. These technologies also provide significant upgrade potential for currently fielded systems.

IHPTET is radically changing the way industry designs and manufactures engine components. Structural design innovation is necessary to take full advantage of the advanced materials under development.

The challenge is to produce affordable structures that maintain their robustness while operating at increased temperatures. Designers require aluminides and new alloys that extend the operating temperatures of metallics to meet these challenges, along with advanced composite and non-metallic materials like the titanium metal matrix composite remote ring compressor rotor.

National ACS Honors Propellant Chemist

Payoff The American Chemical Society (ACS) recently presented Dr. Karl O. Christe (pictured center) with their 2003 Inorganic Chemistry Award. ACS awards recognize individual accomplishments in diverse fields of chemistry and are valued as pretigious awards. Dr. Christe is a research chemist and senior staff advisor at the Propulsion Directorate's Edwards Research Site.

Accomplishment ACS selected Dr. Christe for the 2003 Inorganic Chemistry Award based on his lifetime achievements in chemistry. Described by his colleagues as an unusually creative, imaginative, and highly skilled chemist, he has tackled some of the most difficult and challenging synthesis problems in chemistry.

The Defense Advanced Research Projects Agency (DARPA) and the Air Force Office of Scientific Research (AFOSR) currently fund Dr. Christe's studies, identified as high-energy density matter. He has earned a reputation for finding answers to chemical problems unsolvable by others. He has published more than 300 peer-reviewed papers and holds more than 60 patents.

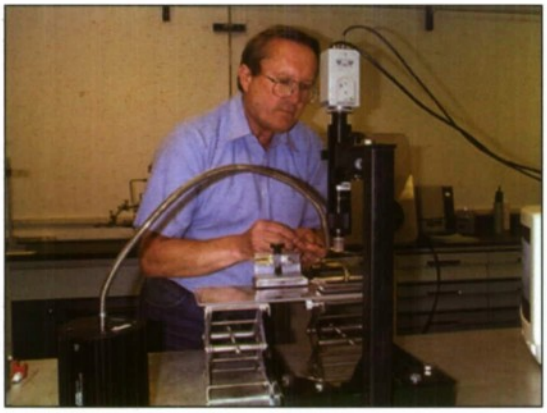
Background Dr. Christe and his coworkers are best known for their discovery of the N5+ cation in 1999. This was the first demonstration of a stable and energetic nitrogen species in 110 years and only the second ever discovered. The *Chemical & Engineering News* magazine recognized Dr. Christe's discovery as one of the top five chemistry achievements for the year. Dr. Christe is also active as a research professor at the Loker Hydrocarbon Research Institute at the University of Southern California, with funding from the National Science Foundation, AFOSR, and DARPA.

In 1986, Dr. Christe was also responsible for a process thought impossible—the preparation of elemental fluorine by chemical means. For almost 200 years, researchers unsuccessfully attempted this chemical process.

Dr. Christe won numerous honors for his scientific work including the 2000 Prix Moissan—an international chemistry prize named in honor of Henri Moissan, the winner of the Nobel Prize in Chemistry in 1906 and discoverer of the element fluorine by electrochemical means. The ACS also awarded Dr. Christe the 1986 ACS Award for Creative Work in Fluorine Chemistry.

New Microtube Patent Issued to Propulsion Researchers

Payoff Two Propulsion Directorate scientists recently received a patent for a new procedure for creating microscopic coils as well as free-standing microscopic tubes with any cross-sectional or axial shape. Drs. Phillip Wapner (left) and Wesley Hoffman (right) explored new ways to fabricate components used in miniature rocket engines, heat exchangers, and fluid separators as well as medical, dental, and scientific instruments. Until directorate scientists conceived this invention, it was impossible to fabricate many of the components this technology enables.



Accomplishment Drs. Phillip G. Wapner and Wesley P. Hoffman, researchers in the Propulsion Directorate's Propulsion Materials Applications Branch, recently received a US patent entitled "Method of Making Microtubes with Axially Variable Geometries." This patent describes a technique for manufacturing microtube devices, which have peripheral geometries that are not uniform along the microtube or microdevice axis.

Background The new process for manufacturing microtubes involves forming a complex mandrel, or core, around which the material is coated, cast, extruded, or pultruded. One or more metallic and/or nonmetallic materials surround the complex mandrel before the manufacturer removes the core by appropriate chemical or physical means, leaving a microtube structure with an axial profile duplicating that of the mandrel.

This technique overcomes some limitations associated with conventional processes such as lithographic techniques that use planar semiconductor material to manufacture microscopic channels. For instance, manufacturers can use this technique to make microtubes with a circular cross section, which is essential for many applications.

Microtubes manufactured by this process have numerous applications including heat exchangers, bellows, and actuators. There is particular interest in this technology for the manufacture of microelectromechanical, microfluidic, and micro-optical systems.

Propulsion Scientist Named SEM Fellow

Payoff The Society for Experimental Mechanics (SEM) selected Dr. Chi-Tsieh (Jimmy) Lui (left), the Propulsion Directorate's recognized expert in solid rocket propulsion, as an SEM Fellow. Mrs. Lui (center) was on hand as Dr. Arun Shukla (right), President of the SEM and Dean of the Engineering School at the University of Rhode Island, presented the award.

The SEM annually selects individuals as Fellows who distinguish themselves in some field in which the society has interest, who are members of the society for at least 10 consecutive years, and whose contributions to the society and the technical community justify this honor. SEM, an international society established in 1943, has selected 101 Fellows since 1975.

Accomplishment SEM selected Dr. Liu as a Fellow for his distinguished work and expertise in the fields of solid rocket propellant fracture mechanics and service-life predictions. Within the solid rocket propulsion world, Dr. Liu is the expert the Department of Defense and industry request for assessments and answers.

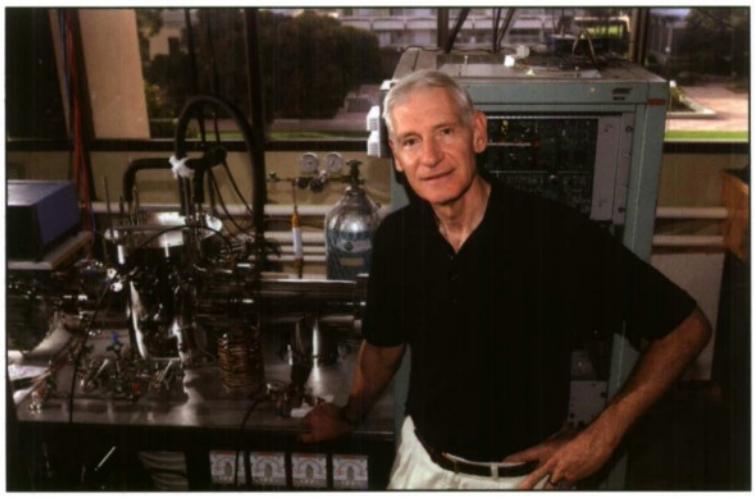
Background Dr. Liu, a retired directorate researcher, is an Intergovernmental Personnel Act (IPA) appointee to the directorate's Propulsion Material Applications Branch. His appointment in 2001 is through the Material Technology Center of Southern Illinois University at Carbondale. The IPA program enables the government to utilize the expertise of professionals in many fields.

The initiation as an SEM Fellow adds to Dr. Liu's prestigious list of awards. Among them is one of the Air Force's top research awards, the Harold Brown Award, named for the former Secretary of the Air Force who later served as the Secretary of Defense. This award, presented by the Air Force chief scientist's office to researchers who have made a substantial improvement to the operational effectiveness of the Air Force, recognizes significant achievements in research and development.

Dr. Liu received the Harold Brown Award for his research in solid rocket propellant behavior and service-life predictions. Dr. Liu's research enabled and validated measures used to improve the lifetime of space boosters, Intercontinental Ballistic Missiles, and tactical missiles, preventing launch delays and replacement costs and saving the nation at least $100 million.

Academic Partnerships Advance POSS Technology Payoff

Payoff The National Academies administer postdoctoral and senior research awards through its associateship programs. Each year there are an average of 800 scientists and engineers in the national program with 200 of the overall awards made to senior doctoral-level scientists. Federal laboratories and the National Aeronautics and Space Administration's research centers sponsor research associateship programs at over a hundred locations in the United States and overseas.



Accomplishment The National Academies selected Professor Stanley Edward Anderson, a member of Westmont College's Department of Chemistry, for a National Research Council Senior Research Associateship Award. The Air Force Office of Scientific Research and the Propulsion Directorate at Edwards Air Force Base, California, is sponsoring Prof Anderson for this internationally competitive award. The award will help him conduct studies of polyhedral oligomeric silsesquioxane (POSS) monomers during his sabbatical at the University of California Santa Barbara Chemistry Department.

Dr. Anderson's study of the nanoscale structure of POSS will help explain the unusual reinforcement or strength these molecules demonstrate. He has matched experimental crosssections of many POSS monomers with theoretical structures, using molecular modeling/molecular dynamics calculations.

Analyzing molecular structures of these special high-performance polymers, using ion chromatography/mass spectrometry techniques, should show, for the first time, the complex shapes of this family of polymers on a molecular level. It will provide greater understanding of their material attributes and the evidence that POSS is a complex nanostructure rather than a simple sphere.

Background POSS technology is an exciting new area of material science. POSS is a silicon-based super-plastic or polymer with ceramic-like material characteristics that provide thermal stability, flame retardation, abrasion resistance, and greater strength to a large family of plastics.

Ms. Kathy Catalano Named Wright-Patterson Senior-Level Security Specialist of the Year

Payoff Wright-Patterson Air Force Base, Ohio, named Ms. Kathy Catalano, of the Sensors Directorate's Security Office, as the base's Senior-level Security Specialist of the Year for her contributions in protecting the directorate's workforce and information.

Accomplishment Ms. Catalano transformed a bare-bones security office into a comprehensive and proactive program through her superb technical and managerial expertise. Her hard work resulted in the on-time occupancy of a new 63,000 square foot, multilevel security addition to the directorate's research complex. She was also instrumental in upgrading the directorate's force protection and operations security programs.

Background Ms. Catalano personally managed all of the security issues for the new $12.2 million addition to the directorate's main complex. She continuously reviewed secure facility regulations and requirements during all stages of installation and accreditation for the laboratories and offices that have multiple levels of security.

In response to the September 11th terrorist attacks, Ms. Catalano quickly integrated new directives and guidance, while rewriting new force protection procedures. She also recognized the need for better force protection for the directorate's people and resources.

Using an operational risk management approach, she assembled a team to determine critical upgrades to enhance the security posture including improved lighting, video surveillance monitoring, alarms, protective fencing, and a new mail delivery procedure. One of her main accomplishments was the creation of the automated public release system.

This restructuring of the directorate's operational security document public release process was in response to heightened concerns to protect United States technological superiority. Under her leadership, a team created, tested, and implemented a computer-automated process to support operational security peer reviews for all documents submitted for public release. The unit compliance inspection cited this process as a best practice.

Mr. Joseph Koesters Honored by Association of Old Crows

Payoff Mr. Joseph Koesters, of the Sensors Directorate's Electro-Optical (EO) Sensor Technology Branch, received the Association of Old Crows (AOC) 2002 EO/Infrared (IR) Award for his outstanding efforts as a supervisor and mentor. His significant developments in advanced technology programs include the areas of threat warning, expendable countermeasures, and deceptive jamming.

Accomplishment Mr. Koesters received the AOC's 2002 EO/IR Award for his outstanding work guiding accomplishments in the Laser Infrared countermeasures Flyout Experiment (LIFE) Advanced Technology program, the EO/IR Tracker Countermeasures Advanced Technology program, and Multifunction EO Defense of United States Aircraft (MEDUSA) program.

Background LIFE is a premier program developing advanced laser-based deceptive jamming technologies for transition to large aircraft. Under Mr. Koesters direction, the LIFE program conducted a series of outstanding live fire tests, demonstrating superior capability to detect and jam infrared threat missiles.

The goal of the EO/IR Tracker Countermeasures Advanced Technology program is to replace reactive directed IR countermeasures (DIRCM) with new laser-based capability, allowing early detection of seekers and acquisition/tracking systems prior to weapons employment. This technology program pushes technology to defeat emerging imaging threats as well as the scanning, reticle-based seekers in the current DIRCM implementations.

The MEDUSA program is investing in a 5-year effort to develop and demonstrate enabling technology to protect fighters, bombers, and low-observable aircraft from the growing EO threat. Solid-state conformal optical transceiver arrays, powerful search-and-detect lasers, and damage-level countermeasures are just a few of the enabling technologies under investigation.

Mr. Donald Tomlinson Receives the Red Cross 2002 All-Ohio Hero Award

Payoff The American Red Cross (ARC) recently awarded Mr. Donald Tomlinson, of the Sensors Directorate's Integration and Operations Branch, with the ARC 2002 All-Ohio Everyday Hero Award during the ARC State Conference. The All-Ohio Everyday Hero Award recognizes volunteers who, through their volunteer support, help the Red Cross accomplish its mission. A total of 11 Ohioans received this prestigious honor from 68 ARC chapters throughout the state.

Accomplishment The ARC recognized Mr. Tomlinson for his volunteer efforts in creating, installing, and maintaining an up-to-date computer network system for the Northern Miami Valley Chapter. For more than a year, Mr. Tomlinson volunteered for the Red Cross when it was undergoing radical information technology changes and at a time when two chapters were trying to merge.

Background Mr. Tomlinson spent countless hours assisting the chapter to ensure it had an adequate, up-to-date, and viable computer system. He volunteered his time to provide technical support to the chapter.

His expertise in computer systems allowed the Red Cross staff to be more efficient and effective in providing their programs to the public. Services improved because of the elimination of downtime due to computer, server, and printer problems. All of this enhances the overall productivity of Red Cross office volunteers and department staff.

Dr. Richard Soref Elected IEEE Fellow

Payoff The Institute of Electrical and Electronic Engineers (IEEE) recognized Dr. Richard Soref, of the Sensors Directorate, by electing him as an IEEE Fellow for his contributions as research scientist in the field of silicon-based photonic and optoelectronics. Each year IEEE recognizes the achievements of its members by selecting a distinguished group of recipients to become IEEE Fellows.

Accomplishment Dr. Soref helped bring into existence a new and commercially important technology with his contributions to silicon optoelectronics (SiOE). Prior to his SiOE work, the technical community was not aware of the practical integrated-photonics aspects of silicon. His efforts ensured a much faster and more complete development of SiOE technologies.

Background Dr. Soref invented and developed a new family of silicon-based photonic and optoelectronic components for direct integration with electronic circuits on a silicon chip or wafer. Construction of the circuits, like the photonics, would involve using silicon-germanium alloys. The photonic components include several types of low-loss optical waveguides—some made with alloys, others made with silicon resting upon a buried insulating layer. Dr. Soref also developed several active components: an optical switch for routing optical signals, a photodetector integrated on a waveguide, a single-mode waveguide that couples well to a glass fiber-optic line, and an electronically pumped laser that consists of a stack of silicon-germanium quantum wells. Dr. Soref designed the laser to emit in the far infrared region. Most of these components are world firsts.

Dr. Soref performed many of these projects collaboratively, but his leadership in the field of Silicon research and development was instrumental in the success of the collaborations. Over a 16-year period, he expertly advocated Silicon-based optoelectronics at universities, the Department of Defense, corporations, and at international conferences. Worldwide growth of this technology resulted, in part, from his efforts and stimulation.

Dr. Brian Kent Elected IEEE Fellow

Payoff Dr. Brian Kent, from the Sensor Directorate's Signature Technology Office, recently received Fellow status from the Society of the Institute for Electrical and Electronics Engineers (IEEE) for leadership in the development and application of radar cross-section (RCS) measurement technologies. Each year the IEEE recognizes the achievements of its members by selecting a group of recipients to become IEEE Fellows.

Accomplishment Dr. Kent serves as the internationally recognized expert on low-observable RCS test and evaluation technologies. He directs the planning and execution of many multimillion dollar research programs designed to significantly improve the state of the art for international government and industrial RCS facilities. IEEE recognized Dr. Kent's contributions in this area and selected him as a Fellow of the society.

Background Dr. Kent develops and implements precision RCS measurement programs for world-class RCS facilities, which supply crucial RCS data for international air vehicle development programs. He transitioned advanced RCS measurement techniques to industry and fostered frequent technical interchanges between competing national RCS measurement facilities. Dr. Kent also developed a common international quality standards program for RCS ranges.

Mr. Ray Hitt Receives AOC Clark Fiester Command and Control Warfare Award

Payoff Mr. Ray Hitt, of the Sensors Directorate's Electronic Warfare Branch, received the Association of Old Crows (AOC) Clark Fiester Command and Control Warfare Award. He demonstrated expertise and technical leadership by cutting across organizational lines to obtain critical technology for the Compass Call program—the AFRL and the Air Force command and control warfare mission.

Accomplishment Mr. Hitt received the AOC Clark Fiester Award for his role as the EC-130H Compass Call systems engineer. He was instrumental in replacing the aging compressive receiver with a modern digital receiver upgrade, removing a significant reliability and maintainability nuisance while at the same time providing superior capability.

Background Mr. Hitt applied his Compass Call weapon system experience as he looked across the directorate for key technologies with application to command and control warfare. He strengthened the ties between the laboratory and the system program office to transition useful technology to the warfighter.

Within the laboratory, Mr. Hitt investigated leading-edge research in silicon-carbide, high-power, solid-state devices with potential for use in jammer applications. He steered advanced research in areas of fratricide avoidance that will increase the survival of friendly forces in the proximity of strong jamming.

Mr. Hitt applied his background in spread spectrum technology, working with other divisions within AFRL to help transition advanced development in these areas to benefit operational capability. He monitored the direction of modern communications and steered new technical efforts to keep Compass Call effective against these modern communications in the future.

Mr. Hitt also provided technical guidance to the Compass Call System Program Office that directly supported the effort in Afghanistan. He provided assistance in transitioning special receiver technology to the Special Operations Forces, using Combat Talon and Spectre Gunship aircraft.

Mr. William E. Austin Receives AOC Modeling and Simulation Award

Payoff Mr. William E. Austin, from the Sensors Directorate's Integrated Demonstrations and Applications Laboratory, received the Association of Old Crows (AOC) Modeling and Simulation (M&S) Award for making significant contributions to M&S capabilities required to effectively demonstrate and evaluate electronic warfare (EW) technology through the use of multispectral synthetic battlespace simulation. Mr. Austin's technical expertise and leadership improved the realism of synthetic battlespace environments generated to evolve and evaluate leading-edge EW input/output technology.

Accomplishment Mr. Austin, the directorate's program manager for Joint Synthetic Battlespace (JSB) demonstration projects and recent recipient of the AOC M&S Award, recently directed the integration of diverse models (joint modeling and simulation system [JMASS] real-time surface-to-air missile, F-16 cockpit, and an uninhabited air vehicle simulation) into the first JSB prototype federation.

Background The JSB provides a persistent common framework of simulations and models for operations, training, experimentation, and analysis. It is a crucial warfighter portal for collaborating with engineers and analysts. Mr. Austin's leadership allowed the Air Force to fully demonstrate the JSB prototype at the Interservice/Industry Training, Simulation, and Education Conference in Orlando, Florida.

He applied his experience with EW system analysis laboratories to lead a team that demonstrated the JMASS architecture could operate in a deterministic real-time mode. His efforts culminated in a chain of successful demonstrations that integrated real-time surface-to-air missile models with a manned cockpit, radio frequency (RF) threat simulator, and operational EW avionics equipment.

Key decisions to the successes achieved during this 18-month project included the selection of a real-time operation methodology (rate monotonic algorithm implemented) and the integration technology used to combine traditional constructive models with a manned aircraft player and RF simulator (an innovative application of Link Agent technology). Mr. Austin also provides key support to the JMASS real-time requirements development group.

Sensors Directorate Donates Surplus Computer Components to Local Schools

Payoff The Educational Partnership Agreements (EPAs) program provides the opportunity to give resources back to the community through Sensors Directorate donations of outdated computer components to area schools. Additionally, this program encourages students to pursue scientific and engineering careers by directly fostering the study of science and math. With the implementation of additional computer equipment to existing curriculums, children from all over the Miami Valley region, who may otherwise obtain minimal experience in computer technology, will now have the opportunity to explore the technology on a broader scale.

Accomplishment The directorate donated more than 60 pallets of surplus computer components to local schools to enhance the study of math and science for tomorrow's scientists and engineers. With the execution of EPA, the laboratory can donate computer components to educational institutions, directly into the hands of future Air Force engineers.

Background The directorate routinely upgrades and/or replaces its computers. This practice is critical to provide the best environment for engineers to perform innovative research with state-of-the-art computer equipment. However, computers that are obsolete by high-tech science and engineering standards still have much to offer students.

Teachers involved with the program say the computer components are exactly what they need. In school districts with high numbers of student population, the gain is immediate and direct in the classroom.

Bringing high-tech components into schools is just one part of the equation. Programs that allow students to certify in basic computer fabrication, networking, and repair have also benefited greatly. By using components to build computers from scratch, future engineers learn how the computer's internal process operates.

Modern-Day Technology Leader Honored

Payoff The *US Black Engineer* magazine recognized Mr. Roderic C. Perry as a modern-day technology leader for his singularly outstanding contributions in the area of real-time person/hardware-in-the-loop electronic warfare simulation technology development. His technical efforts and personal dedication in this area were critical in establishing a foundation to make great strides in increasing AFRL's overall level of capability to accomplish simulation-based acquisition, an important Department of Defense area of emphasis.

Accomplishment The *US Black Engineer* magazine recently honored Mr. Perry as a Modern-day Technology Leader during the 2003 US Black Engineer of the Year Awards Conference. Mr. Perry serves as program manager of the Advanced Threat Alert Advanced Technology Demonstration and program manager of Real-Time Infrared Scene Simulator, Situation Awareness and Real-Time Information into the Cockpit system technologies in the Sensors Applications and Demonstrations Division of the Sensors Directorate.

Background Mr. Perry is a recognized national leader in the development, testing, and demonstration of advanced user/customer needs and emphasizes transition of the hardware/software for follow-on engineering development. His duties include planning, coordinating, reviewing, directing, and implementing real-time man/hardware-in-the-loop technology effectiveness evaluation and electronic warfare simulator developments/modifications/upgrades for the Integrated Demonstrations and Applications Laboratory.

Mr. Perry holds a Bachelor of Science Degree in Electrical Engineering and has completed more than a dozen specialized courses in technical and managerial subjects while serving as a civilian employee of the Air Force. Mr. Perry has authored numerous articles and presentations.

Three Sensors Directorate Research Scientists Receive 2003 Pioneer Award

Payoff The Pioneer Award is the highest award presented by the Aerospace & Electronic Systems Society (AESS) of the Institute of Electrical and Electronics Engineers (IEEE). The IEEE bestows this award not only to individuals who made contributions 20 years ago but also to systems still in existance. Synthetic Aperture Radar (SAR) systems, based on the work of the 2003 Pioneer Award winners, are now operational in numerous Air Force combat aircraft.

Accomplishment The AESS of the IEEE presented the 2003 Pioneer Award to three research scientists associated with the Sensors Directorate for their technical contributions and leadership roles in establishing fine-resolution SAR. The recipients were Sensors Directorate Chief Scientist Dr. William M. Brown (right); Mr. William R. (Russ) Boario (left), retired from Avionics Laboratory; and Dr. Jack L. Walker (bottom right), retired from Environmental Research Institute of Michigan (ERIM). ERIM was the successor organization to Willow Run Laboratories (WRL) at the University of Michigan.

Background In 1960, when Dr. Brown became head of the Radar and Optics Laboratory at WRL, he committed his research team to improving SAR resolution from 100 ft to better than 1 ft. By the late 1960s, the state of the art was 5 ft, and the major challenge was to coherently process data over long time intervals during which points in the target field moved (relative to the radar) through many range and cross-range resolution cells. Dr. Brown conceived and demonstrated a concept that circumvented this problem. The basic idea recorded and processed the range dimension in the Fourier transform domain rather than in the usual time-delay variable.

From the 1950s into the 1970s, Mr. Russ Boario led Air Force research and development efforts in SAR systems. He sponsored and collaborated with the WRL, where focused SAR was first demonstrated. Within the Air Force and Department of Defense, Mr. Boario established advocacy and maintained funding for fine-resolution SAR programs.

As a technical leader at ERIM, Dr. Walker went on to establish Spotlight SAR with polar format processing in the Fourier transform domain. He extended and perfected the theory, conducted definitive ground-based demonstrations, and designed and completely specified an airborne system. In addition, he managed the Air Force-sponsored program that fully demonstrated the technical performance and high military utility of spotlight-mode SAR that had better than 1 ft resolution. The first successful flights were conducted at ERIM in 1974.

Two Sensors Directorate Engineers Receive Association of Old Crows Award

Payoff Lieutenant Colonel (now retired) Donald J. Kessler (right) and Master Sergeant David N. Coates (left) received the Association of Old Crows Command and Control Award for their contributions to US combat effectiveness and survivability with the invention of a revolutionary new radio antenna switch. In less than 3 months, they designed, tested, produced, and fielded nearly 100 Kessler-Coates (KeCo) switches.

Accomplishment Two Sensor Directorate engineers were honored by the Association of Old Crows for their quick response to the Air Force Special Operations Command (AFSOC) commander's request for a solution to a problem the command had with their special operations radios. The innovative switch allows forward-deployed troops to keep in direct contact with both satellite and ground communications systems.

Background The KeCo switch solved a potentially life-threatening limitation of the Special Operations tactical radio that required sharing the single antenna port with both satellite communications and line-of-sight antennas while allocating and coordinating coalition strike forces. This process originally required repeated and quick disconnect and reconnect of antennas when switching back and forth between aircraft/weapon allocation tasks and terminal control of inbound aircraft, often while the combat controller was under fire from ground forces. The KeCo is a custom radio-frequency switch that enables rapid switching between these two antennas, utilizing the radio's single antenna port.

By working directly with Special Operations personnel to identify and incorporate human factors and environmental requirements into the design, they were able to share evolving prototypes with users to optimize design and ensure the ultimate success of KeCo with the warfighters. KeCo was demonstrated to senior leadership under field conditions and was featured at the AFSOC Applied Technology Council.

The KeCo switch completely eliminated lengthy radio communication interruptions between combat controllers by providing rapid switching between satellite communications (command and control connectivity) and the line-of-sight antenna (directing inbound strike aircraft), and it significantly reduced combat controller workload. Currently, more than 1,500 switches have been ordered.

Dr. Yolanda Jones King Named AIAA Fellow

Payoff The American Institute of Aeronautics and Astronautics (AIAA) is the world's largest professional society devoted to the progress of engineering and science in aviation, space, and defense. The AIAA elects only one Fellow each year for every 1,000 voting members, making Fellows part of a select group. The AIAA honors Fellows for making notable contributions to the arts, sciences, or technology of aeronautics or astronautics.

Accomplishment The AIAA recently named Dr. Yolanda Jones King, Technical Advisor in the Space Technology Division, Space Vehicles Directorate, a Fellow for 2003. Dr. King serves as technical advisor for the directorate's Spacecraft Technology Division on a wide spectrum of space research including many facets of active and passive sensing and processing, cryogenic cooling, hyperspectral and polarimetric imaging, active and passive means to eliminate/mitigate man-made and natural threats to space systems, and development/transition of space power and structures

Background Dr. King has a bachelor's degree in chemistry and a doctorate in physical chemistry from the University of New Mexico. Her doctoral research was in chemical kinetics for high-energy laser systems.

Dr. King spent 7 years at the (now) AFRL-Phillips Site in directed energy research obtaining a patent in beam sensing. She then managed the Strategic Defense Initiative Technology program ($300M/year) within the USAF laboratories and served as the division chief for that activity within the Air Force Space Technology Center and then Phillips Laboratory.

Dr. King served as a Congressional Fellow for Representative Ron Dellums advising on science and technology. She is currently the US lead for the North Atlantic Treaty Organization's Sensors & Electronics Technology Panel.

Dr. King led the space-based radar integrated product team (the directorate in conjunction with the Space & Missile Systems Center) and the United States/ United Kingdom/Canada coalition space-based surveillance program. She also served as director of AFRL's International Office in Arlington, Virginia (at the Air Force Office of Scientific Research), for a 2-year period.

Dr. King has authored more than 30 publications and presentations and served on many organizing committees for both national and international meetings and symposiums. She has also served on several technical committees of professional societies.

Dr. Arup Maji Named ASCE Fellow

Payoff The American Society of Civil Engineers (ASCE) recently bestowed Fellow status on Dr. Arup Maji, a senior research scientist and project manager with the Space Vehicles Directorate. The association recognized Dr. Maji's outstanding contributions in the areas of precision smart materials and structures, nondestructive evaluation (NDE) of civil and aerospace structures and materials, acoustic wave propagation and laser interferometry, test design, and data acquisition and instrumentation.

Accomplishment As a senior research scientist, Dr. Maji made it possible to develop new laser interferometry techniques for NDE of structures. The ASCE honored Dr. Maji for his contribution to the understanding of material behavior in civil and aerospace structures through innovative applications of engineering mechanics.

Background Dr. Maji obtained a patent on a new NDE technique for inspecting large steel structures and pipelines based on acoustic wave propagation. During the past 7 years, Dr. Maji and individuals under his supervision have extended the applications of structural mechanics to improve the understanding of processing aerospace composite structures. More specifically, the causes of curvature and residual stresses during filament winding and pultrusion have been quantified, and their detrimental effects have been minimized.

Concurrent research projects on smart materials (shape-memory alloy, piezo-ceramics, piezo-polymers) have demonstrated new applications in satellites and have helped quantify how these materials behave individually and in conjunction with other materials. The understanding of advanced materials processing and smart materials enabled the precise control of structural shape, necessary for space-based sensors. Dr. Maji has authored 40 journal papers and more than 100 papers in proceedings of international conferences.

Professor Mark Balas Named AIAA Fellow

Payoff The American Institute of Aeronautics and Astronautics (AIAA) named Professor Mark Balas, of the Space Vehicles Directorate, a Fellow. The AIAA honors Fellows for making notable contributions to the arts, sciences, or technology of aeronautics or astronautics.

Accomplishment Prof Mark Balas, a world-renowned control systems expert, was named an AIAA Fellow. The AIAA is the world's largest professional society devoted to the progress of engineering and science in aviation, space, and defense. Since the AIAA elects only one Fellow each year for every 1,000 voting members, Fellows are part of a select group.

Background Prof Balas made theoretical contributions in linear and nonlinear systems, especially in the control of distributed and large-scale systems. His results in low-order control of infinite-dimensional systems are the key to practical controller design and operation for many new engineering system applications such as large aerospace structures and flexible mechanical systems, high-precision optics, and high-precision aircraft.

He was one of the founders of aerospace structure control. His work in reduced-order control and the alleviation of instability via residual mode filtering is well known throughout the field of active aerospace structures. Prof Balas also developed controllers for many space systems, including the Hubble Telescope, Teledesic Communications Satellite Array, and the United States Air Force Deployable Optical Telescope Demonstration Project.

Prof Balas produced many control theories and applications, and has a textbook in progress: *Control Theory for Finite and Infinite Dimensional Systems—A Unified Approach*. His survey article, "Trends in Large Space Structure Control Theory: Fondest Hopes, Wildest Dreams," is often one of the most cited papers in the field of aerospace structure control. He was a plenary lecturer on adaptive control for the International Federation of Automatic Control held in Bologna, Italy.

Dr. Peter Wegner Receives the Harold Brown Science and Technology Award

Payoff Dr. Peter Wegner, of the Space Vehicles Directorate, received the Harold Brown Science and Technology Award for his outstanding contributions in the area of space vehicles structures. His extraordinary accomplishments directly improved the operational effectiveness of the Air Force by providing important new capabilities that significantly enhance space vehicle performance and save operational costs.

Accomplishment Dr. Wegner's vision and creativity resulted in the development, fabrication, flight qualification, delivery, and transition of a new capability that will utilize excess/unused evolved expendable launch vehicle (EELV) payload margins. The EELV secondary payload adapter (ESPA), the first and only system of its kind available on a US launch system, has the capability to deploy up to seven satellites on a single EELV.

Building on the success of the ESPA effort, Dr. Wegner directed his team to move aggressively to develop five additional spacecraft and launch vehicle structural technology programs. In addition to these contributions, Dr. Wegner has been actively developing new spacecraft component technologies for precision space systems including surveillance systems and directed energy weapons.

Background Dr. Wegner is responsible for directing, coordinating, and planning a comprehensive set of technology programs that support more than 30 near-term space systems. His 18-person team performs both basic and applied research and manages 20 spacecraft and launch technology transitions/transfers, flight experiments, numerous ground-based demonstration programs, and over 100 contractual efforts. His tremendous leadership, engineering, and program management skills have distinguished him as a top performer.