UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

Materials & Manufacturing Directorate

Wright-Patterson Air Force Base • Dayton, Ohio Winter 2003

Materials and Manufacturing Directorate Meets Challenges of Space Environment

During the early days of America's space program, man ambitiously envisioned missions of space exploration and discovery. But without important developments by Air Force scientists and engineers, man could never have developed systems capable of meeting the challenges of the harsh and dynamic space environment.

In the late 1950s, materials engineers at the Wright-Patterson Plastics and Composites Branch conducted research critical to finding a material that would protect space vehicles, and the astronauts in them, from the extreme heat that they'd face during entry and re-entry to the earth's atmosphere.

By exposing materials to extreme heat from an oxyacetylene and kerosene torch and measuring erosion rates, engineers determined that a phenolic silica glass fabric would provide the thermal insulation needed to protect astronauts and space vehicles during flight. Their research led to the development of a heat shield for the Mercury space vehicle.

During the same period, materials engineers in the Elastomers and Coatings Branch, now Air Force Research Laboratory Materials and Manufacturing Directorate's Nonstructural Materials Branch, were solving other space-related challenges. Experts at the directorate exposed materials to vacuum and ultraviolet (UV) radiation and measured the materials' optical properties in the space simulation facility. This facility, known as the Space Combined Effects Primary Test and Research (SCEPTRE) facility, has been around since 1958 and through the years has contributed to the advancement of spacecraft materials and thermal control subsystems that have enabled exploration of space and commercialization of Department of Defense (DoD), NASA, and commercial space vehicles.

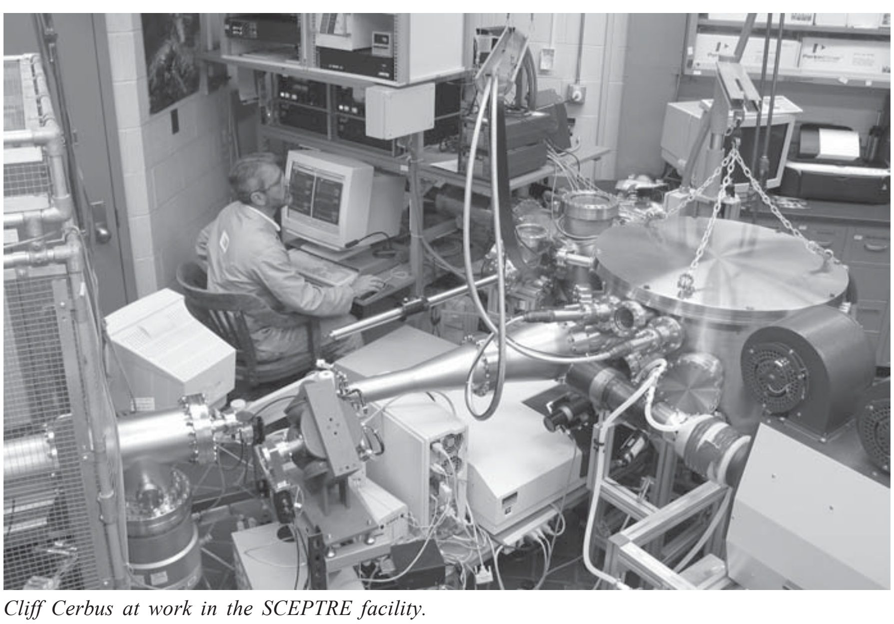
Exposure to the harsh space environment can cause a range of problems and challenges to space system materials. UV radiation, electron and proton radiation, vacuum effects, atomic oxygen, micrometeorites, space debris from other space vehicles and satellites, and thermal cycling are the primary environmental effects that impact space materials.

Because of the conditions materials face in space, all new materials must be space flight qualified prior to implementation on space hardware. Testing new materials in a simulated space environment prior to an actual space flight testing opportunity is the first step toward acceptance and transition of new materials. When a new material surpasses the current state-of-the-art performance criteria, the material will be tested in orbital space flight tests. However, the extreme cost and limited availability of space flight testing greatly impede this stage of the acceptance process.

Throughout the years, the SCEPTRE facility has been continually modified and upgraded to meet ML and Air Force testing needs and requirements. "The SCEPTRE facility is a one of a kind resource within the Air Force. As the Air Force continues its migration to space, the capability to test and develop new spacecraft materials in a simulated space environment is critical to the mission," Elizabeth Berman, an engineer from the Space Materials Testing Group said.

The facility is able to simulate a variety of orbital environments that do not naturally occur on earth including: vacuum effects, solar simulation and electron radiation. The simulated environment accurately reproduces the rate and extent a material will degrade in the actual space environment. During its early years, SCEPTRE focused primarily on testing satellite thermal control materials. These materials are crucial to the overall design of a satellite,

(continued on page 3)



Cliff Cerbus at work in the SCEPTRE facility.

Laboratory Develops Detector and Software for Inspection at Air Logistics Centers

Researchers from the Air Force Research Laboratory traveled to Hill AFB, Utah recently to train depot production radiography personnel to use Digital Radiography (DR) systems. This technology could improve and simplify nondestructive inspection (NDI) of aircraft airframes and structures.

Researchers demonstrated the use of a high-resolution digital flat panel x-ray detector and its respective software. The transition to DR technology provides personnel at Air Logistics Centers (ALCs) with highly improved tools for evaluating complex aircraft structures.

Under a contract with the AFRL Materials and Manufacturing (ML) Directorate's Nondestructive Evaluation Branch, General Electric (GE) Corporate Research and Development Center, Advanced X-ray Inc. (AXI) and Varian Inc. were asked to deliver products for use in the nondestructive inspection of aircraft structures. Nondestructive inspection and evaluation of aircraft eliminates the need for unnecessary maintenance and aircraft disassembly, which has the potential for creating additional damage and problems in aging Air Force systems.

Radiography inspection, an NDI method, is used during aircraft manufacturing, maintenance and repair to locate hidden defects such as cracking, corrosion, foreign object damage, voids, and moisture in aircraft materials and structures. It is also used extensively during the manufacturing of aircraft turbine engine components to detect and evaluate cavities, micro-shrinkage, porosity, inclusions and cracking, and to inspect the internal geometry of components.

DR technology offers significant advantages over conventional film-based radiography including a wider dynamic range (thickness range), and eliminates the need for film development and associated hazardous chemicals. DR technology provides for real-time data acquisition because digital images are acquired and displayed on a computer screen in a fraction of the time it takes to produce similar film images; typically around 15 seconds depending on the application. The technology also enables instant data retrieval, storage and sharing of data, and possibilities for equipment automation.

Perhaps the most significant advantage of DR technology is that it offers quantitative results for statistical analysis. Image processing software is available to assist in the analysis of the digital images. When the analysis is complete, the digital image may be annotated, logged into a database, and archived to long-term digital storage media where it can be easily accessed.

Researchers from GE and ML tested and evaluated commercially available digital radiography panels to determine whether the products met criteria required by ALCs. These criteria included the resolution of images taken by the panel, the size of the viewing area, pixel pitch, and imaging of real aircraft parts. The Varian 4030 amorphous silicon (a-Si) flat panel detector emerged as the detector of choice.

AXI developed the software package, which enables a technician to communicate with the detector panel, to capture a raw image, and to transfer the image to the data processing and viewing station. When the image has been transferred, a technician can retrieve the raw image, and process and analyze the data. Data filters and processing routines, which digitally enhance the image, can be applied to yield the best possible results.

The ability of the new detector to identify cracking, corrosion, and water damage at high-resolution was examined by representatives from ML and all of the ALCs.

The successful demonstration of DR technology is a cost- and time-saving milestone, which aids the transition of this technology.

Charles Buynak, AFRL/MLLP, evaluates resolution and contrast capabilities of digital flat detector panel inspection results on a computer monitor after x-raying a line pair gage specimen at Hill AFB, Utah.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 02-468 .

Completed Contracts

- Nano-Aluminum Alloys Technology For Space Launch - F33615-00-2-5203
- Robust Cast Discontinuously Reinforced Aluminum Turbine Housing For Liquid Fueled Space Launch F33615-99-C-5219
- Development Of Improved Aircraft Thermal Protection - F33615-01-M-5221
- Probe Technology For Low Observable Nondestructive Evaluation - F33615-00-C-5201
- Broadband Low Observable Nondestructive Evaluation Sensor Technology (BLONDE) F33615-01-M-5223
- Structural Repair Of Aging Aircraft - F33615-98-2-5113
- Simulation-Based Design System For Multi-Stage Manufacturing Processes - F33615-99-C-5709
- Enhanced Sensor Modules - II - F33615-96-C-5469
- Periodically Poled Stoichiometric Lithium Tantalate - F33615-02-M-5420
- Novel Systems For Bulk Growth Of Semi-Insulating Silicon Carbide - F33615-02-M-5422
- Gallium Nitride Semi-Insulating Substrates - F33615-02-M-5423
- Production Hydride Vapor Phase Epitaxy Technology For Gallium Nitride-Based Electronics - F33615-02-M-5425
- Gallium Nitride Wafer Preparation For Epitaxial Growth - F33615-02-M-5426

VISIT US AT WWW.AFRL.AF.MIL

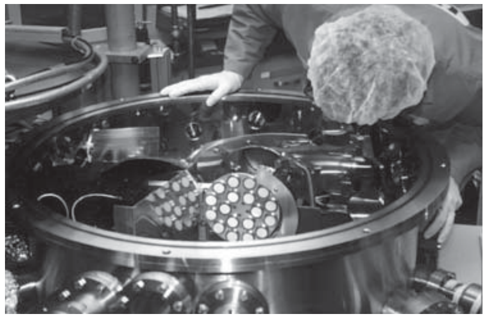
Challenges of Space

(continued from page 1)

enabling the satellite's thermal subsystem to maintain appropriate temperature environment for electronic payloads. "Radiator materials need to be very reflective in order to reject incoming heat from the sun, and to radiate heat away from electronics," Berman said. "With a satellite encountering UV radiation, electrons, and protons in orbit, the radiator materials darken over time and lose their reflectivity. One of our jobs is to find thermal control coatings that will be resistant to this environment, and keep spacecraft working longer."

In addition to thermal control materials and coatings, SCEPTRE has expanded its testing to a wide variety of materials including polymeric films, optical thin films, and threat protection materials. The facility has also been used in charging studies, space stability studies of optical and thin films, and degradation mechanics. "Besides SCEPTRE, the directorate provides additional materials characterization capabilities pre- and post-exposure to the simulated space environment."

"We have the Optical Measurements Facility, and a wide variety of highly advanced analytical chemistry and surface analysis techniques," Berman said. "This makes the



A lab technician views the inside of SCEPTRE's 30-inch diameter vacuum chamber.

directorate a 'one-stop shop' where present and future space materials can be tested."

"In the past, we've only had the opportunity to flight test materials every few years," Berman said. "But because more satellites, nano-satellites, and pico-satellites are being launched today than ever before, we expect that there will be more actual in-orbit data collection and testing opportunities available in the future."

Materials researchers from the directorate and around the country recently had the opportunity to send 1,700 material samples into orbit as part of a cooperative effort with NASA, the Space Test Program Office, and the aerospace industry. The materials are in orbit on the International Space Station (ISS) as part of the Materials on the International Space Station Experiment (MISSE). The first phase of this experiment determines the effects of the space environment on a large variety of space materials after over a year of exposure. This will be complete as early as March 2003, when 900 materials are returned to the directorate for post-exposure analysis. At the same time, an additional 800 material samples will be added to the experiment for three more years of space exposure testing. "MISSE offers the opportunity to demonstrate and qualify promising new materials that offer weight, performance and cost-saving benefits, characteristics that are critical to the adoption of new materials to space systems," Berman said.

"The impact of work done by space materials researchers at the directorate today is enabling the development and transition of space materials throughout the space industry. This is positioning the Air Force to meet its present and future space objectives, and is posturing exploration and discovery for another 50 years," Berman said.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 02-502.

Biotechnology Could Enhance Performance of Defense Technologies

Scientists at the Air Force Research Laboratory Materials and Manufacturing Directorate have made significant advancements in the area of biotechnology and "biomimetics," meaning literally to imitate life. Their efforts support the Air Force's goal of producing hybrid materials with properties superior to those made of either entirely synthetic or biological alternatives.

Biomimetic technologies could have a profound impact on materials science as well as national defense. The principal objective of this research is to use the best biology has to offer to enhance Air Force systems, particularly sensor and detection systems. To achieve this, scientists in the Air Force Research Laboratory Materials and Manufacturing Directorate's Survivability and Sensor Materials Division (AFRL/MLP), working with the Air Force Office of Scientific Research (AFOSR) and researchers at various universities, are drawing upon biology's innate ability to organize materials at the molecular level.

In a practical sense, biomimetics refers to interdisciplinary efforts to understand biological principles, then applying them to improve existing technologies or create new ones. MLP's most concentrated effort is directed at understanding 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 infrared or "IR" region of the electromagnetic spectrum. The quest for understanding this phenomenon has escalated even further as a result of the extreme sensitivity reported in biological IR/thermal detection, and because biology achieves this without cryogenics as compared to synthetic systems.

Materials researchers continue to be intrigued, as well, by various organisms' ability to sense IR radiation using the readily available elements carbon, hydrogen, oxygen and nitrogen, while science's only option has been a reliance on toxic formulations of inorganic alloys. Studies supported by ML are subsequently underway at various universities in the United States using a variety of specimens with unique properties and abilities. These include the IR-sensitive beetle (Melanophila acuminata), snakes from the Boidae (boa and python) and Crotalidae (pit viper) families, and bacterial-based systems of thermal detection. These investigations have yielded critical insights and helped scientists progress toward the development of bio-inspired and bio-derived technologies—the principal research paths for the growing field of biomimetics.

The resourcefulness of nature in accomplishing electromagnetic radiation detection is evident. Less clear is how to engineer these traits to enhance vital technologies and lower their costs. Biological signal transduction, for example, is very complicated and well beyond the scope of current biomimetics. Instead, the researchers are focusing on isolating biological "triggers," the molecules responsible for the initial stimulus detection. The emphasis is on coupling the triggers into optical and electrical detection systems and bypassing the impossible task of recreating biological signal transduction. In-house researchers have been successful in creating composite polymer films that electronically report protein conformational changes and an array based

(continued on page 4)

(continued from page 3)
on this technology has been fabricated, resulting in the world's first biomimetic thermal imager.

The biological processes associated with biotechnology and biomimetics are enormously complex, multi-step, and often operate non-linearly. 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 that cannot be achieved by any single material, and they give researchers the ability to differentiate minute differences, a useful property for building advanced sensors. In addition, they provide scientists with the ability to generate and screen an incredibly large number of combinations. Of primary importance, biotechnology and biomimetics facilitate the ability to organize materials with nanometer resolution into complex structures.

The materials science community has been experiencing an enormous reductionist push from the macro- to nano-scale. Other researchers are migrating from the molecular to the nano- and micro-level. Hence, the frontiers of science and technology are being created where these two groups meet. Biology and biomimetics will no doubt continue to inspire and guide this interface, and materials scientists will continue leading the way in the exploration of these new frontiers.

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.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 01-386.

The USAF Materials Technology Highlights is published quarterly to provide information on materials research and development activities by Air Force Research Laboratory's Materials & Manufacturing Directorate. For more information on subjects covered in "Highlights" or to be added to the "Highlights" mailing list, contact the Materials & Manufacturing Directorate Technology Information Center at (937) 255-6469 or e-mail at techinfo@afrl.af.mil. Approved for Public Release (ASC/PA#02-3149).

UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

AFRL/MLOP-TIC BLDG. 653
2977 P STREET, SUITE 13
WRIGHT-PATTERSON AFB OH 45433-7746

OFFICIAL BUSINESS

Air Force
Research Laboratory
AFRL