

(NASA-CR-196016) RESULTS FROM LDEF
EXPERIMENT A0114: THE INTERACTION
OF ATOMIC OXYGEN WITH MATERIALS
SURFACES AT ORBITAL ALTITUDES Final
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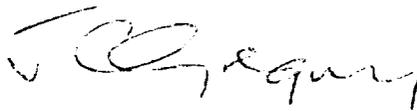
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FINAL REPORT

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**RESULTS FROM LDEF EXPERIMENT A0114: THE
INTERACTION OF ATOMIC OXYGEN WITH MATERIALS
SURFACES AT ORBITAL ALTITUDES**

Submitted by:



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**SUBMITTED TO NASA LANGLEY RESEARCH CENTER
LDEF PROJECT OFFICE**

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I should also like to thank Tom Parnell at Marshall who first suggested to me the possibilities of LDEF, and Chuck Lundquist, who provided some research support during the lean years of the project.

The Interaction of Atomic Oxygen with Materials Surfaces at Orbital Altitudes

LDEF Experiment A0114

In 1975 the University of Alabama in Huntsville proposed an experiment for the Long Duration Exposure Facility to NASA, Langley Research Center. The experiment, entirely passive, was designed to investigate the effects of the collision of the ambient orbital atmosphere (mainly consisting of atomic oxygen) with satellite surfaces travelling at about 8 km per second. The active chemical nature of the upper atmosphere was, of course, well-known at this time, and indeed the reaction with silver-plated articles on Skylab had been noticed in the early 1970's. However, the possibilities of important changes in the properties of materials exposed on satellites in low Earth orbit did not attract the serious attention of engineers and designers until 1981 and years following, after the STS had flown a few times. In 1976, the UAH proposal entitled "The Interaction of Atomic Oxygen with Materials Surfaces at Orbital Altitudes" was accepted for flight by NASA under the condition that the experimental hardware and support be provided at no cost. The UAH instrument, designated A0114, was built at a cost of \$5,000 and delivered to NASA a few years later.

In 1989, the last year of the six-year LDEF flight, the potential for recovery of significant data from A0114 on a wide variety of materials was recognized by Code R and LaRC, and funding for three years of data analysis was appropriated. This analysis has resulted in 16 conference publications. These papers are being followed by refereed articles in the archival journals where appropriate. A listing of these articles is attached, and copies may be obtained from our laboratory on request.

Some of the significant or unique findings from the experiment A0114 include:

- Numerous first-time measurements of oxidation rates of surfaces under fast O atom bombardment, including Si, Ge, GaAs, SiC and optical quality metal films.
- Definitive measurement of the stable attitude of the LDEF spacecraft in orbit using the gas dynamics pinhole camera.
- Description of the formation of thick oxide films on copper at 20°C with fast oxygen.
- Measurement of erosion rates of Kapton™ and other polymers at Space Station lifetime atomic oxygen fluences (10^{22} atoms cm^{-2})
- First measurement of the cosmogenic isotopes Be-7 on spacecraft surfaces.

PUBLICATIONS RESULTING FROM LDEF-A0114 MEASUREMENTS AND SUBSEQUENT ANALYSIS

a) Refereed publications

1. *Observation of Be-7 on the Surface of LDEF Spacecraft*, Fishman, G.J., Harmon, B.A., Gregory, J.C., Parnell, T.A., Peters, P., Phillips, G.W., King, S.E., August, R.A., Ritter, J.C., Cutchin, J.H., Haskins, P.S., McKisson, J.E., Ely, D.W., Weisenberger, A.G., Piercey, R.B., and Dybler, T.: *Nature*, 349, 1991, pp678-680.
2. *Satellite Attitude Stability Measurements Using a Gas Dynamics Pinhole Camera*, Palmer N. Peters, Paul L. Whitehouse, John C. Gregory, **Rarefied Gas Dynamics: Experimental Techniques and Physical Systems**, edited by B.D. Shizgal and D.P. Weaver, Volume 160, Progress in Astronautics and Aeronautics, AIAA, Washington, D.C., 1994, pp 478-487.
3. *A Measurement of the Attitude Stability of the LDEF Satellite Using a Silver/Silver Oxide Detector*, J.C. Gregory, P.N. Peters, **Journal of Guidance, Control and Dynamics**, AIAA, Vol. 15, No. 1, Jan-Feb, 1992, pp 282-284.
4. Oxidation of Copper by Fast Atomic Oxygen, G.N. Raikar, J.C. Gregory, P.N. Peters, *Oxidation Of Metals*, Vol. 42, Nos. 1/2, pp 1-15, 1994, in press.
5. *¹⁰Be in Bauxite and Commercial Aluminum*. Middleton R., Klein J., Dezfouly-Arjomandy B., Albrecht A., Xue S., Herzog G.F. and Gregory J. (1994) **Nucl Instrum. Meth. Phys. Res.**, in press.
6. Surface Characterization of SiC Mirrors Exposed to Fast Atomic Oxygen, G.N. Raikar, J.C. Gregory, W.D. Partlow, H. Herzog, and W.J. Choyke, submitted to **Surface and Interface Analysis**, 1994.

b) Conference Proceedings

1. *¹⁰Be in Terrestrial Bauxite and Industrial Aluminum: An LDEF Fallout*, J.C. Gregory, A.L. Albrecht, G. Herzog, J. Klein, R. Middleton, B.A. Harmon, T.A. Parnell, **Proceedings of the Third LDEF Post-Retrieval Symposium**, Williamsburg, VA, Nov. 8-12, 1993, in press.
2. *Measurements of the Optical Properties of Thin Films of Silver and Silver Oxide*, P.N. Peters, J.C. Gregory, Pallob Nag, **Proceedings of the Third LDEF Post-Retrieval Symposium**, Williamsburg, VA, Nov. 8-12, 1993, in press.
3. *Atomic Oxygen Dosimetry Measurements Made on STS-46 by CONCAP-II*, J.C. Gregory, G.P. Miller, P.J. Pettigrew, G.N. Raikar, W.T. Sutherland, **Proceedings of the Third LDEF Post-Retrieval Symposium**, Williamsburg, VA, Nov. 8-12, 1993, in press.
4. *In Flight Resistance Measurements on High Temperature Superconducting Thin Films Exposed to Orbital Atomic Oxygen on CONCAP-II (STS-46)*, J.C. Gregory, J.A. Bijvoet, G.N. Raikar, A. Mogro-Campero, Hoi Kwok, I.D. Raistrick, D.W. Cooke, **Proceedings of the Third LDEF Post-Retrieval Symposium**, Williamsburg, VA, Nov. 8-12, 1993, in press.

5. *Changes in Chemical and Optical Properties of Thin Film Metals Mirrors on LDEF*, P.N. Peters, J.C. Gregory, G.N. Raikar, in Proceedings of the **LDEF Materials Results for Spacecraft Applications Conference**, Huntsville, AL, October 27-28, 1992.
6. *Preliminary Results from the EOIM-3 and CONCAP-2 Experiments on STS 46*, J.C. Gregory, G.N. Raikar, in Proceedings of the **LDEF Materials Results for Spacecraft Applications Conference**, Huntsville, AL, October 27-28, 1992, NASA Conference Publication 3257, p. 439.
7. *Attitude Stability of LDEF: Refinement of Results from the Silver Pinhole Camera*, P.N. Peters, J.C. Gregory, in the Proceedings of **Second LDEF Post-Retrieval Symposium**, San Diego, CA, June 1-5, 1992, NASA Conference Publication 10097.
8. *Interaction of Atomic Oxygen with Thin Film and Bulk Copper: an XPS, AES, XRD and Profilometer Study*, G.N. Raikar, J.C. Gregory, L.C. Christl, P.N. Peters, in the Proceedings of **Second LDEF Post-Retrieval Symposium**, San Diego, CA, June 1-5, 1992, NASA Conference Publication 10097.
9. *Cosmogenic Radioisotopes on LDEF Surfaces*, J.C. Gregory, A. Albrecht, G. Herzog, J. Klein, R. Middleton, in the Proceedings of **Second LDEF Post-Retrieval Symposium**, San Diego, CA, June 1-5, 1992, NASA Conference Publication 10097, page 25.
10. *Fluorescence Measurements of the Thermal Control Coatings on LDEF Experiments S0069 and AO 114*, J.M. Zwiener, R.J. Mell, P.N. Peters, D.R. Wilkes, E.R. Miller, J.C. Gregory, in the Proceedings of **Second LDEF Post-Retrieval Symposium**, San Diego, CA, June 1-5, 1992, NASA Conference Publication 10097.
11. *Optical Transmission and Reflection Measurements of Thin Metal Films Exposed on LDEF*, J.C. Gregory, Proceedings of the **LDEF Workshop**, Langley Research Center, November 19-22, 1991.
12. *The Interactions of Atmospheric Cosmogenic Radionuclides with Spacecraft Surfaces*, J.C. Gregory, G.J. Fishman, B.A. Harmon, and T.A. Parnell, in the Proceedings of **The LDEF First Post-Retrieval Symposium**, Orlando, FL; June 1991. NASA Conference Publication 3134, part 1, p. 237-247.
13. *Interactions of Atomic Oxygen with Material Surfaces in Low Earth Orbit: Preliminary Results from Experiment A0114*, J.C. Gregory, L. Christl, G.N. Raikar, J.J. Weimer, R. Wiser, P.N. Peters, in the Proceedings of **The LDEF First Post-Retrieval Symposium**, Orlando, FL; June 1991. NASA Conference Publication 3134, Part 2, p. 753.
14. *Effects on LDEF Exposed Copper Film-and Bulk*, J.C. Gregory, L. C. Christl, G. N. Raikar and P. N. Peters, in the Proceedings of **The LDEF First Post-Retrieval Symposium**, Orlando, FL; June 1991. NASA Conference Publication 3134, part 2, p. 755-762.
15. *Measurements of Erosion Characteristics for Metal and Polymer Surfaces Using Profilometry*, J. C. Gregory, L.C. Christl and P.N. Peters, in the Proceedings of **The LDEF First Post-Retrieval Symposium**, Orlando, FL; June 1991. NASA Conference Publication 3134, part 2, p. 723-735.

16. *Pinhole Cameras as Sensors for Atomic Oxygen in Orbit: Application to Attitude Determination of the LDEF*, J.C. Gregory and P.N. Peters, in the Proceedings of **The LDEF First Post-Retrieval Symposium**, Orlando, FL; June 1991. NASA Conference Publication 3134, part 1, p. 61-67.