AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

TITLE: ON ORBIT PERFORMANCE OF THE ALEXIS EUV TELESCOPES

AUTHOR(S): J. Bloch, B. Edwards, W. Friedhorsky, D. Roussel-Dupre', B. W. Smith

SUBMITTED TO: SPIE
San Diego, CA
July 24-29, 1994Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Form No. 836 RS
ST 2629 10/81

MASTER

On Orbit Performance of the ALEXIS EUV Telescopes

J. Bloch, B. Edwards, W. Priedhorsky, D. Roussel-Dupre', B. W. Smith

Los Alamos National Laboratory, Astrophysics and Radiation Measurements Group
Mail Stop D436, Los Alamos, NM, 87545

O. H. W. Siegmund, T. Carone, S. Cully, T. Rodriguez-Bell, J. Warren, and J. Vallergera

University of California-Berkeley, Space Sciences Laboratory
Berkeley, CA 94720

ABSTRACT

The Array of Low Energy X-ray Imaging Sensors (ALEXIS) satellite is Los Alamos' first attempt at building and flying a low cost, rapid development, technology demonstration and scientific space mission. The ALEXIS satellite contains the two experiments: the ALEXIS telescope array, (which consists of six EUV/ultrasoft x-ray telescopes utilizing multilayer mirrors, each with a 33 degree field-of-view), and a VHF ionospheric experiment called Blackbeard. A ground station located at Los Alamos exclusively controls the spacecraft.

The 248 pound ALEXIS satellite was launched by a Pegasus booster into a 400 x 450 nautical mile, 70 degree inclination orbit on April 25, 1993. Images from a video system on the rocket indicated that ALEXIS had been severely damaged during launch with one of the 4 solar panels breaking away from its mounting. (It later turned out that the solar paddle was still attached to the spacecraft but only through cable bundles.) Attempts at communicating with the satellite were unsuccessful until a surprised ground crew received a short transmission on June 2. By mid July, ground station operators had regained full control of the satellite and began to initiate scientific operations with both the telescope array and the VHF experiment.

In this paper we will discuss a preliminary analysis of the on-orbit performance of EUV telescopes on ALEXIS.

1. INTRODUCTION

The ALEXIS (Array of Low-Energy X-Ray Imaging Sensors) satellite^{1,2} contains an ultrasoft x-ray or EUV monitor experiment that consists of six compact normal-incidence telescopes operating in narrow bands centered on 66, 71, and 95 eV (see Figure 1). The satellite also contains a VHF broadband ionospheric survey experiment called BLACKBEARD. The ALEXIS satellite and experiments are funded by the Department Of Energy (DOE), and have been built as a collaboration between Los Alamos and Sandia National Laboratories (LANL, SNL), and Space Sciences Laboratory/UC Berkeley (SSL/UCB). The spacecraft bus, built by AeroAstro, inc., is a custom, low-cost, miniature satellite, made to be compatible with several expendable launch vehicles. The Air Force Space Test Program launched ALEXIS via a Pegasus air-launched booster into a 400 x 450 nautical mile orbit on April 25, 1993.

The six EUV telescopes are arranged in three co-aligned pairs and cover three overlapping 33° fields-of-view. During each rotation of the satellite, ALEXIS was designed to monitor the entire anti-solar hemisphere. Each telescope consists of a spherical mirror with a Mo-Si layered synthetic microstructure (LSM) coating, a curved profile microchannel plate detector located at the telescope's prime focus, a UV background-rejecting filter, electron rejecting magnets at the telescope aperture, and image processing readout electronics (See Figure 2). The geometric collecting area of each telescope is about 25 cm², with spherical aberration limiting resolution to about 0.25°. Analysis of the pre-flight x-ray throughput calibration data indicates that the peak on-axis effective collecting area for each telescope's response function ranges from 0.25 to 0.05 cm². The peak area-solid angle product response function of each telescope ranges from 0.04 to 0.015 cm²-sr.

The spacing of the molybdenum and silicon layers on each telescope's mirror is the primary determinant of the telescope's photon energy response function. The ALEXIS multilayer mirrors also employ a "wavetramp" feature to significantly reduce the mirror's reflectance for He II 304Å geocoronal radiation which can be a significant background source for space borne EUV telescopes. These mirrors, produced by Ovonix, Inc., are highly curved yet have been shown to have very uniform multilayer coatings and hence have very uniform EUV reflecting properties over their entire surfaces. Our efforts in designing, producing and calibrating the ALEXIS telescope mirrors have been previously described in Smith *et. al.*, 1990.

Figure. 1. The ALEXIS satellite in its intended on-orbit configuration. The damaged solar paddle hinge and magnetometer are indicated. The satellite height is 113 cm, base to antenna tip, and the spacing from solar paddle tip to paddle tip is 228 cm. The top BLACKBEARD antenna (shown) points opposite the Sun, and the satellite currently rotates with a spin period of approximately 50 seconds.

Figure 2. - Cross section of an ALEXIS telescope.

The ALEXIS experiment weighs 100 pounds, draws 45 watts, and produces 10 kilobits/second of data. Position and time of arrival are recorded for each detected photon. ALEXIS will always be in a survey-monitor mode, with no individual source pointings. It is well-suited for simultaneous observations with ground-based observers who prefer to observe sources at opposition. Coordinated observations need not be arranged before the fact, because most sources in the anti-Sun hemisphere will be observed and archived. ALEXIS will be tracked from a single ground station in Los Alamos. Between ground station passes, data are stored in an on-board solid state memory of 78 Megabytes.

ALEXIS, with its wide fields-of-view and well-defined wavelength bands, complements the scanners on NASA's Extreme Ultraviolet Explorer (EUVE) and the ROSAT EUV Wide Field Camera (WFC), which are sensitive, narrow field-of-view, broad-band survey experiments. ALEXIS's results will also highly complement the data from EUVE's spectroscopy instrument. ALEXIS's scientific goals were to: 1) map the diffuse background in three emission line bands with the highest angular resolution to date⁴, 2) perform a narrow-band survey of point sources, 3) search for transient phenomena in the ultrasoft X-ray band, and 4) provide synoptic monitoring of variable ultrasoft X-ray sources such as cataclysmic variables and flare stars. Unlike other ultrasoft X-ray experiments, the 66 and 71 eV ALEXIS bandpasses are tuned to the Fe IX-XII emission line complex. This set of emission lines is characteristic of million degree optically thin plasmas which exist in the coronae of stars and which are thought to fill a large fraction of interstellar space around the sun, creating the soft X-ray background.

Figure 3 shows the estimated on-axis response curves from pre-flight calibrations of the telescopes. While the maximum effective areas are small compared to other instruments such as EUVE or WFC (which have peak effective areas of several cm²), Fig. 4 demonstrates that ALEXIS has quite comparable area-solid angle response curves, which is the true figure of merit for sky survey experiments. The difference is that each ALEXIS telescope has a 33° field-of-view, whereas EUVE or WFC have field-of-views of only a few degrees. As a result, ALEXIS can also excel in diffuse background studies, where large area-solid angle products are needed. Table 1 describes the makeup of each of the telescope's filters and detector photocathodes.

Table 1. ALEXIS Telescope Filter and Photocathode Characteristics

Telescope ID	Filter Type	Photocathode	Bandpass Center
1A	Lexan/Titanium/Boron	MgFl	93 eV (130 Angstroms)
1B	Aluminum(Silicon)/Carbon	NaBr	71 eV (172 Angstroms)
2A	Lexan/Titanium/Boron	MgFl	93 eV (130 Angstroms)
2B	Aluminum(Silicon)/Carbon	NaBr	66 eV (186 Angstroms)
3A	Aluminum(Silicon)/Carbon	NaBr	71 eV (172 Angstroms)
3B	Aluminum(Silicon)/Carbon	NaBr	66 eV (186 Angstroms)

2. LAUNCH, LOSS, AND RECOVERY - IMPACT ON TELESCOPE RESULTS

ALEXIS was launched by a Pegasus booster on 1993 April 25 into a 844 x 749 km orbit of 70° inclination. The Pegasus dropped from the wing of a B-52 bomber at 13:56 UT. Initial reports from the launch site indicated a perfect, nominal launch.

Initial attempts to contact the ALEXIS satellite after the April 25 launch were unsuccessful. The first passes over the Los Alamos ground station were on the evening of the 25th. Video taken from the second stage of the Pegasus booster became available before these passes. The video showed the ALEXIS +Y solar paddle to have prematurely unstowed. The paddle pivoted into the video field during a booster attitude maneuver. The back side of the paddle showed, proving that its lower hinge attachment to the bus had failed. The upper latch mechanism securing the paddle to the payload was designed to actuate via a hot wax plunger. This mechanism had either prematurely deployed or broken. The cause for the premature release, and the damage it caused, could not be deduced from the video, and is the subject of an anomaly investigation, whose report was released in early January, 1994. (The root cause of the anomaly was found to be a too-flexible bracket that held the solar paddle hinge assembly. The bracket on the paddle that failed was much more flexible than the other three brackets. Another contributing cause was some modifications that were made to the hot wax actuator mating plates which put additional stress on the tab that the actuators mated to.)

Figure 3 - Pre-flight on-axis effective area estimates for each ALEXIS telescope.

Figure 4 - Pre-flight area-solid angle product estimates for each ALEXIS telescope.

During the weeks after launch, data gathered from external assets indicated that all four solar paddles had deployed. This implied that ALEXIS was not dead on arrival in orbit, but turned on and stayed on long enough to deploy the three undamaged solar paddles. This was our greatest cause for hope during the weeks that followed.

On 2 June, ALEXIS spoke via a 15-second transmission. The ALEXIS transmitter turns on as soon as ALEXIS receives an uplink signal, but housekeeping data is transmitted only after a full acknowledgment between uplink and downlink. Until this

acknowledgment, ALEXIS repeats a time packet word based on the spacecraft clock. The transmission consisted only of time packets, but was enough to prove that a) the transmission was, without a doubt, from ALEXIS, b) the processor, receiver, and transmitter were functional, and c) the batteries were functional, because the clock indicated that ALEXIS had run through the last orbital night. Hopes buoyed, but ALEXIS did not respond again for four more weeks. The team occupied itself with various false alarms from the Los Alamos and Vandenberg Tracking Sites.

On June 30, ALEXIS transmitted a strong signal and stayed in contact for 4 minutes. The housekeeping data were complete and revealed the status of the satellite. ALEXIS was spinning about an axis nearly 90° from the Sun. All systems appeared functional except the magnetometer, which was flatlined. The transmission ceased after 4 minutes when the battery power was drained. A brief contact on July 1 returned a smaller set of housekeeping data. Because ALEXIS's solar arrays were approximately edge-on to the sun, they generated little power. Both the 30 June and 1 July contacts ended when the power code set the spacecraft into a power conservation mode ("nap"), which turned off the transmitter and receiver. Analysis of the housekeeping data showed that the spacecraft bus was drawing ~ 425 ma (~ 13 W), while the power system generated an orbit average of only 300 ma (~ 9 W). Aggravating the power situation was the fact that, with the magnetometer out, the attitude control code set the X and Y torque coils to maximum settings. As 225 ma of the bus draw was due to the torque coils, and nap mode turned off the torque coils, it seemed that ALEXIS would cycle in and out of nap mode. Contact would only be possible when the spacecraft was not in nap mode. By July 5, commands had been successfully sent to ALEXIS to conserve power usage and the batteries became fully charged.

The information gleaned from the first contacts with the spacecraft provided the basis for a scenario of what happened after launch. When the spacecraft was deployed from Pegasus, the lack of valid magnetometer readings prevented the autonomous attitude control system from working. With the magnetometer readings at a constant DC level, the control system would actuate the two radial coils (X and Y) at a maximum level in a vain attempt to spin the spacecraft up. In fact, the spacecraft was already spinning at 4 rpm about the Z axis from the impetus of the launch vehicle. The spacecraft was programmed to attempt to attain proper attitude within 30 hours. If the proper attitude had not been attained by this time, the solar arrays would be deployed and the spacecraft would attempt to make contact with the ground station. During the interval between separation and automatic paddle deployment the spacecraft entered a "flat spin" about a transverse axis. When the paddles deployed there was roughly an equal chance that the positive or negative Z axis would align with the spin vector. In yet another demonstration of Murphy's law, the spacecraft -Z axis ended up aligned with the spin vector and the spacecraft was facing almost exactly away from the Sun. Shortly thereafter the batteries discharged and the spacecraft became inactive.

Once regular contact with ALEXIS had been established, we devised a manual method of controlling the magnetic torque coils that did not depend on the broken magnetometer to control the orientation of the spin axis for the satellite (See Bloch *et. al.* 1994 for more details). By the end of July, the solar panels were finally facing the Sun. Telescope doors were opened, and scientific operations with the telescopes began.

It may be important to note that while the telescopes were sealed at vacuum before launch, they were not actively pumped during the period of lost contact. The original operational plan called for telescope door opening to occur a several days after launch, a period of time chosen to allow for spacecraft outgassing. Instead, a period of 2.5 months on orbit passed before the first telescope door could be opened. There was some concern that the NaBr photocathode material on four of the telescopes might be damaged or that the microchannel plates would absorb too much residual gas while being stored in such a partial vacuum of unknown character.

The remaining outstanding issue for the ALEXIS experiment is the creation of a new attitude determination algorithm that takes into account the modified mass properties of the spinning satellite, the missing magnetometer, and the possible motion of the broken solar paddle. Three separate efforts are underway to devise this algorithm. Progress so far has given us methods that recover the attitude with an accuracy of 2 to 3 degrees. We are very optimistic that we can improve these methods to recover the original 0.25 degree accuracy specification (0.25 degrees is the FWHM of the telescopes' spatial response). The modified mass properties of the satellite have also changed the way that the telescopes scan the sky (see Figure 4.).

Figure 4 - Top: Original arrangement of the ALEXIS telescopes' fields-of-view with respect to the satellite's spin axis. The spacecraft Z axis was the originally intended spin axis. Bottom: Post launch damage situation.

In the meantime, we have since July of 1993 been collecting time tagged photon data with all six telescopes. As improved attitude determination software comes on line, we can back-process all of the archived data to produce better sky maps.

3. ON-ORBIT OPERATIONAL CHARACTERISTICS

Prior to launch, the experiment team had expected that the ALEXIS telescopes would be highly robust to a variety of on-orbit non-cosmic backgrounds that have been problematic for other x-ray and EUV telescope systems. The fact that the design uses normal incidence, rather than grazing incidence mirrors means that any charged or neutral particles have to bounce at a large angle off of the mirror surface (thereby losing a lot of energy) in order to travel towards the detector. After that the particle would still have to travel through the filter material before reaching the microchannel plate. High energy particles which might fluoresce the mirror and generate a photon background for the detector were to be rejected by an octopole magnet assembly at the aperture of the telescope. These magnets were designed to reject electrons of up to 0.5 MeV. The filters were carefully optimized to reject FUV radiation present on orbit. Count rates outside of the auroral zones and South Atlantic Anomaly were expected to range from 10 to 50 counts per second over the entire telescope field-of-view depending on the telescope and the assumptions about the spectrum of the soft x-ray background. He II 304Å radiation from the geocorona would cause ~1 count/second/Rayleigh in the telescopes with Aluminum/Carbon filters (typical intensity values for He II 304Å range from 0 to 12 Rayleighs), and not effect the telescopes with Lexan/Boron/Titanium filters at all. In the calibration laboratory, all detectors had background rates between 5 and 8 counts/second due to residual radioactivity in the microchannel plate glass. Penetrating radiation on orbit was expected to add an additional ~5 counts/second of background over the entire field-of-view.

First light for the ALEXIS experiment occurred on July 27, 1993 at 5:45 UT when a set of real-time commands turned on high voltage to the microchannel plate detector on telescope 3A during a nighttime pass over the Los Alamos groundstation. For safety, the voltage was set so that the detector operated at a very low gain level. Count rates were monitored in real time and the high voltage was shut down prior to losing contact with the satellite. Repeated operations of this type showed that count rates were fluctuating up and down at the spin period of the satellite, and at times were significantly higher than expected prior to flight. With no attitude information available at the time, a precise understanding of the character and mechanism producing the higher than expected backgrounds was elusive.

From August through November of 1993, the ALEXIS experiment team tried to characterize empirically the on-orbit backgrounds and devised ways to optimize data collection procedures. One strategy was to run telescopes at very low gain settings for several orbits to survey the places and times when low and high count rates occurred. In order to implement new schemes for safe, autonomous high voltage operations with the count rate time profiles that were actually seen on-orbit, the team also uploaded several new versions of the Data Processing Units (DPUs) software. This software controls the high voltage supplies for the telescopes. By late 1993, all six telescopes were operating at nearly full gain.

Figure 5 shows detector count rates as a function of time for all six ALEXIS telescopes for a portion of one orbit's data that was collected April 25, 1994 (by coincidence, the one year anniversary of the launch). The character of these plots is typical for most ALEXIS telescope data. Note the large oscillations that occur at approximately the spin period of the satellite. This data comes from pulse counting rate scalers in the telescope front end electronics whose accumulations are reported in the telemetry stream every 0.5 seconds. The electronics can only digitize events at rates below 200 counts/second per telescope, so no individual event information is available at rates higher than this.

The large oscillations in count rate were very puzzling. The duty cycle of low count rates to high count rates is about 50%, as if half the sky were very bright, and half the sky very dark. The low count rate values for each telescope are consistent with what we reasonably expected prior to flight. The double horned appearance of the count rate profiles in telescopes 1A, 1B, 2A, and 2B suggested that perhaps they were scanning over an airglow layer beneath the satellite. The "horns" would occur when the telescope was looking tangentially to the layer. Also, telescope pair 3, which looks closest to the spin axis and looks farthest away from the earth during orbit night tended to not display the oscillatory behavior as often, which might indicate that the background was earth related.

By early 1994, some preliminary software routines became available for attitude reconstruction. When this attitude information was combined with the count rate data, it became apparent that the high count rates were not associated with the Earth. Figure 6 shows the same count rate data as in Fig. 5, but plotted instead against local zenith angle. As can be seen, zenith angle is not a good predictor of high or low counting rates. In fact, examination of telescopes 1A and 1B's zenith angle plots show that the earth is quite dark (the earth at ALEXIS' orbital altitude is located at zenith angles greater than ~116°).

Another possibility to explain the highly oscillatory signals would be a correlation with angle between the telescope look direction and the local direction of the magnetic field. Figure 7 shows the same count rate data as Fig. 5 but plotted against angle

between the telescope look direction and the local magnetic field lines. Again there is no striking relationship. If the telescopes were responding to trapped electrons spiraling around the field lines, there should be a sharp peak at 90° on these plots. Plots of count rate vs. Declination and Right Ascension (not shown) also do not show any sensible correlation, as would be the case if the background source were fixed in inertial space.

The most intriguing results to date arise from plots of count rate vs. angle to the velocity or ram direction, as shown in Fig. 8. It appears that the low count rates all occur for ram angles higher than 90° to 100° on all six telescopes, i.e. when the ram flow can no longer get into the telescope aperture. This suggestion is still highly speculative, and needs further investigation.

4. OBSERVATIONS OF HZ43 AND THE MOON

The white dwarf HZ 43 is the brightest soft x-ray source in the sky. ALEXIS was positioned favorably to view HZ 43 with telescope pair 3 during the period between April 25 and April 27 1994. A special effort was made to generate attitude

determination files for that period. These attitude files were used to generate the plots of section 3. The Moon had been detected with ALEXIS several times prior to April, but HZ 43 was the first stellar EUV source that was unambiguously identified in the data. During the same 3 day period, the full Moon also tracked across telescope pair 3's scan path. The image that resulted from adding all the data from April 25-27 is shown in Fig. 9. It shows the counts from HZ 43 smeared over a 2 or 3 degree wide area, giving a current indication of the attitude software's performance. These data are being used to further evaluate the attitude determination algorithms.

HZ 43 has a well known spectrum and is therefore well suited to use as a standard candle for measuring the EUV response of a telescope. Table 2 shows the preliminary results from a throughput calculation for telescope 3A. As can be seen from the table, the telescope appears to have roughly the same performance after 9 months of being exposed to the space environment as when it was measured prior to flight. Needless to say this is very good news.

Figure 6. - Count rates in all six ALEXIS telescopes as a function of zenith angle. The time period included in the data is the same as that for Fig. 5.

Figure 7. - Count rates in all six ALEXIS telescopes as a function of angle between the telescope look direction and the local magnetic field line. The time period included in the data is the same as that for Fig. 5.

Table 2 - HZ 43 Telescope Throughput Analysis

HZ43 Spectral Intensity:	0.13 Photons/Second/cm ² /Å
Telescope 3A Integrated Response (Preflight Calibration):	1.19 cm ² -Å
Expected Count Rate in Telescope 3A from HZ43:	0.15 Counts/Second
# of Orbits Analyzed:	2.5 Orbits
# of Raw Counts in HZ43 Signal:	136 Counts
# of Estimated Background Counts Based on Surrounding Pixels:	83 Counts
Effective Exposure Estimate for HZ43:	470 Seconds
Estimated Count Rate from HZ43:	0.11 +/- 0.024 Counts/Second

Figure 8. - Count rates in all six ALEXIS telescopes as a function of angle between the telescope look direction and the velocity vector. 0 degrees indicates that the telescope is looking along the direction of motion. The time period included in the data is the same as that for Fig. 5.

5. Current Status and Conclusions

The ALEXIS spacecraft and payload continue to function nominally. Over 40 CDROMs of telemetry data (650 MB each) have been collected as of late July 1994. About 50% of that is telescope data. The rest is evenly divided between BLACKBEARD and spacecraft data. All of the archived telescope data can be processed into sky maps once a reliable, fast, and accurate attitude determination software system becomes available.

Much more work needs to be done in order to fully evaluate the performance of the ALEXIS telescopes on-orbit. The preliminary analysis described here indicates that the anomalous backgrounds ALEXIS sees may have a very complex nature. Further understanding of the phenomena could help with the designs of future soft x-ray or EUV spaceborne instrumentation. Yet these backgrounds are not totally debilitating to the instrument's performance. Half of the sky scanned by ALEXIS at any one time

appears free of this contamination. We have demonstrated that at least one telescope, after being exposed to the space environment for almost a year, still has performance similar to that measured before flight. Hence, the scientific potential for ALEXIS data already archived and yet to be collected could be quite substantial. Since there are no technical factors that currently pose a limit to the mission lifetime, we can expect to eventually obtain an EUV survey dataset that covers several years in time and achieves significant limiting sensitivities.

Figure 9 - This image shows the sky view returned by telescope 3A on the ALEXIS satellite. The image combines eight hours of data taken over three days, April 25-27, 1994, and has been processed to show fluctuations about the mean background rate in each area of the the image. The telescope traced out a doughnut pattern because the satellite has an off-axis spin due to a damaged solar panel. The bright emissions of HZ 43 and the Moon are labeled on the image. The image of the Moon is elongated due to its motion across the sky. The dotted lines represent celestial latitude and longitude. Superimposed are a circle representing the 33° field-of-view of the telescope and two arrows indicating the direction that the telescope scans as satellite rotates. Telescope 3A's reponse peaks at 71 eV or 172 Å.

ACKNOWLEDGEMENTS

ALEXIS would not have been possible without the dedication of a great many people over five years. We would like to particularly thank those who lent their hearts and minds to the launch and rescue, and those that continue to work tirelessly on flight operations. These include Ron Aguilar, Frank Ameduri, Mark Bibeault, Doug Ciskowski, Don Cobb, Jim Devenport, Bryan Dunne, Don Enemark, John Gustafson, Mark Hodgson, Dan Holden, Irma Gonzales, Dave Guenther, Meg Kennison, Ciudy Little, Lisa May, Carter Munson, Greg Nunz, Greg Obbink, Mick Piotrowski, Sean Ryan, Ernie Serna, April Smith, Steve Smoogen, Ralph Stiglich, and Steve Wallin of Los Alamos; Bob Dill, Frank McLoughlin, Robert Miller, Mark Psiaki, Richard Warner, and Chris Wright of AeroAstro; David Bullington, Jim Griffie, Jim Klarkowski, and Harvey Temple of Sandia National Laboratories; David Hastman and Jean Floyd of Orbital Sciences, Inc.; Lt. Frank Dement and Capt. Kurt Hall of the United States Air Force, and the staff of the Vandenberg Tracking Site. The ALEXIS detectors were built and calibrated at the University of California-Berkeley Space Sciences Laboratory by Oswald H. Siegmund, Scott Cully, and John Warren. This work was supported by the U.S. Department of Energy.

REFERENCES

1. W. C. Priedhorsky, J. J. Bloch, F. A. Cordova, B. W. Smith, M. Ulibarri, O. H. W. Siegmund, H. Marshall, J. Vallerger, and P. Vedder, "ALEXIS: A Narrow Band Survey/Monitor of the Ultrasoft X-ray Sky", in Extreme Ultraviolet Astronomy, ed. R. Malina and S. Bowyer, (New York: Pergamon Press) (1991).
2. W. C. Priedhorsky, J. J. Bloch, B. W. Smith, K. Strobel, M. Ulibarri, J. Chavez, E. Evans, O. H. W. Siegmund, H. Marshall, J. Vallerger, and P. Vedder, "ALEXIS: An Ultrasoft X-Ray Monitor Experiment Using Miniature Satellite Technology", in X-Ray Instrumentation in Astronomy II, **982**, (1988).
3. B. W. Smith, J. J. Bloch, D. Roussel-Dupre', "Metal multilayer mirrors for EUV/ultrasoft x-ray wide-field telescopes", SPIE conference on X-ray/EUV Optics for Astronomy and Microscopy, R. B. Hoover ed., **1160** (1989).
4. J. J. Bloch and B. W. Smith, "The ALEXIS Project and the Local Interstellar Medium," in Extreme Ultraviolet Astronomy, ed. R. Malina and S. Bowyer, (New York: Pergamon Press) (1991).
5. J. J. Bloch, W. C. Priedhorsky, D. Roussel-Dupre', B. C. Edwards, and B. W. Smith, "Design, Performance, and Calibration of the ALEXIS Ultrasoft X-Ray Telescopes", 154-164, SPIE Vol. **1344** EUV, X-Ray, and Gamma-ray Instrumentation for Astronomy (1990).
6. D. Roussel-Dupre', J. J. Bloch, D. Ciskowski, R. Dingler, C. Little, M. Kennison, W. C. Priedhorsky, and S. Ryan, "On-Orbit Science in a Small Package: Managing the ALEXIS Satellite and Experiments", SPIE proceedings: Advanced Microdevices and Space Science Sensors, **2267**, (1994).
7. J. J. Bloch, W. T. Armstrong, R. Dingler, D. Enemark, D. Holden, C. Little, C. Munson, W. C. Priedhorsky, D. Roussel-Dupre', B. W. Smith, R. Warner, B. Dill, G. Huffman, F. McLoughlin, R. Mills, and R. Miller, "The ALEXIS Mission Recovery", American Astronautical Proceedings: **86**, Advances in the Astronautical Sciences, p-505, (1994).
8. W. C. Priedhorsky, J. J. Bloch, D. H. Holden, D. C. Roussel-Dupre', B. W. Smith, R. Dingler, R. Warner, G. Huffman, R. Miller, B. Dill, and R. Fleeter, "The ALEXIS Small Satellite Project: Initial Flight Results", SPIE proceedings: EUV, X-ray, and Gamma-Ray Instrumentation for Astronomy, **2006**, 114, (1993)

DATE

FILMED

8 / 31 / 94

END