The NIXT and SWATH Experiments

Leon Golub

*Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138, USA*

**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. The mission has been named SWATH, for Space Weather and Terrestrials Hazards, and is based in large part on the highly successful Normal Incidence x-ray Telescope (NIXT) experiment. 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. Results from recent flights of the NIXT payload will be used to illustrate the types of data to be produced by the SWATH satellite.

1. **Introduction**

I have, in effect, been asked to give two presentations at this meeting: On the one hand, the organizers would like to hear about the small satellite experiment which we are in the process of building and which is scheduled to be launched in mid-1995. At the same time, they want to hear about the latest results from our coronal x-ray telescope sounding rocket experiment, the NIXT. In the following, I will do both: The SWATH satellite is to a large extent based on the NIXT instrumentation, so that I can concentrate on discussing the satellite and illustrate the types of data we will be obtaining by using the NIXT and coordinated data as examples. Of course, the data we have in hand already were obtained under rather special circumstances, such as a rocket flight exactly simultaneous with a total Solar eclipse. The satellite will enable us to carry out such observations routinely, rather than as one-time events.

2. **Scientific Objectives**

The 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 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. This satellite is one in a series being built under the auspices of the Ballistic Missile Defense Organization (BMDO).
These objectives are being addressed by direct observation of the relevant sources: debris detection will be carried out by instrumentation which views the light from debris particles seen at small forward scattering angles between the Sun and the sensor. The bright disk of the Sun is occulted and the instrumentation is designed to detect light levels more than eight orders of magnitude fainter than the disk. The activity and instability of the corona is observed by direct detection of the primary radiation, which is the x-ray emission line spectrum of the hot coronal plasma. Coronal transient events originate in the inner corona, at or near the solar surface, and they are detected as they move outward toward the Earth by both the XUV and coronagraph instruments.

3. Instrumentation

The SWATH payload consists of two dual-purpose telescopes, each with a large format CCD camera and related electronics. The basic layout of the payload is shown in Fig. 1. There are two nearly identical graphite-fiber tubes which act as metering structures: one tube contains a high resolution x-ray telescope (Spiller et al. 1991) and white light continuum imager; the other contains a white light coronagraph and XUV imaging telescope. The cameras in the two units are nearly identical; both are sensitive to visible and x-ray light, both are 2K x 2K format and are read out by a sophisticated image capture board with high-speed digital signal processor. The only difference between the two is in the thickness of the phosphor coating used to convert x-rays to visible light at the focal plane, since the XUV camera can use a much thinner phosphor layer.

The design of the instruments and of the electronics is based on the NASA-funded NIXT (Golub et al. 1990) 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. A summary of the basic instrument parameters is given in Table 1.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Wavelength</th>
<th>Ion</th>
<th>F.O.V.</th>
<th>Pixel size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronagraph</td>
<td>White Light</td>
<td>N/A</td>
<td>192 arcmin</td>
<td>6 arcsec</td>
</tr>
<tr>
<td>XUV Telescope</td>
<td>193 Å</td>
<td>Fe XII</td>
<td>66 arcmin</td>
<td>1.8 arcsec</td>
</tr>
<tr>
<td>X-ray Telescope</td>
<td>63.5 Å</td>
<td>Fe XVI/Mg X</td>
<td>16 arcmin</td>
<td>0.5 arcsec</td>
</tr>
<tr>
<td>Continuum</td>
<td>6000 Å</td>
<td>N/A</td>
<td>16 arcmin</td>
<td>0.5 arcsec</td>
</tr>
</tbody>
</table>

The electronics for the experiment are mounted in two boxes which sit alongside the main telescope tubes; these also serve as structural elements which hold the telescopes in place and attach to the spacecraft. Each of the telescopes has a filter wheel near the focal plane, which provides the means for switching functions. In the x-ray telescope, the wheel moves neutral density filters
Figure 1. Layout of the SWATH instruments, showing the two dual-purpose telescopes, the structural design and the location of the electronics boxes.
Figure 2. Simultaneous NIXT coronal x-ray and photospheric white light continuum images, 1991 February 22.
into position, which allows for a controlled amount of white light continuum to reach the focal plane; thus we obtain either an x-ray image, or a photospheric continuum image, or a combination of both so that coronal structures can be traced down to their photospheric roots. Because the two images are produced by the same reflecting surface, they 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. An example of the type of data obtained in this way is shown in Fig. 2.

In the coronagraph/XUV channel, a filter wheel moves a flat mirror into place to feed the white light coronal image to the detector, or it rotates a thin aluminum filter into place, which blocks the visible light and transmits the 193 Å XUV image to the detector. The two images have very different fields of view: the XUV channel sees the corona on the disk of the Sun and out to nearly one solar radius above the limb. We have therefore chosen a plate scale which sees the corona with respectable resolution (2 arcsecond pixels), while providing a field which will record dynamic transient events as they are ejected from the Sun. This image overlaps the field of the coronagraph, which begins at 0.5 solar radius from the limb and images out to 5 solar radii above the limb.

The instrument is being built by the Smithsonian Astrophysical Observatory, Dr. J. Bookbinder, Project Scientist and G. Nystrom, Project Engineer. The coronagraph portion of the instrumentation is being built at the National Solar Observatory (Sac Peak), Dr. R. Smartt, P.I. The contract is managed by the Phillips Laboratory (PL/SXAD), V. Baker, Program Manager.

The SWATH team, in addition to the individuals already named, includes: G. Austin, K. Daigle, E. DeLuca, J. Gomes, K. Kalata and A. Viola at SAO; R. Dunn and J. Zirker at NSO; D. Neidig and G. Simon at PL/GPSS; S. Koutchmy at IAP (France), W.K.H. Schmidt at MPAE (Germany), and S. Kahler at PL/GPSG. The multilayer-coated x-ray mirrors are being manufactured at Wilc Instruments by Drs. E. Spiller and J. Wilczynski and at LLNL by Dr. T. Barbee.

4. Conclusion

The SWATH satellite combines the high-quality imaging capabilities of the NIXT sounding rocket payload with the capability of observing the outer corona out to several solar radii. The spatial resolution of the x-ray images, depending upon the satellite’s pointing stability, will be nearly as good as can be achieved in the sounding rocket, and will almost certainly exceed that obtained by the Yohkoh SXT and the EIT on SOHO. The white light coronagraph will be an exceedingly high quality instrument by itself; in combination with the x-ray instruments it will provide unprecedented capability for studying coronal mass ejections, flare-related surge events, high-speed streams originating in coronal holes, and the large range of dynamic phenomena identified by the SXT in the “transition corona” located above active regions. Finally, if the present launch schedule can be maintained, the SWATH is likely to be the only instrument available to provide coronal imaging for the North polar passage of the Ulysses spacecraft.
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References


Group Discussion

Ginet: What is the typical duration of the rocket experiments and do you see much variation in the x-ray images over this interval?

Golub: In a typical sounding rocket flight we get about five minutes of solar-pointed observing time. We have certainly made it a high priority to search for variability in the coronal structures, and our exposure sequences are optimized with that goal in mind. To summarize briefly: in active regions the large loops have not shown any measurable changes over five minutes. Small loops of the order of 15 arcseconds or less do vary, and we see even smaller “point-like” features which change quite rapidly. In addition we have observed at least one flare event on every NIXT flight and of course these changes are seen there.

Fisher: Regarding your Fe XII filter at 193 Å, there is also an Fe XXIV line at nearly the same wavelength which forms at much higher temperatures that Fe XII; 20 – 30. \(2 \times 10^6\) K as opposed to 1 – 2 \(2 \times 10^6\) K

Golub: The line you mention is indeed within the passband of our 193 Å telescope. This means that when a flare occurs, we will see both the flare itself and the region in which the flare is occurring within the same image.

Klimchuk: To what plasma temperatures will the EUV images be sensitive?

Golub: The SWATH EUV telescope will use the same 193 Å passband as the NIXT image that I showed, which means that FeXII at about \(2 \times 10^6\) K. I note however, that it is a very simple matter to substitute a different wavelength. However, for the moment, we do not plan such a change.