Georgia Tech

Research News

Georgia Institute of Technology
Research Communications Office
Atlanta, Georgia 30332-0800
404 894 3444

For Immediate Release
December 12, 1991

LDEF'S SIX YEARS IN SPACE: EXPOSURE HARMS OPTICAL FILTERS & MIRRORS; LEAVES OTHER MATERIALS UNCHANGED

Electro-optic components exposed to the rigors of space for nearly six years aboard NASA's Long Duration Exposure Facility (LDEF) show some unexpected performance changes that could affect future spacecraft design, a preliminary study has reported.

Analysis of 136 electro-optic components carried by LDEF revealed significant changes in the performance of items such as bandpass filters and mirrors, possibly because of deterioration in their structure and in materials used for their manufacture. Other components appeared unchanged by their six-year sojourn -- while at least one material seemed to work better after being struck by meteorites, shocked by temperature changes and scoured by upper atmospheric oxidants.

Dr. Don Blue and NASA's Dr. Jim Robertson examine a tray of electro-optic components exposed to space conditions aboard the Long Duration Exposure Facility (LDEF). (Color/B&W Available)

In interpreting the performance changes they measured, however, the scientists had to consider the variations that would be produced by normal aging processes. Examination of the materials continues, with particular interest in holographic crystals which could be used for computer mass memories.

"We are finding that organic materials like paints and polymer films, along with mirrors and filters made by depositing dielectric films, are degraded in space," said Dr. Don Blue, principal research

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scientist with the Georgia Tech Research Institute (GTRI). "We were surprised because we really didn't anticipate anything of real significance would happen to these components during the few months they were originally expected to be in orbit."

Certain filters are used to help satellites receive laser signals by screening out all but the color of light produced by the signalling laser. The researchers found that six years in space shifted the frequency of light admitted by the filters -- and reduced the amount of light transmitted.

These filters were made by cementing together plates within which a thin film stack had been deposited. Blue believes that age and space exposure affected the cement and the deposited layers, and he suggests that space scientists should consider these color shifts and transmission losses in planning future missions.

"For many U.S. space programs from the Strategic Defense Initiative to programs for exploring planets, it's good to be aware of this potential for degradation and loss of performance in mirrors and filters that are made in multi-layer stacks," he said. "Just a few Angstroms of frequency shift could be important. The shift is small, but significant -- and unexpected."

Holographic crystals, which have potential to store large amounts of computer data, did not appear to be damaged, although the holograms originally stored on them have been degraded due to the length of the LDEF mission. Performance of the bulk crystals is being studied by Dr. William R. Callen and Dr. Thomas K. Gaylord, professors in the School of Electrical Engineering.

"Study of the bulk crystalline properties is important for understanding the space-worthiness of the electro-optic crystals, which could be used in ultra-high capacity space data storage and retrieval systems," said Callen. "This is particularly significant in view of several planned commercial ventures using electro-optic crystals such as lithium niobate in holographic mass memories."

Some components carried on LDEF did not seem any the worse for wear. Infrared detectors performed as well after their return from space as they did when first installed on the LDEF test tray back in 1978. A silicon-based infrared detector still performed as designed, despite a crater caused by the impact of space debris, Blue said. And though scarred by the impact of micrometeorites, light-emitting diodes still worked well.

As expected, gas lasers containing helium did not work because the helium leaked out in the vacuum of space. Even on the ground, Blue noted, gas lasers must be periodically refilled.

The researchers were surprised to find that six years in space appeared to improve the performance of black paints used for thermal control and low-reflectivity coatings. Preliminary study shows the ability of the paints to absorb far-infrared emissions seemed to improve, possibly due to the creation of new light-absorbing sites by the breakup of paint binders and pigments.

The filters, mirrors, diodes, lasers and other components were part of a tray assembled in 1978 by Georgia Tech researchers to study the effects of space on electro-optic components. The components were placed to simulate how they would actually be used, and were partially covered by a sun shield. The tray was one of 86 experiments on LDEF, carried aloft by the Space Shuttle Challenger in 1984.

The components were originally scheduled for a nine to 12-month visit, but the Challenger disaster forced LDEF to wait nearly six years for its return to Earth in January of 1990.

Since the experiments were returned, researchers have been re-measuring and analyzing the performance of the components -- a task made more difficult because of the long delay. Research teams have scattered, while component suppliers have gone out of business, original equipment used for the measurements has been lost or modified and measurement techniques have changed.

"One of the problems we are having is that certain test data were supplied by the companies, but they are often not in a position to do any retesting," he noted. "Companies have been merged, and the information sometimes scattered to the winds."

Still, Blue believes it is worthwhile to obtain as much information as possible from the LDEF because so little is known about the effects of space exposure on modern electro-optic equipment.

"We are putting points on an empty plane," he explained. "There is no other information available about this. Who knows when we will ever have a chance to do this again?"

Also contributing to the NASA-supported work were R. G. Shackelford, J.J. Gallagher, D. O. Gallentine, Marie Fair, Kevin Bottler, C. W. Gorton and Amitava Roy, all of Georgia Tech; and S. Perkowitz of Emory University.

This research was done under the support of the Langley Research Center, National Aeronautics and Space Administration (NASA). A paper describing the results has been accepted for publication in Applied Optics.