A Space Weather and Terrestrial Hazards Experiment for the MSTI Program

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ABSTRACT

This paper discusses the instrumentation being built under BMDO auspices to construct a small, lightweight, low-cost satellite that provides measurements of local hazards affecting satellites in low-Earth orbit. In the following, we describe the objectives of the mission, the instrumentation being built and the mission profile for acquisition and utilization of the data products.

I. Overview

The Space Weather and Terrestrial Hazards (SWATH) experiment is a small, lightweight and inexpensive payload designed to place into low-earth orbit a set of instruments for measurement and study of local space hazards. The SWATH instrumentation is designed to utilize the bus being developed for the Miniature Sensor Technology Integration program. The mission has three major scientific objectives: 1. to track and measure space debris in low-earth orbit; 2. to monitor, track and study large disturbances originating at the Sun and propagating to the near-earth environment; 3. to monitor and study the activity of the solar corona.

The instrument is being built by the Smithsonian Astrophysical Observatory, with a portion of the instrumentation being built at National Solar Observatory (Sac Peak); the contract is managed by the Phillips Laboratory (PL/SXAD). The SWATH team, in addition to the individuals listed as co-authors of this contribution, includes: E. DeLuca, K. Kalata and A. Viola at SAO, D. Neidig, G. Simon and J. Zirker at NSO, S. Koutchmy at IAP (Paris), W.K.H. Schmidt at MPAE (Germany), and S. Kahler at PL/GPSG. The multilayer-coated X-ray mirrors are being manufactured at IBM and at LLNL, and the CCD cameras are modified commercial systems purchased from Photometrics Corp.

II. Instrumentation

Primary instrumentation consists of two dual-purpose telescopes, each an independent system with its own CCD detector (Figure 1). Each camera is sensitive to both X-rays and visible light and the two cameras share a ruggedized 386-class control computer.

The design of the instruments and of the electronics is based on the NASA-funded NIXT sounding rocket payload, which has flown successfully five consecutive times in the past five years. Both of the x-ray telescopes have been flown on the NIXT rocket, prototype versions of the x-ray CCD cameras have flown, and the PC-based image acquisition and processing electronics were successfully flight tested earlier this year. The coronagraph feed is a new instrument.

One of the dual-purpose telescopes includes a white-light coronagraph, used to measure coronal mass ejections originating at the Sun, and also to measure space debris as it crosses the field of view. This instrument shares a 2KX2K CCD detector with a small XUV telescope operating at

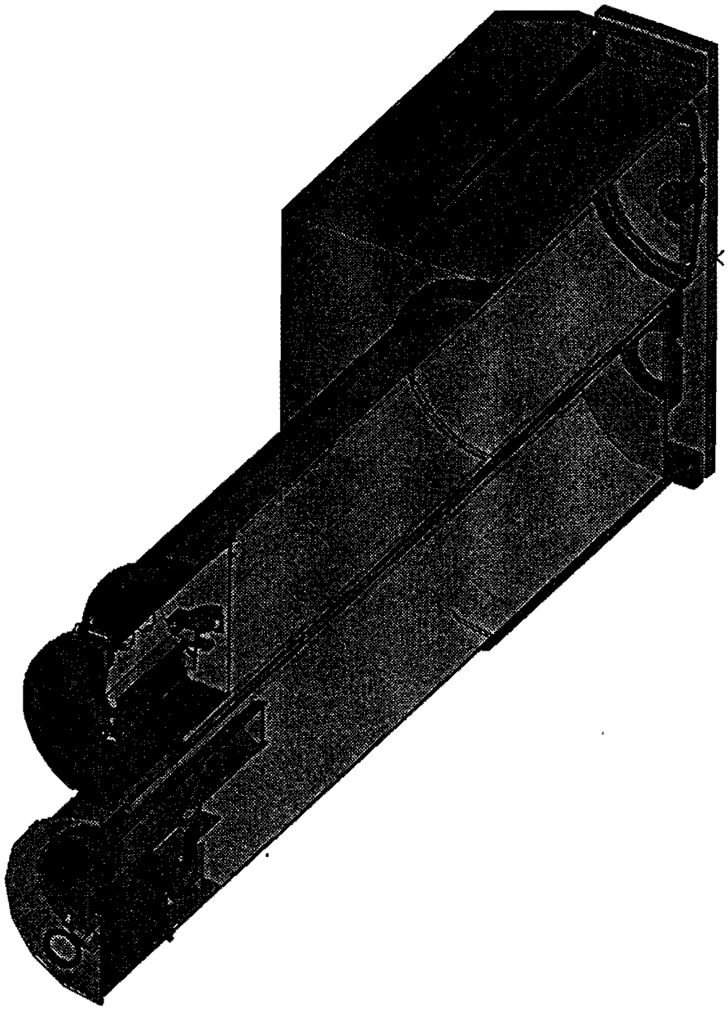
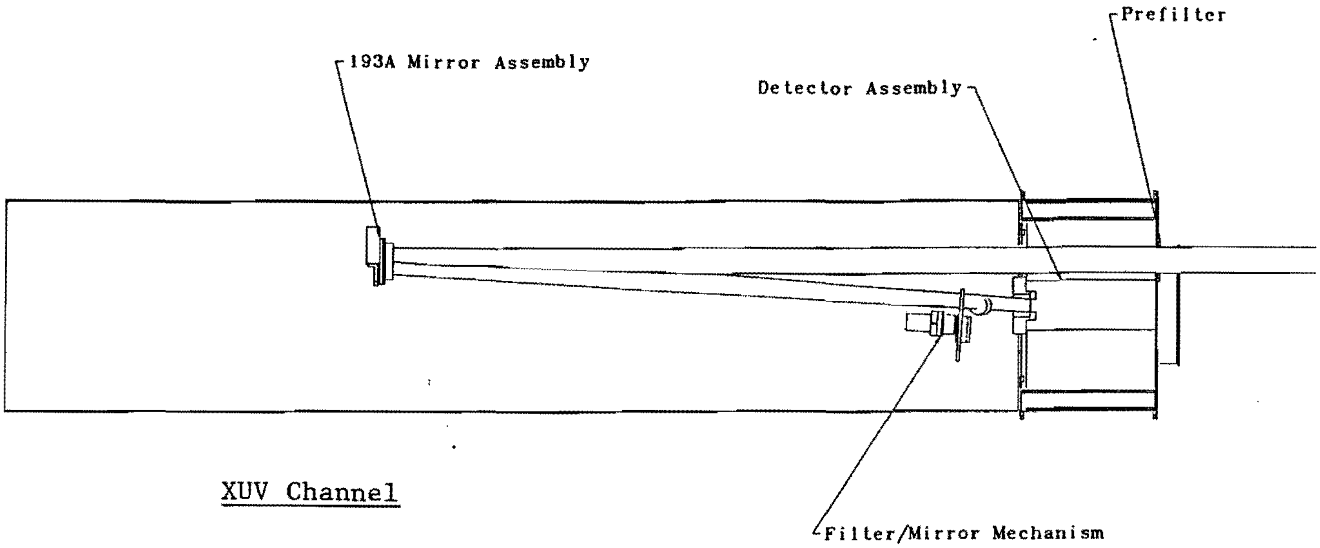
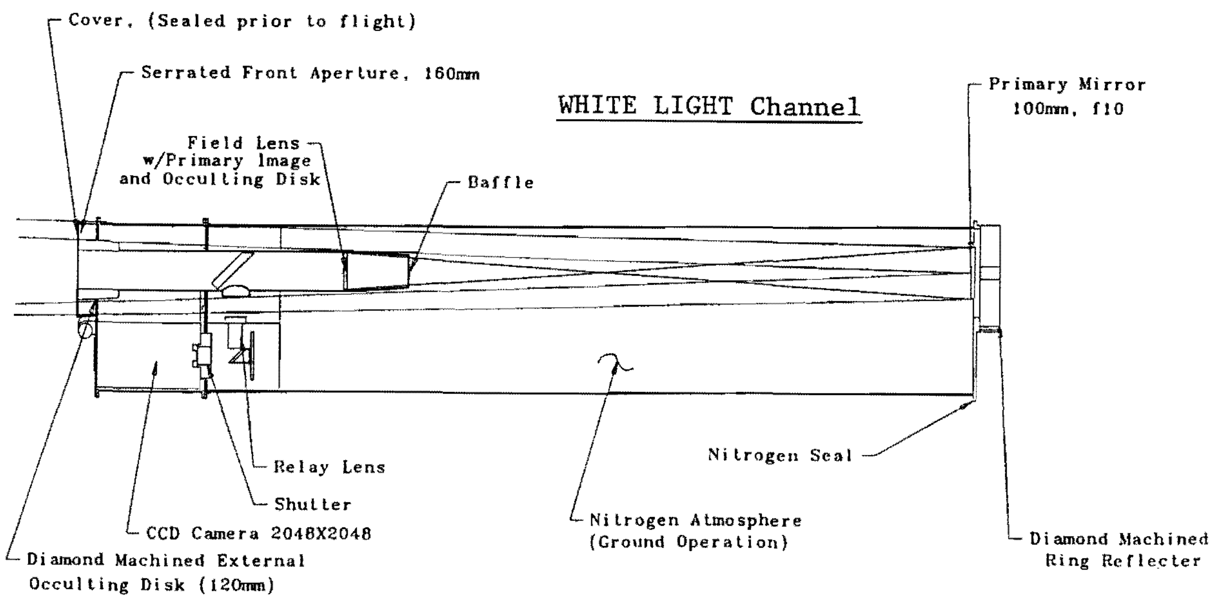


Figure 1. Conceptual layout of the SWATH experiment.

193 Å wavelength, which images the solar coronal emission at 2×10^6 K temperature. The design of the coronagraph is novel (Figure 2), to the extent that it will have a superpolished primary mirror objective and external occulting, so that the coronal light is reflected symmetrically about the optical axis. This design has significant advantages with regard to aberration correction, and will provide extremely high sensitivity and good spatial resolution over a field of view from less than one Solar radius above the surface out to ~6 Solar radii. The XUV channel provides direct coronal imaging of quiescent and transient emission on the Solar disk and out to a Solar radius. The overlap between the two fields of view will provide a unique ability to trace coronal mass ejection events from the Solar surface out into interplanetary space.

The common detector has a thin (0.4μ) phosphor coating that converts the XUV to visible light, thereby making it usable at both wavelengths. This technique has been used by us a three rocket flights with complete success, and laboratory tests indicate that the phosphor coating





SWATH Coronagraph

Figure 2. Conceptual layout of the SWATH coronagraph/XUV instrument.

is stable under vacuum conditions for at least several years.

The second telescope contains a large multilayer-coated mirror for imaging of the solar corona at X-ray and visible light wavelengths (Figure 3), with arcsecond spatial resolution. This telescope provides state-of-the-art capability for studies of the activity and stability of the corona. Taking into account the fact that X-ray multilayer coatings also reflect visible light, we employ a moveable neutral density filter which provides imaging of either the corona or the photosophere, or both simultaneously (Figure 4), at high resolution. Because they are produced by the same reflecting surface, the images are automatically coaligned, co-registered and simultaneous, so that the relationship between the surface turbulence of the Sun and the activity of the corona can be studied in the most effective manner.

III. Mission Profile

The timescales over which the coronal phenomena to be studied occur range from a few seconds to many months. In addition, debris detection will be low probability (~1%) within a given coronagraph image, while the debris population may be highly variable as a function of geocentric latitude, so that a large number of images at all latitudes is desireable for adequate detection. The satellite will therefore be placed in a polar, sun-synchronous orbit for nearly continuous monitoring of the Sun and for pole-to-pole mapping of the space debris population. The nominal mission lifetime is 90 days, with a basic turn-on and checkout period of 30 days and a design goal of two years for completion of the full range of scientific programs. Present plans call for a Pegasus XL launch.

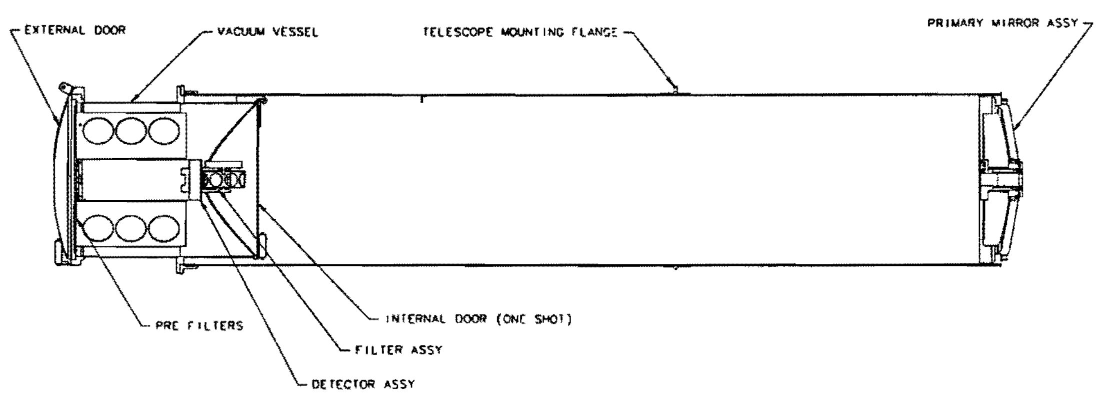


Figure 3. Layout of the SWATH high resolution X-ray instrument.

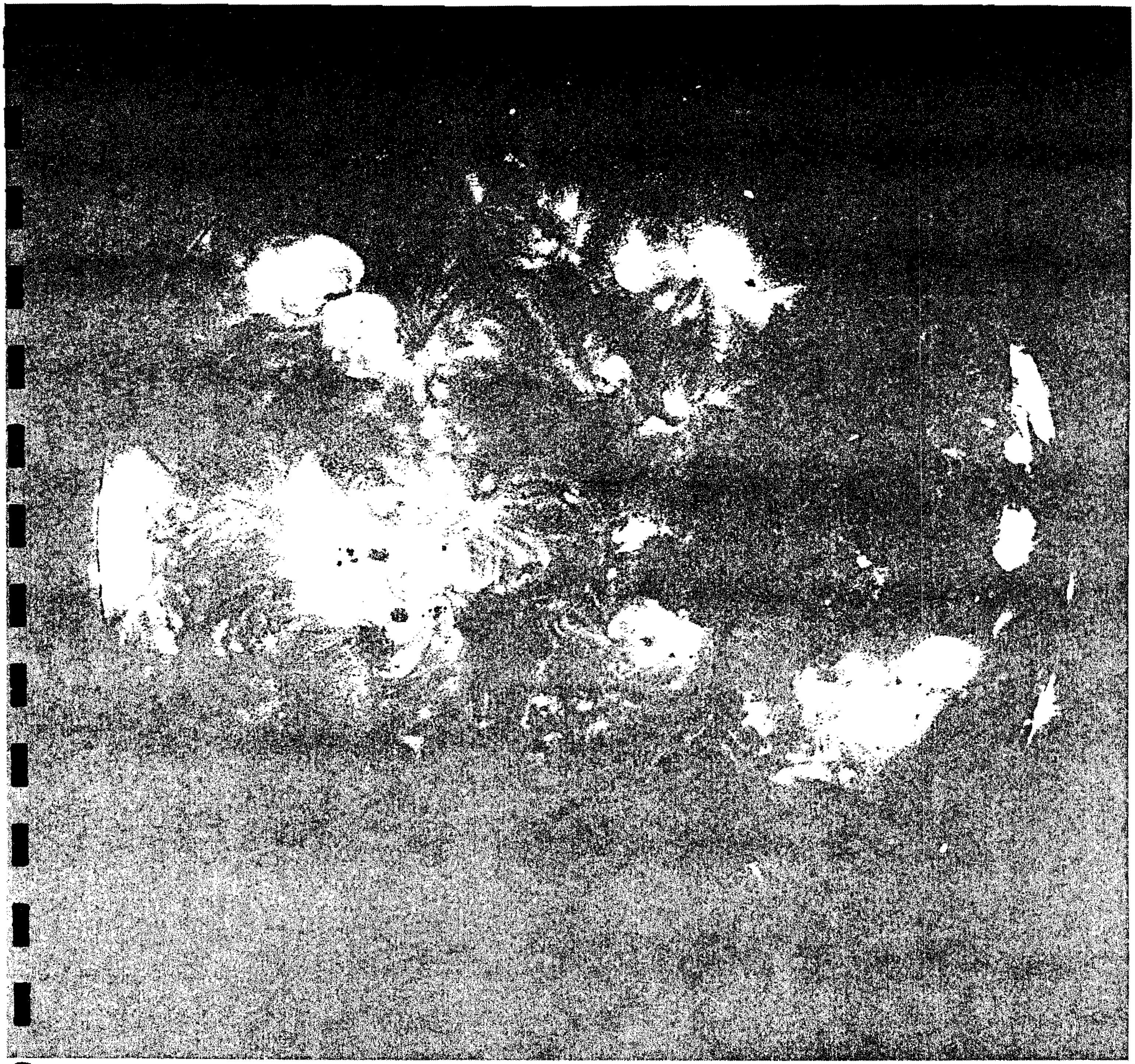


Figure 4. Simultaneous high resolution coronal X-ray and white light Solar image.

Commencement date for the program was April 1993. The Preliminary Design Review was held early in September, and the CDR is scheduled for late Fall of 1993. Instrument and spacecraft integration are currently scheduled to take place in the Fall/Winter 1994 timeframe and the anticipated launch date is in the Spring of 1995.