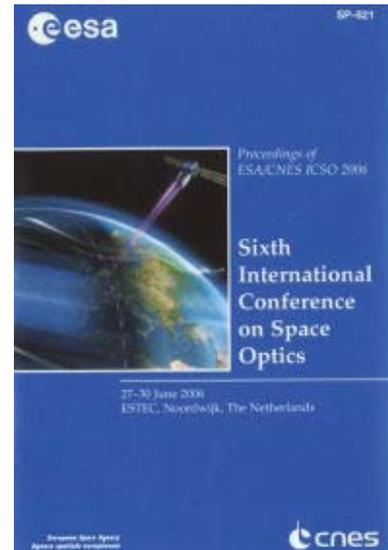


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FIRST RESULTS FROM THE TOPSAT CAMERA

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ABSTRACT

The TopSat camera is a low cost remote sensing imager capable of producing 2.5 metre resolution panchromatic imagery, funded by the British National Space Centre's Mosaic programme. The instrument was designed and assembled at the Space Science & Technology Department of the CCLRC's Rutherford Appleton Laboratory (RAL) in the UK, and was launched on the 27th October 2005 from Plesetsk Cosmodrome in Northern Russia on a Kosmos-3M.

The camera utilises an off-axis three mirror system, which has the advantages of excellent image quality over a wide field of view, combined with a compactness that makes its overall dimensions smaller than its focal length. Keeping the costs to a minimum has been a major design driver in the development of this camera.

The camera is part of the TopSat mission, which is a collaboration between four UK organisations; QinetiQ, Surrey Satellite Technology Ltd (SSTL), RAL and Infoterra. Its objective is to demonstrate provision of rapid response high resolution imagery to fixed and mobile ground stations using a low cost minisatellite.

The paper "Development of the TopSat Camera" presented by RAL at the 5th ICSO in 2004 described the opto-mechanical design, assembly, alignment and environmental test methods implemented. Now that the spacecraft is in orbit and successfully acquiring images, this paper presents the first results from the camera and makes an initial assessment of the camera's in-orbit performance.

1. INTRODUCTION

RAL (Rutherford Appleton Laboratory) provided the high-resolution camera for the UK TopSat satellite mission, launched in October 2005. The mission commenced full operations in January 2006 and the satellite is now routinely producing imagery. This paper presents some of the first results from the camera and describes the work that is presently being conducted in analysing these images.



Fig. 1. The TopSat spacecraft



Fig. 2. The TopSat camera

2. MISSION PARAMETERS

Orbit : 686km altitude, sun-synchronous polar orbit

Resolution : 2.85m panchromatic & 5.7m colour
(at 600km altitude, 2.5m pan & 5.0m colour)

Swath : +/- 15km

Mass : 140kg including 29kg camera

Launched : 27th October 2005 on Kosmos-3M

Lifetime : > 2 years

In order to increase the signal to noise in the detector, the satellite can perform a pitch compensation manoeuvre (PCM) to slow the ground velocity of the field of view of the detector through the image. This is shown pictorially in fig. 3 & fig. 4.

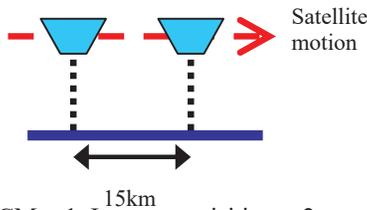


Fig. 3. PCM = 1, Image acquisition = 2 seconds

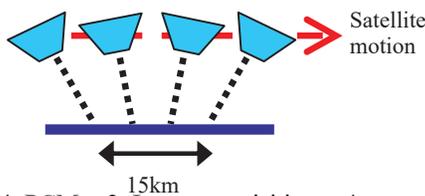


Fig. 4. PCM = 2, Image acquisition = 4 seconds

The camera operates in a push-broom mode, with the camera focal plane assembly (FPA) having two linear CCDs scanned along the surface of the Earth by the motion of the satellite. One detector generates panchromatic data and the other three-band multi-spectral data.

3. GROUND SAMPLING DISTANCE (GSD) ANALYSIS

An investigation of the achieved GSD has been performed using the image of Dartford, UK (fig. 6) taken on the 7th December 2005 with a PCM factor of 4.

Features with large separations were selected from the image, then the distance between points measured using an ordnance survey landranger 1:50,000 scale map (10.0m accuracy). Corresponding points were then located in the image data and pixel separation calculated. The effective GSD was calculated as the ratio of distance between points (km) to the distance between points (pixels). Only features completely along track or across track were selected. By selecting large distances between points, accuracy of GSD measurement is < 0.5%.

The across track results summarised in Table 1 match well with the expected GSD values (2.85m panchromatic and 5.7m colour). The along track GSD corresponds to a smearing effect of ~6%. This could be the result of small inaccuracies in the PCM.

Table 1 – Summary of GSD Analysis

	Across track GSD (m)	Along track GSD (m)
Multi-spectral	5.74	6.10
Panchromatic	2.87	3.05

4. CCD OFFSET AND GAIN SETTINGS

The panchromatic and colour CCDs on TopSat have adjustable offset and gain settings that can be changed using a control file called a wavetable. These wavetables are stored in the Data Handling Unit and are uploaded prior to an image acquisition. The default offset and gain settings were established by ground testing, but these needed to be confirmed once on orbit. So to this end some images were taken of uniform dark and bright scenes during the commissioning phase of TopSat. The figures in tables 2 & 3 are in engineering units or counts, with full scale equal to 1023 (i.e. 10 bit digitisation). The offset and gain for the images were 43mV and 1.0 respectively.

Table 2 – Dark Scene Image Statistics

Image 4 – Atlantic at night PCM=4				
	mean	s.d.	min	max
Pan	23.932	1.084	21	26
Red	30.349	0.499	29	33
Green	37.509	0.504	36	39
Blue	5.492	0.504	4	19

Table 3 – Typical Urban Scene Image Statistics

Image 30 Dartford (fig.6), UK SZA=77° PCM=4			
	min	max	% of DR
Pan	22	817	80
Red	86	1023	100
Green	89	748	73
Blue	83	470	46

SZA = Solar Zenith Angle
DR = Dynamic Range
s.d. = standard deviation

For the dark scene, the output from the pixels should be as close to zero as possible so that the full dynamic range of the CCD can be utilised. However, it can be seen from Table 2 that the pan, red and green channels are significantly above zero suggesting the offset for these channels could be reduced. The blue channel offset is about right so does not need to be adjusted by much. Unfortunately, due to the design of the CCD electronics, it is not possible to adjust the offset for the red, green and blue channels independently, so only a small decrease in the offset can be implemented before the blue channel would start to produce negative values. However, this small change in the RGB channel offsets might be sufficient to overcome some of the problems with saturation of the red channel (table 3) and so may be worth implementing. A reduction in the pan channel offset can be implemented quite easily by uploading a new wavetable. The dark scene image also gives some information about the level of noise from non-signal dependant sources, such as dark current and read-out

noise. For the pan channel the noise is 1 LSB rms and the colour 0.5 LSB rms.

The data in table 3 shows that for imaging at relatively high latitudes (Dartford is at 51.5 deg N) with high solar zenith angles, a gain of 1 and a PCM of 4 utilises the full dynamic range of the sensor.

5. FLAT FIELDING

To provide information about the pixel to pixel variation under constant illumination conditions, an image was taken over the Antarctic ice with a SZA of 60° and PCM of 1. Figure 5 shows how the response varies across the pan channel array. Data from this flat-field image will be used to develop de-stripping algorithms for correcting images after they have been received on the ground.

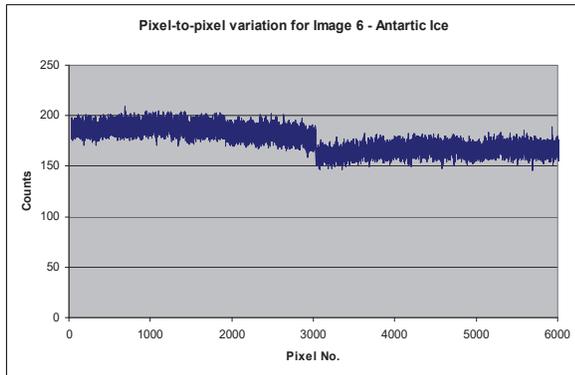


Fig. 5 - Pixel-to-pixel variation for uniform scene.

6. FUTURE WORK

Most of the images shown in this paper have been taken with the camera operating below its nominal operating temperature, in order to conserve power during the commissioning phase. It is known from ground based testing that the camera performance will improve when the heaters are switched on, so some of the scenes will be re-imaged and a comparison of image quality made. This work should help establish an optimum operating temperature for the camera before proceeding to make further performance measurements.

An evaluation of the camera's in-orbit modulation transfer function (MTF) is also planned. The use of well characterised ground targets, such as black and white square pattern targets, is being considered for this purpose.

Other activities include assessing the pointing stability during high rate pitching manoeuvres and oversampling scenes to improve the along track GSD.

7. EXAMPLES OF EARLY IMAGES



Fig. 6 – Dartford, UK, 7th Dec '05, 1030am, PCM=4.



Fig. 7 – Oklahoma, USA, 22nd Dec '05



Fig. 8 – Northern Australia, 8th Jan '06



Fig. 10 – Washington, USA, 31st Mar '06



Fig. 9 – Saskatoon, Canada, 15th Dec '05

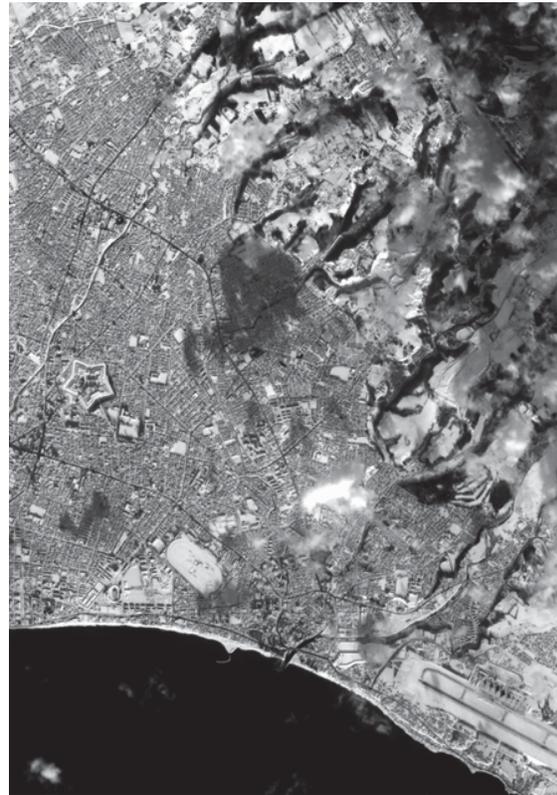


Fig. 11 – Hakodate, Japan, 11th Jan '06

8. ACKNOWLEDGEMENTS

We would like to acknowledge Nick Waltham from RAL and our colleagues from the TopSat consortium at SSTL (Surrey Satellite Technology Ltd), QinetiQ and Infoterra.

9. REFERENCES

1. P.Greenway, I.Tosh & N.Morris, Development of the TopSat Camera, International Conference on Space Optics 2004, Toulouse.