ESC-TR-95-022

Project Report
STK-235
Volume I

Proceedings of the 1995 Space Surveillance Workshop

(Title UNCLASSIFIED)

K.P. Schwan
Editor

28 – 30 March 1995

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

Prepared with partial support of the Department of the Air Force
under Contract F19628-95-C-0002.

Initial results from the new sensor system on the UK SOI facility at Herstmonceux

Dick, J., Sinclair, A., (Royal Greenwich Observatory, Cambridge, UK)
Greenaway, A., and Liddell, P., (Defence Research Agency, UK)

1. Introduction

In support of the UK's SOI programme, a new sensor system has been installed on the 0.5 m satellite-tracking telescope at Herstmonceux. The new system, known by the acronym FOX, is used principally for acquiring photometric SOI data and also provides a general-purpose optical bench for enhanced-resolution imaging experiments. FOX has been in use since mid-1994. This paper describes both the system and some of the observations taken.

2. The FOX system

The FOX system has five main components:

i) a camera assembly that holds two scientific-grade charge-coupled device (CCD) cameras and their associated optics. Within this assembly, there is a beam-director to direct the light from the telescope to one or both cameras, to the optical bench, or to the bench and one camera. In front of each camera is a carousel that holds up to eight filters. At present, each carousel is fitted with a range of neutral density filters. Immediately prior to each camera is another holder that can used to hold other optical components (*e.g.* colour filters).

ii) a telescope-resident microcomputer system that controls the positioning of the optics within the camera assembly. The beam-director and the two neutral density carousel wheels are controlled by this microcomputer. The microcomputer is, in turn, controlled remotely by the FOX's main computer system via a serial link.

iii) the camera controller units. There are two camera controllers that are housed near the telescope, provide drive signals to the cameras, and process the low-level analogue output signals from the cameras.

iv) the main computer system that controls the experiment, acquires and processes data. This is sited in the telescope control room. It contains interface cards that enable it both to control and to receive image data from the cameras.

v) a platform structure which can host optics experiments. This is mounted on the telescope and has a matrix of tapped holes for standard optical bench components.

The general layout of FOX is shown in Figures 1 and 2. The camera system is driven from application-specific software that was written in-house. The software allows images to be taken with the cameras and recorded to disk; quite sophisticated image processing can be carried out *post hoc*.

For photometry, the software measures the positions and integrated intensity of any objects that are detected within each and every frame taken by the cameras.

Results from photometric observations are in the form of a dictionary that has one entry for each object detected during a given observing session.

Fig. 1 General layout of FOX

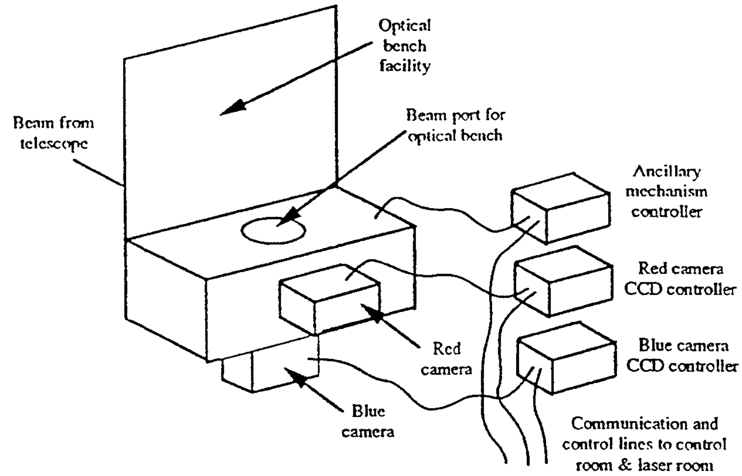
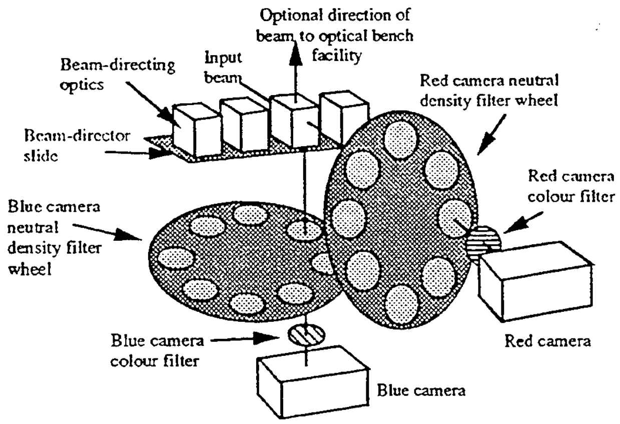


Fig 2. Optical components within FOX



Each entry in the dictionary contains positional information about the object it describes as well photometry.

The photometry is stored as a list of {time, intensity} pairs for one-camera operation or {time, red intensity, blue intensity} triplets for two-camera operation. From one frame to the next, nearness in position is used as the criterion for same-object identification. If, possibly due to tracking error, an object strays far enough between frames so that it fails the nearness test then the system does not lose that object (because all objects are tracked and measured) but merely identifies it as a new object (*i.e.* a different entry in the dictionary). In practice, such discontinuities in the dictionary can be rectified during off-line data analysis and so continuous data collection is possible. Occasionally, because another object (*e.g.* a star) passes the nearness test, it is possible within one frame for two objects to be identified with the same dictionary entry. In such a case, photometry for both objects is logged.

3. Commissioning results

Since installation, FOX has been used for both photometry and imaging, although the imaging work was done without the system being configured for such work.

A variety of photometric and astrometric tests have been carried out to characterize FOX. The photometric sensitivity of the FOX cameras has been tested both in the laboratory and on stars of known irradiance; astrometric tests have been carried out using star clusters.

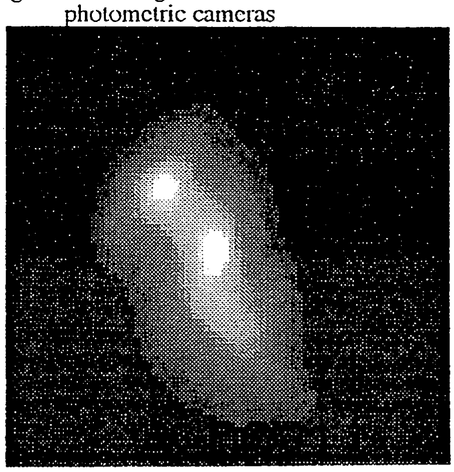
3.1. Imaging

Shortly after FOX was installed on the telescope, the space station MIR was observed during a high-elevation pass. During this pass, a short exposure image of MIR was taken and this is shown in Figure 3.

Although blurred, the shape of MIR can be seen clearly. (This image was taken with one of FOX's photometry cameras, which is *not* designed for high-resolution imaging work.)

At the range of MIR, one pixel is roughly 1 m; the total size of the image is therefore about 35 to 40 m.

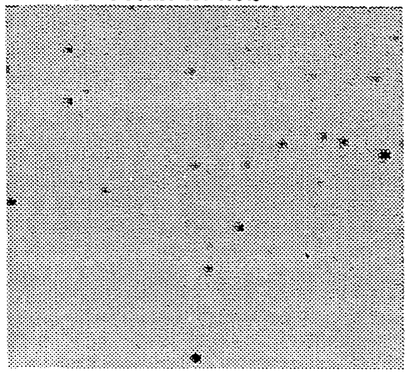
Fig. 3 MIR imaged with one of FOX's photometric cameras



In the near future, it is hoped to commission a fully-sampled imaging facility that will be located on the optical bench. After initial observations have been taken to characterize the guiding accuracy of the system, a fast image stabilization system using a tip-tilt mirror will be designed. Later, low-order corrections for wavefront curvature will be introduced.

It is possible for one of the FOX cameras to be installed on the SLR's 20 cm wide-angle telescope (co-mounted with the main telescope). FOX has been used in this mode for a European debris-watch campaign. Figure 4 shows a short exposure of the open star cluster NGC752 used for astrometric characterization tests; on-line star catalogues are used to establish field identification and positional data for satellites within the observed field.

Fig. 4 Star cluster NGC752 used for astrometric tests



3.2. Photometry

FOX has been used for photometry of satellites in low-, high-, and geostationary Earth orbit. In summary, the system has proved to be more sensitive than its predecessors and has much better signal-to-noise even in bright-sky conditions; typically, the sky background *noise* in an observation is about 20 times smaller with FOX than with the previous photometer.

Figure 5a shows the red-only signal from the TOPEX satellite (92-052-01, 22076).

Observation starts at 02:16 on 18th October 1994 and shows the satellite coming out of shadow, a plateau of near-constant brightness, and a bright long-lived flash.

Fig. 5a Red-light irradiance from TOPEX

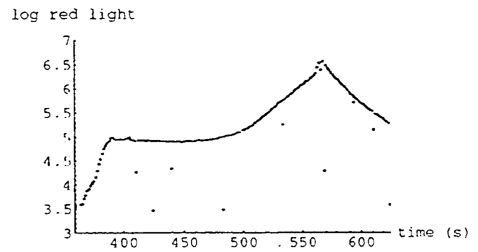
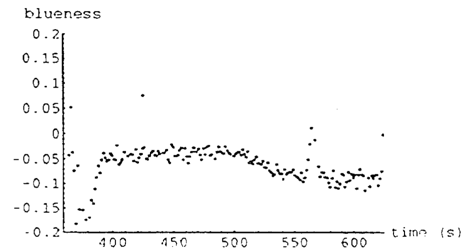


Figure 5b shows the blueness of the satellite during the same period of time: the satellite emerges from the Earth's umbra red, becomes bluer as it passes through the penumbra into direct sunlight, and then gives a bright blue flash.

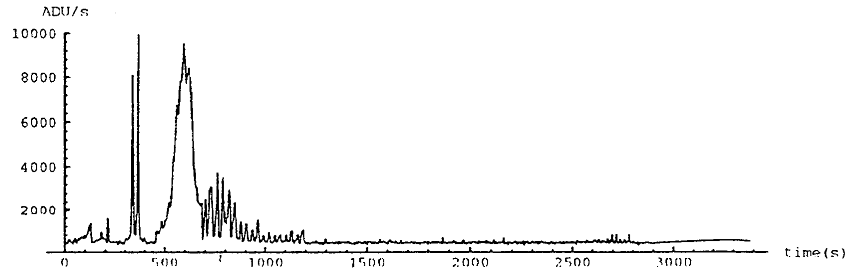
Figure 6 shows a rich-featured photometric observation of one of the Glonass series.

Fig. 5b Blueness analysis for TOPEX



Geostationary satellites have also been observed successfully. Figure 7 shows the apparent visual magnitude of Intelsat 6 F-1 (1991-075-01) during a night. This observation was taken during a joint US-UK observation campaign called JOVIAN. Observations of three geostationary satellites were taken simultaneously by the

Fig. 6 Photometry of 92-005-03



Phillips Laboratory Malabar telescope facility and by the SLR at Herstmonceux. The JOVIAN program showed that the two sites could work together, acquiring bistatic photometric SOI information.

3.3. Spectral information

To extend the colour capability of the system, a transmissive diffraction grating can be placed in the optical path.

Fig. 7 Photometry of the geostationary satellite 91-075-01 obtained during the JOVIAN campaign.

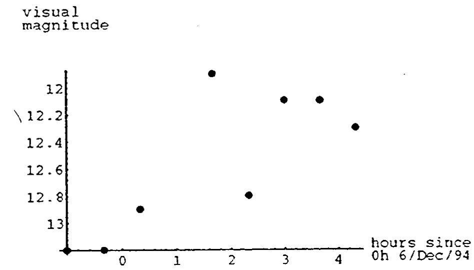
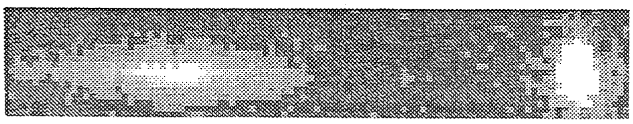


Figure 8 shows a typical image obtained with FOX configured with the grating. The image shows both the "white light" image of the object (which acts as an in-image calibrator), and, to the left, the first-order spectrum of the object.

Fig. 8 FOX spectral data



4. Summary

FOX has been successfully commissioned on the SLR at Herstmonceux.
FOX has extended the SLR's optical SOI capability by enabling colour information to be acquired on objects in all orbital regimes, including geostationary. During its first year, as well as carrying out routine SOI work, FOX has been used for joint UK/US geostationary observations and in a European debris campaign. The authors would like to thank the SLR Group staff for their contributions to the work reported in this paper, and the UK MoD for funding support.