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WAS THE MSSTA II MISSION SUCCESSFUL?

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SCIENTIFIC OBJECTIVES

The Multi-Spectral Solar Telescope Array (MSSTA) is a rocket borne solar observatory designed to address a wide range of scientific questions relating to two aspects of the structure and dynamics of the solar atmosphere:[11]

(a) The heating and dynamics of chromospheric and coronal structures including spicules, coronal loops, bright points, and planes; and the role of the fine scale structure of the chromospheric network in the transport of mass and energy between these structures.

(b) The large scale structures of the corona, including the interface of prominences and filaments with material at coronal temperatures, the transition region structure of coronal holes and plumes, and their relationship to the solar wind.

In order to address these fundamental scientific problems, the observational objective of the MSSTA is to obtain a set of high resolution spectroheliograms with the following properties:[11]

(i) Sufficiently broad spectral coverage and accurate photometry to allow modeling of structures covering the full range of temperatures observed in non-flaring chromosphere/corona, 10^4 K to 10^7 K.

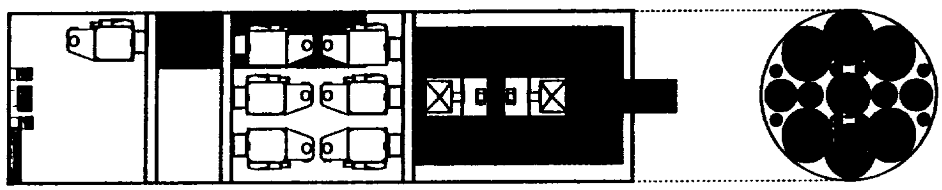
(ii) Sufficient spectral resolution ($\lambda / \Delta\lambda$~30-100) in each spectroheliogram to allow isolation of the emission from lines excited over a narrow range of temperatures.

(iii) To address objective (a), spatial resolution sufficient to resolve structures on the sun on a scale of 100-200 km (0.1-0.3 arc seconds); to address objective (b), [illegible]

MSSTA II CONFIGURATION

The Multi-Spectral Solar Telescope Array (MSSTA)[1] is a sounding rocket borne observatory designed to image the sun at many spectral lines in soft X-Ray (XUV) [44.1-93.9Å], Extreme Ultraviolet (EUV) [150-335Å], and Far Ultraviolet (FUV) [1215.6-1550Å], wavelengths. MSSTA is a joint project of Stanford University NASA/Marshall Space Flight Center, and Lawrence Livermore National Laboratory. MSSTA II flown on November 3, 1994 at White Sands Missile Range consisted of nineteen telescopes; two Cassegrain telescopes, six Ritchey - Chrétien telescopes and eleven Herschellian telescopes (Figure 1).[10]

MSSTA Configuration [10]



Type	Wavelengths (Å)	Focal Length	Diameter Primary	Diameter Secondary	Mirror Separation
Ritchey-Chrétien	150, 193, 284, 304, 1550	350 cm	12.7 cm	4.9 cm	80 cm
Short Ritchey-Chrétien	1216	230 cm	12.7 cm	5.7 cm	55 cm
Cassegrain	173, 211	230 cm	6.4 cm	2.5 cm	42.3 cm
5" Herschellian	93.9	100 cm	5.0 in		
4" Herschellian	193, 211	140 cm	4.0 in		
1.5" Herschellian	44, 143	140 cm	4.0 cm		
	54.7, 150, 284	100 cm	4.0 cm		
	180	100 cm	1.5 in (spherical)		

Pentax 649 70mm camera

Figure 1

The two Cassegrain telescopes (with coated optics designed to reflect wavelengths of 173 and 211Å) were both flown on the first MSSTA payload on May 13, 1991. The 173 Å telescope was also flown on the Stanford-Marshall Space Flight Center Rocket Spectroheliograph sounding rocket payload on October 23, 1987. These Cassegrains are two-mirrored telescopes with spherical optical elements and were found to be defraction limited in visible wavelengths. The maximum resolution, however, is limited to 0.5 arc sec due to abberations.[10]

The six Ritchey-Chrétien telescopes are two mirrored telescopes with hyperbolic optical elements. These mirrors are held in place in their cells with a vacuum compatible Dow Corning Silastic RTV which also allows for slight motion during vibrational loading.[10] To maximize changes in mirror separation, the optical benches were constructed of graphic fiber in an epoxy resin.[4] Earlier theoretical studies revealed that the Ritchey-Chrétien telescopes could obtain spatial resolutions of better than 0.3 arc sec over 48 arc min field of view at 1216Å (with the best possible resolution of 0.03 arc sec occurring near the optical axis at a wavelengths of 173Å).[3] This flight carried five Ritchey-Chrétien telescopes with mirrors coated to image wavelengths of 150, 193, 284, 304, and 1550Å. A Short Ritchey-Chrétien telescope was constructed and is capable of obtaining resolutions of 0.22 arc sec at its operating wavelength of 1216Å.[5]

The eleven Herschellian telescopes flown were of five different types and designed to operate at 44.2, 54.7, 93.9, 143, 150, 180, 193, 211, and 284Å. All were off-axis paraboloids except for the 180Å telescope which was a General Optics 1.5 inch concave sphere with a 2 meter radius of curvature.[10] The multilayer coating for this optic was deposited at MSFC by Palmer Peters a few weeks before launch.[9]

THE FLIGHT

The MSSTA II payload was launched aboard a Terrier-Black Brant VC Rocket from White Sands Missile Range at 1915 UT (1215 Local) November 3, 1994. The payload weighed 1072 lbs. The payload reached an altitude of 142.8 statute miles went down range approximately 52.0 statute miles (Figure 2).

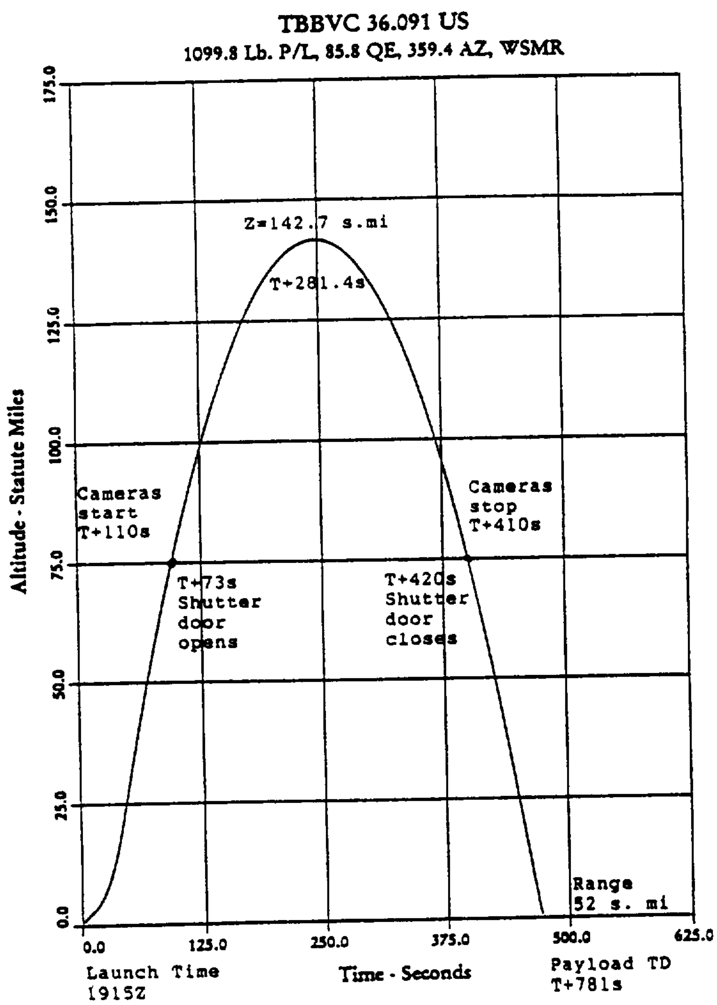


Figure 2 Altitude vs. Time[12]

At T+ 73 seconds into the flight the shutter door opened and at T+ 110 seconds (At an altitude of ~ 75 statute miles) the cameras began to operate (Figure 2). The cameras continued to operate for 300 seconds. Then at T+ 410 seconds (Again at an altitude of ~ 75 statute miles) the cameras shut down and at T+ 420 seconds the shutter door closed. The payload (MSSTA II) touched down at T+ 781 seconds.

MSSTA II RESULTS

MSSTA II obtained some outstanding solar images. In fact, it obtained the highest resolution images of the chromosphere ever photographed in the C IV line λ 1550Å.

The Cassegrain I telescope was able to image the corona in the Fe IX/X line at λ 173Å at a temperature of ~ 1,000,000 K (Photo 1). The fine lines in the photo are due to cracking of the XUV-100 film under vacuum. The image shows bright points, active regions, polar plumes and a coronal hole.

The Ritchey-Chrétien 2 telescope obtained the highest resolution images of the chromosphere ever photographed in the C IV line λ 1550Å at a temperature of ~ 100,000 K (Photo 2). The images show active regions, chromospheric network structure, spicules, small scale loops, and a coronal hole coincident with that observed in Photo 1.

The Short Ritchey-Chrétien yielded numerous images of the chromosphere in the H I Lyman α line at λ 1216Å at a temperature of ~ 20,000 K (Photo 3). The images also reveal active regions, chromospheric network, spicules, and small loops.

Photo 1. The corona at ~ 1,000,000 K
Fe IX/X λ173Å

Photo 2. The chromosphere at ~100,000 K
C IV λ1550Å

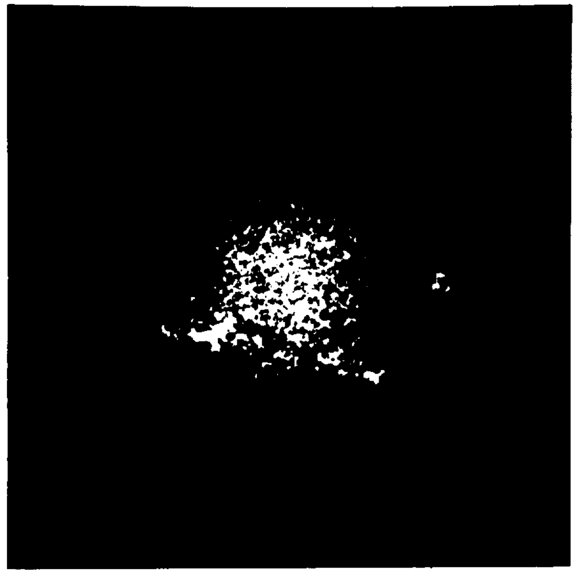


Photo 3. The chromosphere at ~ 20,000 K H I
Lyman α λ 1216Å

SUMMARY AND CONCLUSIONS

The MSSTA II payload with its compliment of nineteen telescopes was flown on November 3, 1994. The images obtained on this flight are still being analyzed. The 1550Å Ritchey-Chrétien yielded sub-arc second images of chromospheric fine structures which are correlated with coronal features shown in the 173Å Fe IX/X images. The MSSTA II payload was able to bring back images in wavelengths ranging from 173Å to 1550Å at temperatures ranging from 20,000K to 1,000,000K. The MSSTA II results were fully consistent with flight mission success criteria. Therefore, the mission was successful.

Detailed digitalization of all images obtained on this mission will be analyzed and compared with images obtained simultaneously or in close proximity with H-α, Ca K magnetograms and x-ray images from the Yohkoh Satellite. Subsequent research opportunities for these multilayer telescopes from a MIDEX Satellite, sounding rocket and the MIR Space Station are now being explored.

ACKNOWLEDGMENTS

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REFERENCES

[1] A.B.C. Walker, Jr., et al., "Multi-Spectral Solar Telescope Array," Optical Engineering, 29, pp. 581-591, 1990.

[2] R.B. Hoover et al., "Solar Observations with the Multi-Spectral Solar Telescope Array," SPIE Proc., 1546, pp. 175-187, 1991.

[3] J.B. Hadaway, et al., "Design and Analysis of Optical Systems for the Stanford/MSFC Multi-Spectral Solar Telescope Array," SPIE Proc., 1160, pp. 195-208, 1989.

[4] R.B. Hoover, et al., "Performance of the Multi-Spectral Solar Telescope Array III. Optical Characteristics of the Ritchey-Chrétien and Cassegrain Telescopes," SPIE Proc., 1343, pp. 189-202, 1990.

[5] R.B. Hoover et al., "Design and Fabrication of the All-Reflecting H-Lyman α Coronograph/Polarimeter," SPIE Proc., 1742, pp. 439-451, 1992.

[6] Arthur B.C. Walker, Center for Space Science and Astrophysics, Stanford University Stanford, CA 94305, Private Communication.

[7] A.B.C. Walker, et al., "Soft X-Ray Images of the Solar Corona with a Normal-Incidence Cassegrain Multilayer Telescope," Science, 241, pp. 1725-1868, 30 Sep. 1998.

[8] D.L. Shealy, R.B. Hoover, D.R. Gabardi, "Multilayer X-Ray Imaging Systems," SPIE Proc., 691, pp. 83, 1986.

[9] P.N. Peters, et al., "Fabrication of Multilayer Optics by Sputtering: Application to EUV Optics with Greater Than 30% Normal Reflectance," to appear in SPIE Proc., 2515, 1995.

[10] D.B. Gore, J.B. Hadaway, R.B. Hoover, A.B.C. Walker, "Optical Focusing and Alignment of the Multi-Spectral Solar Telescope Array II Payload," SPIE 1995.

[11] A.B.C. Walker, Jr., et al., "Multi-Spectral Solar Telescope Array: Initial Results and Future Plans," SPIE Proc., 1742, pp. 500-514, 1992.

[12] NASA, "Flight Requirements Plan for Terrier-Black Brant VC," pp. 6-18, 1992.