ESC-TR-96-026

Project Report
STK-245
Volume I

Proceedings of the 1996 Space Surveillance Workshop

K.P. Schwan
Editor

2–4 April 1996

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.

Unclassified

PIMS: progress report on a deep-space metric sensor project

Dick, J., Sinclair, A., (Royal Greenwich Observatory, Cambridge, UK),
Liddell, P., (Defence Research Agency, UK), & Holland, D., (Ministry of Defence, UK).

1. Introduction

At present, optical photometry and metric (*i.e.* positional) information to support the UK's SOI programme are acquired with the Satellite Laser Ranger (SLR) facility at Herstmonceux, operated by the Royal Greenwich Observatory.

The SLR system, built in the early 1980s, is a high-precision tracking telescope with a 50 cm aperture and is designed to work in a laser ranging mode: the times-of-flight of short (<100 ps) 30 mJ laser pulses, at 532 nm, from the SLR to a satellite and back are measured with sufficient resolution to give object ranges to centimeter precision.

The field of view of the SLR main telescope is ~ 4 arcminutes, quite adequate for its laser ranging task, where the position of satellites is known to a few arcseconds. For acquiring satellites without precision ephemerides, the SLR is equipped with a co-mounted 20 cm telescope with a 1° field of view when operated with an intensified TV camera or a 0.25° field of view when operated with one of the FOX system's CCD cameras. (FOX is a MoD-funded SOI photometer mounted on the SLR.) The wide-field telescope has only 16% of the collecting area of the main telescope and its intensified TV system is affected by noise at the single-photon level from the sky background, which produces a very high "clutter" level on the operator's display.

In summary, the SLR system is disadvantaged for search/map operations because the large-aperture telescope has too small a field of view and the small-aperture telescope has too small an aperture and a detector system configured for other purposes.

To overcome these limitations, a new optical sensor system is being procured that has enhanced sensitivity and a wide field of view. Such a sensor is an excellent tool for the GEO/HEO metric mission and it releases the inappropriately-configured SLR system from time-consuming searching or mapping missions. The new system is called PIMS: Passive Imaging Metric Sensor. It is passive because, unlike the SLR, it does not actively illuminate its targets and it forms an image to make a metric observation.

2. Opportunities with PIMS

PIMS can map efficiently large areas of sky in satellite-search mode for space situation awareness (SA) tasking, and, when deployed at Herstmonceux, or other near-0° longitude site, would be able to observe the area of GEO from ~35° West to ~35° East, thus including UK SKYNET and NATO satellites, as well as satellites deployed to service a geographical region from the Saudi peninsula to the western Atlantic.

PIMS metric observations can complement observations taken with range/range-rate radar systems, so providing more information for both orbit-determination and SOI missions. In particular, accurate position-on-sky measurements can help provide correct satellite identification where GEO satellites are close enough together to be difficult to distinguish by range or to be confused within a lobe of a radar system.

We estimate that PIMS will be able to provide metric (*i.e.* positional) information about GEO satellites to an accuracy of approximately 2 arcseconds or better; a trial system on the SLR produced sub-arcsecond RMS errors.

In addition to GEO/GTO targets, PIMS can also be used for metric observations of HEO objects and, for slow moving objects, can be used to take low-precision photometric observations. PIMS sensor's comparatively wide field of view makes the sensor useful for high-altitude debris studies, too.

3. PIMS in more detail

PIMS consists of a telescope, a detector, and a data processing facility.

The telescope is a Meade Instruments 16-inch (40 cm) LX200 telescope with focal reducer giving an f/6 optical system. The Schmidt-Cassegrain optical system gives a flat, CCD-compatible focal plane. The telescope has a computer-controllable drive system with built-in automatic calibration for the pointing model. The telescope is tripod mounted so enabling the system to be relocated and set-up within a few hours using a three-person team at a remote site. The drive system will allow staring (in fixed elevation and azimuth) or siderostatic pointing (*i.e.* star tracking) so geostationary or nearly-geostationary objects can be tracked against a background of trailed stars and objects with larger motion against the celestial background can be allowed to trail through a static stellar background.

The detector is a Peltier-cooled (air-venting) slow read-out CCD with 1024x1024 pixels of 24 μm linear size or ~2 arcsec angular measure, capable of read-out times of the order of 2.5 seconds per frame at a digitization precision of 16 bits. For the metric mission, higher-speed frame read-out (such as is available on the SLR's FOX system) is not seen as a requirement but could be achieved using on-chip binning.

The computer system (an Apple PowerMacintosh) contains the detector interface, a modem for communications facilities, an interface to a GPS receiver for time and geographical location information, and three CD-ROM readers for on-line access to star catalogues. Initially, the Hubble Space Telescope Guide Star Catalog (GSC) will be used for information about the stellar background in any CCD frame. The GSC contains stellar positions and magnitudes for ~15 million stars, measured in the northern hemisphere by the US Palomar Schmidt telescope and, in the southern hemisphere, by the UK Schmidt telescope, sited in Australia. Higher-accuracy astrometry can be obtained by using other catalogues such as those from the Hipparcos satellite or the part-RGO-operated Carlsberg Meridian Circle on La Palma. Although capable of being operated interactively, the PIMS control kernel can take its tasking commands from a file that will have been down-loaded into the system prior to nightfall.

PIMS "home" will be at Herstmonceux and a new building, next to the SLR building and its adjacent office accommodation, houses the system. The proximity to the SLR allows PIMS and the SLR to be operated by an observer; a CCTV link between the PIMS enclosure and the SLR observer's desk provides feedback to the duty observer.

Because PIMS is minimally dependent on the precision of the telescope mount, the system can be relocated easily and observations from UK sites in Gibraltar and Cyprus are to be collected in the near future.

PIMS operation is conceptually simple. From a list of operational requirements, the telescope points to some area of sky — for example, an area of the GEO belt for which a satellite search is required. The detector system takes a series of frames of the chosen area of sky. Each frame will contain images of stars present in the celestial background, and any satellites in that area of sky.

From its knowledge of the time, the telescope location, and the co-ordinates of the sky area observed, PIMS then consults on-line star catalogues and matches the catalogue stars to those detected on any frame of that area. PIMS then calibrates each frame by using the background starfield to give a mapping function that converts an object's $\{x, y\}$ position in a CCD frame to a celestially-derived $\{alt, az\}$ position-fix.

PIMS offers significantly superior searching/mapping performance when compared with either the SLR main or finder telescopes and also enables the SLR to work contemporaneously on other different or collaborative observing programmes.

4. Progress

The MoD authorized the start of procurement in September 95; first "on-sky" engineering trials were carried out in January 96.

Acknowledgements

The SLR is operated by the Royal Greenwich Observatory on behalf of the UK Natural Environment Research Council, the Department of Trade & Industry, and the Ministry of Defence. PIMS is funded by the Ministry of Defence. PIMS work programme is managed jointly by the Defence Research Agency and the Ministry of Defence. The PIMS system was conceived and developed by the Satellite Laser Ranger Group at the Royal Greenwich Observatory.