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IN-ORBIT RESULTS FROM UOSAT-12 EARTH OBSERVATION MINISATELLITE MISSION

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ABSTRACT

This paper describes SSTL's accomplishment in dramatically reducing the cost of Earth observation satellites through adopting commercial off-the-shelf (COTS) technologies for small satellites. Surrey's experimental UoSAT-12 minisatellite was successfully launched into low Earth orbit in April 1999 to demonstrate the feasibility of various low-cost state-of-the-art small satellite technologies. The remote sensing payloads on-board UoSAT-12 are described and images are provided as an illustration. Building on from this success, SSTL is currently building a number of high resolution Earth observation missions such as BILTENSAT, the Disaster Monitoring Constellation, RAPIDEYE and TOPSAT.

UoSAT-12 MINISATELLITE

The UoSAT-12 minisatellite was designed, built and funded by SSTL as a £6M ($10M) research and development project to demonstrate advanced high resolution Earth observation payloads, low Earth orbit microwave digital communications, as well as a number of innovative propulsion and attitude control technologies.

UoSAT-12 was launched on 21April 1999 from Baikonur Cosmodrome silo on a converted SS18/Dnepr Intercontinental Ballistic Missile (ICBM) in collaboration with ISC Kosmotras of Moscow.

Since the launch of UoSAT-12, over 1000 multispectral images from around the world have been gathered, downloaded and analysed. The UoSAT-12 images are found to be comparable to data from existing LANDSAT TM and SPOT Earth Observation satellites but are attainable at a tiny fraction of conventional satellite mission costs (typically $200-300M).

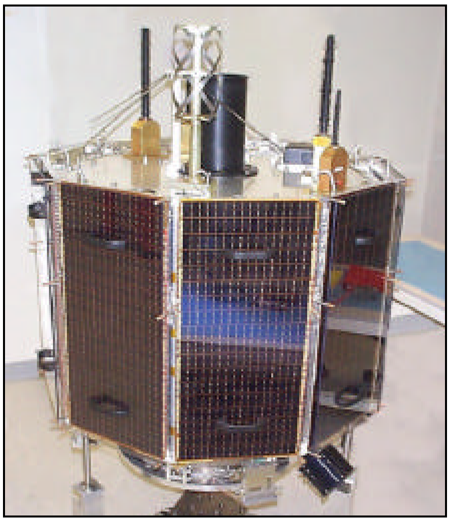

Figure 1: UoSAT-12 minisatellite

Based on the images obtained from both UoSAT-12 multi-spectral and panchromatic cameras, a significant breakthrough has been achieved in providing low cost and timely data for a variety of Earth observation applications.

Mounted on the Earth facing facet of UoSAT-12 are two 32m ground sampling distance multi-spectral cameras operating in tandem to provide wide swath width and system redundancy. Each camera comprises a 1024x1024 pixel Kodak staring array CCD area sensor with a rotating filter wheel in 4 LANDSAT-compatible (Green, Blue, Red, Near-Infrared) spectral bands providing a 64km ground swath. The filter wheel is driven by a stepper motor.

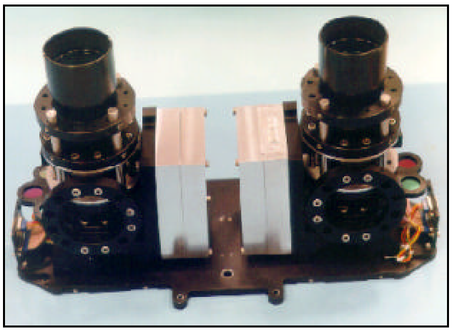

Fig-2: Multi-spectral cameras on UoSAT-12

The rotating filter wheel was an experimental design that had been incorporated into UoSAT-12 to enable in-orbit comparisons with the three-camera concept previously adopted successfully on the Thai-Paht microsatellite launched in 1998 and Tsinghua-1 microsatellite launched in 2000.

The lessons learned through in-orbit operations with UoSAT-12 have thus enabled SSTL to perform trade-offs and comparisons amongst its different camera designs and associated ground image processing.

The filter wheel enables a single camera to capture multiple images in different spectral bands and the wheel can accommodate many spectral filters. Furthermore, mass and volume of the payload are reduced as only a single optical system is required and the optical effects are common to all images. Whilst a multiple beam splitter could be used, however the alignment is more critical and illumination losses are incurred.

Although the multi-spectral cameras have performed remarkably well, one consequence of the rotating filter wheel design is that the various multi-spectral images need to be aligned due to time differences between each image capture. A 360 millisecond delay between spectral frames results in displacements of 2.5km and aligning several frames can be a labour intensive process.

Fig-3: High-resolution panchromatic camera

Figure 3 depicts the high resolution panchromatic camera providing 10m ground sampling distance utilising COTS optics with 1024x1024 pixels CCD staring array sensor covering a 10km swath. Similar to the multi-spectral cameras, the panchromatic camera has proven to be remarkably successful. However, due to the non-sun-synchronous orbit of UoSAT-12, wide temperature excursions were experienced causing periodic variations in focus of the 10m panchromatic camera.

The success of UoSAT-12 has verified the many benefits of using COTS optics and mechanics in small inexpensive satellites. Both camera designs have been proven to be highly successful and are the basis for commercial missions in the very near future.

Two images from the m/s cameras are described in the following section. Each image has been selected to highlight the spatial details and spectral differentiation of land usage.

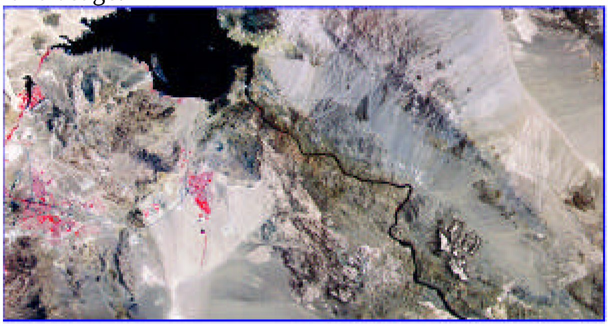

Fig-5: UoSAT-12 m/s image of Hoover Dam, USA

This 32-m multi-spectral image of the Hoover Dam was taken on the 30th August 2000 and covers a 60 $\times$ 33 km area. The surrounding terrain towards the East is mountainous and the South, barren. Roads and highways are clearly visible, interconnecting highly concentrated farmlands and populated areas. Sporadic areas of vegetation indicated in red are observed along the river banks. Of the many possible combinations of multispectral data, the most useful is the Green/Red/Near-IR. In the false colour image, vegetation appears red due to the strong reflectance of chlorophyll in near-IR. Varying shades and intensity of reds can provide valuable information on vegetation stress and crop yield.

Fig-4: UoSAT-12 pan image of Beijing, PR China (10m GSD panchromatic)

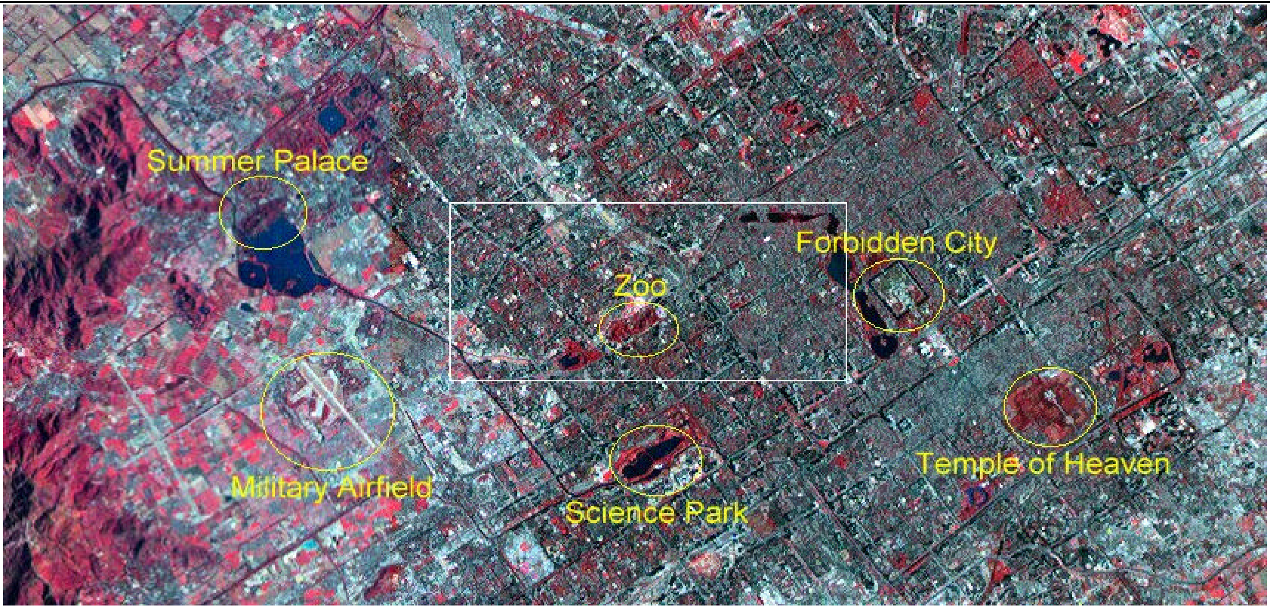

Fig-6: UoSAT-12m/s image of Beijing, PR China

The image of Beijing taken on 5th July 2000, provides a contrast to Image 1. Dense urban areas appear blue-grey and vegetation red. The city centre is especially dense, with a large number of buildings and apartments. Major landmarks include the Forbidden City, Tianamen Square, the Beijing Zoo and Temple of Heaven Park. The panchromatic image of Beijing in Fig-4 reveals in detail the major highways, side streets, buildings, and houses in the city centre.

Surrey's Future EO Missions

A great deal of experience has been acquired by Surrey from flying 36 cameras using COTS sensors in-orbit during sixteen years on eleven missions. The UoSAT-12 in-orbit results and Surrey's heritage will be applied indirectly to enhance future Surrey Earth observation missions. Future missions will incorporate the panchromatic camera with enhanced designs for thermal compensation, new 2048x2048 pixel staring arrays and push-broom linear arrays. Current research is looking towards a new generation of higher resolution 2.5m panchromatic and 6.5m multispectral cameras on board future Surrey minisatellites.

BiltenSat EO Microsatellite

SSTL is providing a know-how transfer and training programme to TUBITAK-BILTEN in Turkey. The 100kg BILTENSat microsatellite being built by SSTL will carry 12m panchromatic and 26m multispectral Earth observation cameras.

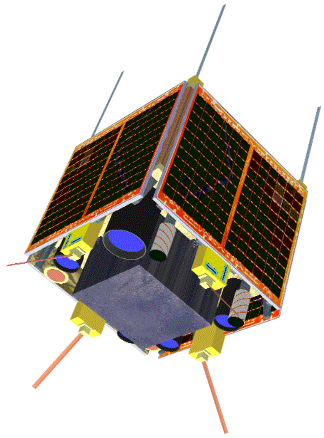

Fig-7: BILTENSAT enhanced microsatellite

Disaster Monitoring Constellation

The Disaster Monitoring Constellation (DMC), first proposed by SSTL in 1996, is now under construction for launch in Dec 2002 will be the first low-cost and integrated Earth observation constellation in the world dedicated to the humanitarian objectives of disaster assessment and monitoring.

RAPIDEYE EO Minisatellite Constellation

SSTL is the prime contractor and spacecraft platform supplier for RAPIDEYE AG (RE) of Germany for a constellation of four advanced Earth Observation minisatellites. The RapidEye Earth Observation system, to be launched in 2002, will provide 6.5-metre resolution multispectral imaging with a daily revisit at European regions and is targeted primarily at agricultural applications. The information will assist the accurate prediction of crop harvests for precision farming and thus generate significant impact upon the agriculture, food and trading sectors.

TOPSAT High Resolution Microsatellite

TOPSAT is a collaborative mission between SSTL, DERA, RAL and NRSC to provide high-resolution imagery at 2.5m GSD, integrated with a microsatellite that is capable of delivering this image data direct to a small mobile ground station.

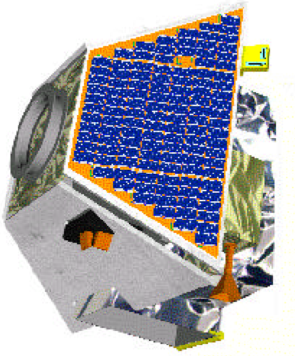

Fig-8: TOPSAT EO Microsatellite

CONCLUSIONS

Surrey's experimental UoSAT-12 minisatellite was successfully launched into low Earth orbit in April 1999 to demonstrate the feasibility of various low-cost state-of-the-art small satellite technologies.

A rotating filter-wheel experimental camera design was used on UoSAT-12 for in-orbit comparison with the three-camera concept previously adopted successfully on the Thai-Paht microsatellite, launched in 1998 and the Tsinghua-1 microsatellite in 2000.

The lessons learned through in-orbit operations with UoSAT-12 have thus enabled SSTL to perform trade-offs and comparisons amongst its different camera designs.

SSTL's accomplishment in dramatically reducing the cost of Earth observation satellites through adopting commercial off-the-shelf (COTS) technologies for small satellites has led to a number of high resolution Earth observation missions such as BILTENSAT, the Disaster Monitoring Constellation, RAPIDEYE and TOPSAT.