THE LARGE AREA MODULAR ARRAY OF REFLECTORS

(LAMAR)

NASA Contract NAS8-38665

Final Report

For the Period 1 June 1989 through 31 January 1994

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1 Introduction

The Large Area Modular Array of Reflectors (LAMAR) was selected as an attached payload for the Space Station Freedom in June 1989. It is a high throughput multiple X-ray telescope system that was capable of performing both imaging and dispersive spectroscopy measurements simultaneously. If it had been constructed as proposed it would have been the largest focussing X-ray telescope system ever constructed, larger than the ESA telescopes on the European XMM mission and the Danish/Russian telescopes on the Russian Spectrum-X-Gamma mission which are due to be launched in 1999. The institutions collaborating on the program were the Smithsonian Astrophysical Observatory, the Marshall Space Flight Center, and University of California (Berkeley), U. of Chicago.

The LAMAR program was halted in 1990 when attached payloads were removed from the Space Station.

2 Technical Description of LAMAR

2.1 Experiment Description

The aperture of LAMAR was tohave been 2m×2m providing a mirror effective area of about 10^4 cm^2 at 1 keV. The two dimensional modular array would have been between 3×3 and 5×5 modules depending on how long a focal length the point system allows. The longer system (8m) is more desirable because fewer detectors are required. LAMAR performs imaging and dispersive spectroscopy simultaneously. Each module contains a K-B telescope, a stack of reflection grating which intercepts about 40% of the rays, and a dual section position sensitive gas proportional counter. One section detects the direct image, the other, the dispersed spectrum which is displace dot one side. The arrangement is shown in Figure 1. For two thirds of the modules the blaze angle and line density of the gratings are optimized at 16Å simulated for one-third, at 60Å. LAMAR has no moving parts. A sketch of LAMAR integrated into a pointing system and deployed on the Space Station is shown in figure 2.

Table 1
Imaging Capabilities
On Axis Ang. Resolution: 30″, 50% Power width
Field of View: 40′ FWHM at 2 keV, 30′ FWHM at 6.2 keV

Energy	(W.L.)	Net Effective Area (cm^2)*
0.28 keV	(44Å)	5700
1.0	(12)	4000
4.0	(3)	2700
7.0	(1.8)	1600

Limiting sensitivity is 10^{-14} ergs/cm^2sec (0.2–8 keV). It is set by confusion limit of 1 source/30 detection cells and is reached in 3×10^3sec.
*On Axis, including detector efficiency

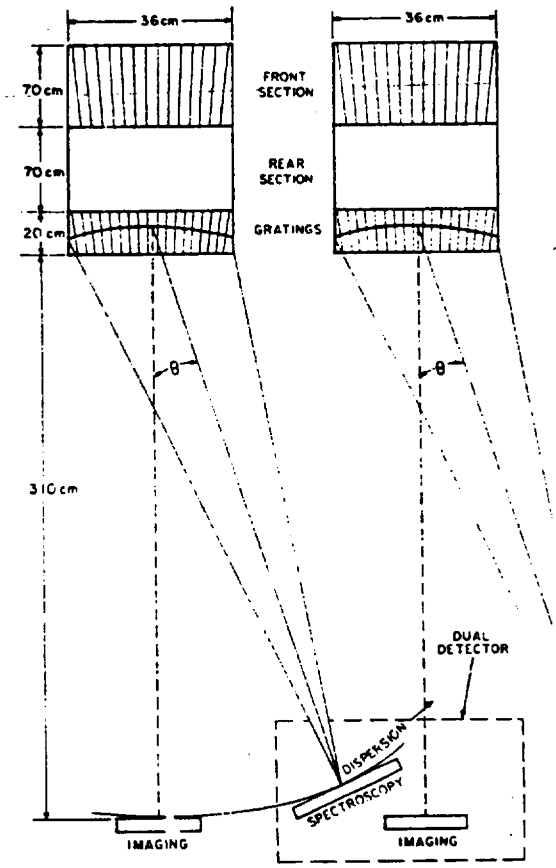

Figure 1: Imaging and dispersive spectroscopy detectors of LAMAR.

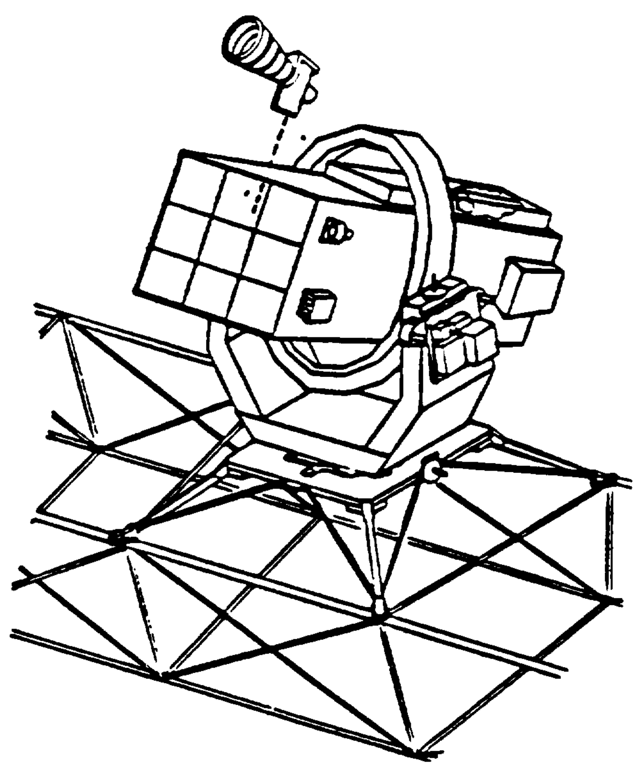

Figure 2: LAMAR Experiment within Pointing System on Space Station.

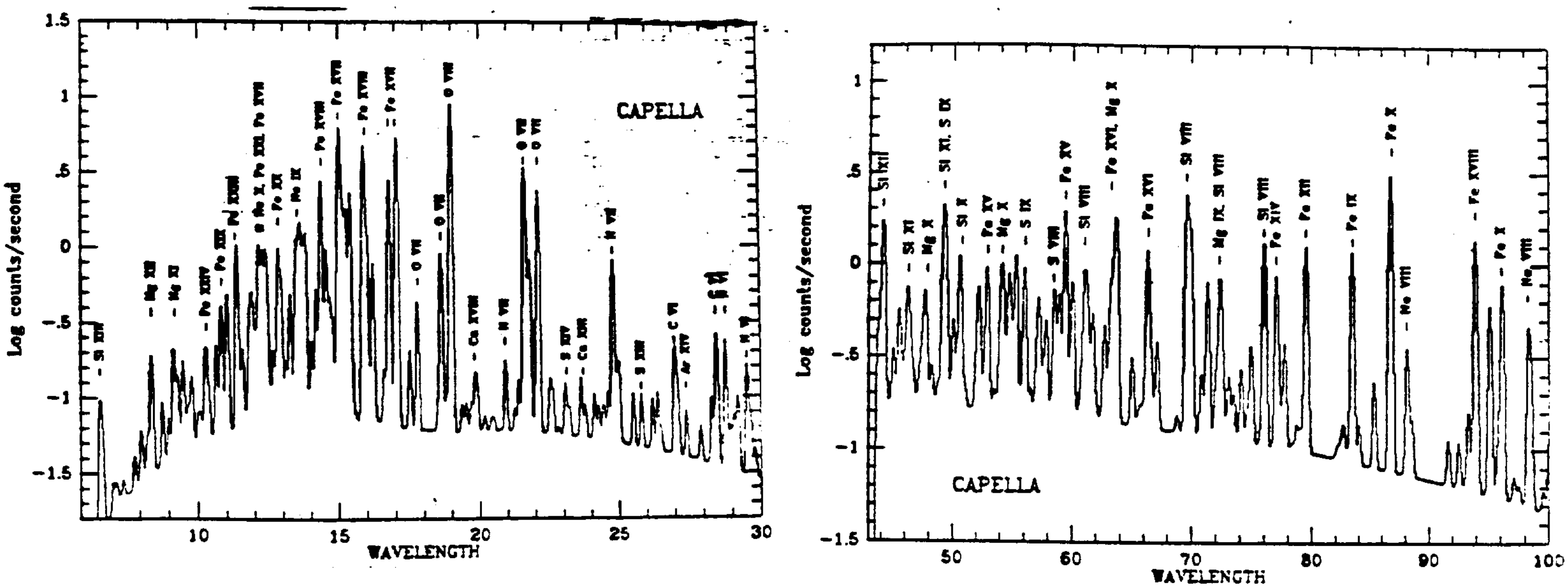

Figure 3: Simulated spectrum of Capella in two bands, 44-80Å, right panel and 8–30 Å, left panel as it would be observed in LAMAR. SMM is sensitive only to the short band.

LAMAR's net effective area including the detector efficiency for imaging and spectroscopy are shown in Table 1 and Table 2. The dispersive spectroscopy is effective below 2 keV. A simulated spectral observation of Capella is shown in Figure 3. A comparison of LAMAR's effective area and resolution with AXAF and XMM is shown in Table 3.

Table 2
High Resolution Spectroscopy Capabilities.
Field of View: 6′ × 12′

Energy	(W.L.)	Net Effective Area*(cm²)	Resolution (E/ΔE)
0.15 keV	(80Å)	305	450
0.28	(44)	433	260
0.50	(24)	414	320
0.78	(16)	736	230
1.0	(12)	734	180
2.0	(6)	158	80

*Including Detector Efficiency

Table 3
Comparison of Spectroscopy Capabilities at Longer Wavelength

		LAMAR		XMM		AXAF	
W.L.	E	E/ΔE	Area	E/ΔE	Area	E/ΔE	Area
16Å	0.77keV	230	720 cm²	300	250 cm²	600*	60* cm²
14Å	0.516	315	380	400	120	850*	25*
60Å	0.207	350	400	-	-	850	20**

*Medium Energy + High Energy Gratings, **Low Energy Gratings

2.2 Comparisons between LAMAR and XMM

2.2.1 Moderately High Resolution Spectroscopy

In 1989 LAMAR and XMM were the highest throughput missions planned. They were also the only high throughput missions with angular resolution better than an arcminute and the only missions offering high throughput dispersive spectroscopy below 2 keV. The two are complementary. XMM's goal for angular resolution is 20″ HPD as compared to LAMAR's goal of 30″ HPW along an axis which was achieved by a smaller mirror. Although their effective area is the same at 7 keV, XMM has much better energy resolution about 2 keV thanks to CCD detectors whereas LAMAR, at least its initial configuration, has only imaging proportional counters. On the other hand, LAMAR has more effective area below 2 keV. LAMAR has large effective area int he 44–80Å band for both imaging and dispersive spectroscopy whereas SMM does not extend longer than 30Å. The significance of the greater spectroscopic bandwidth is illustrated in Figure 3, the dispersed spectrum of Capella. LAMAR is sensitive to both bands, 8–30Å (left) and 44–80Å (right). XMM is not sensitive in the 44-80Å band. Furthermore, LAMAR has three times as much effective area as SMM in the 8–30Å band.

Figure 4 illustrates absorption edge features expected in many AGN's and quasars from material around the central engine (Kallman and Mushotzky, 1985). The most detectable feature is the oxygen edge where the quasar continuum flux is high. Indeed, such an oxygen edge features was probably observed in one BL Lac object by the *Einstein* Observatory (Canizares and Kruper 1984). The figure shows the bands of LAMAR (L-S) and XMM (X-S) relative to the emitted spectrum for a quasar at $a = 0$, $z = 1$, and $z = 2$. at $z = 1$, the XMM acceptance band is becoming marginal whereas the red shifted oxygen absorption edge is still well within the LAMAR band. With three times as much spectroscopic effective area as AMM in the 6–30Å band, LAMAR can study absorption features of many more AGN's.

2.2.2 Surveys

Future x-ray surveys should not only be more sensitive than, ROSAT, but should also extend beyond ROSAT's 2 keV cut-off to provide spectroscopic information for distinguishing between stars and extra-galactic objects. LAMAR is much better suited for surveys than XMM because LAMAR's two-dimensional field of view is four times larger and LAMAR has a larger bandpass and larger effective area. The combination of broader field of view and higher throughput made LAMAR nearly an order of magnitude more effective than XMM for surveys. In fact, surveys can be easily carried out on the Space Station by pointing towards the zenith or during the return slews of the pointing system form the setting of a source.

2.2.3 Upgrade Capability

Although the Space Station is not the ideal platform for astronomy, it is unique in providing access to the instrument for upgrade. It is likely that x-ray detector technology will

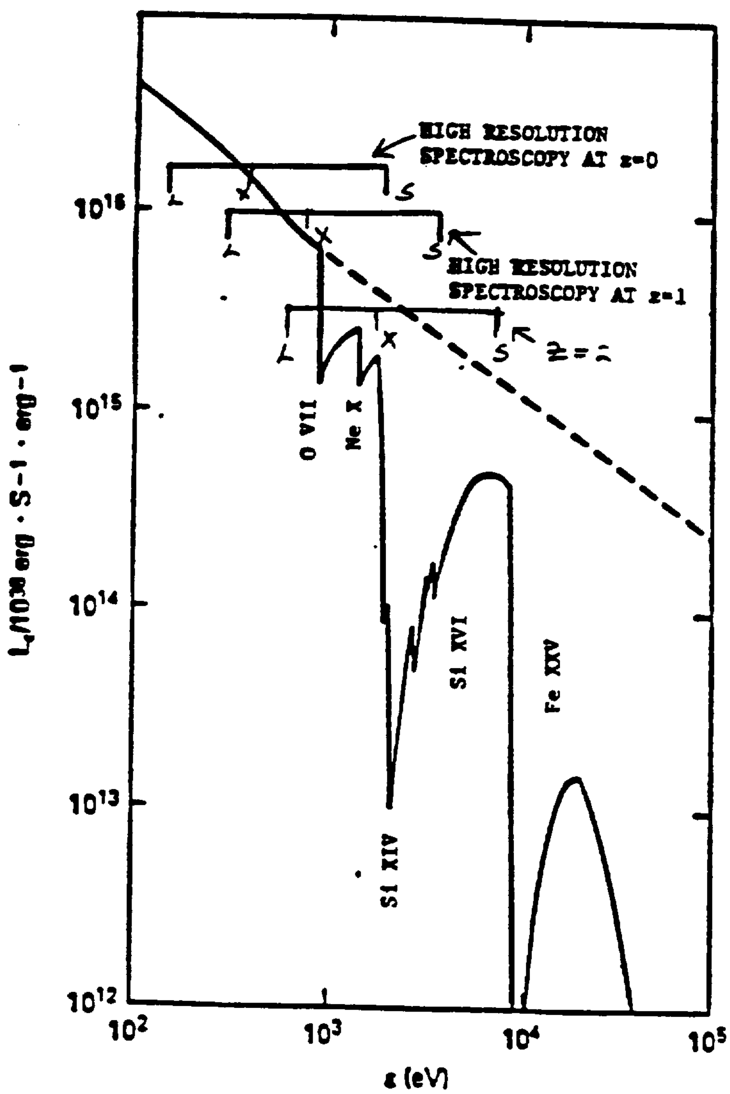

Figure 4: Theoretical absorption line spectrum of a quasar (Kallman and Mushotsky 1985). The lines between "L" and "S" denote the acceptance band of LAMAR in the rest frame of the quasar when it is at distances of $z = 0$, 1, and 2. The segment of the lines between "X" and "S" is the acceptance band of XMM.

be considerably more advanced in a decade. We can expect imaging detectors with better energy resolution, larger format, and better spatial resolution from improved CCD's, microcalorimeters, and superconducting devices. Hence, after several years of observing, it should be possible to replace LAMAR's imaging proportional counters with future state of the art detectors. The cost is very low compared to constructing an entire new observatory with LAMAR's throughput.

3 Termination of the LAMAR Program

The first year of the LAMAR program was spent refining cost estimates, refining the configuration, and working on a development plan. However, we were informed in November 1990 by L. A. Fisk the then NASA Associate Administrator for Space Science and Applications that funding for the development of attached payloads would not be provided. At that point the attached payloads program of Space Station Freedom was effectively cancelled. However, for several years more we requested and received approvals for no-cost extensions to the contract in be ready in case the attached payloads program was restored. Finally, after several years when it become clear that the new configuration of the space station now renamed the "International Space Station" did not include the former attached payloads the LAMAR contract was terminated.

4 Future High Throughput Missions

The scientific studies that would have been carried out by the LAMAR are still valid and still need to be done. Indeed, we now know that an instrument several times larger than LAMAR (at 10 cm^2 effective area) is needed. At the present time, May 1996, the study of such a mission is being undertaken as a NASA Supported Mission concept study being carried out by a consortium of scientific groups. The scientists of this consortium known as the High Throughput Spectroscoy Mission include the LAMAR's Principal Investigator.

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