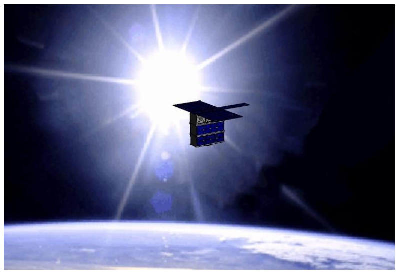

Title: Distributed Multi-Spectral Imaging System (DiMSIS)

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Need

This satellite constellation provides low-cost, sustainable, modular distributed multi-spectral Earth imaging capabilities with the flexibility for rapid upgrade, reconfiguration and augmentation. It is able to inform such applications as agriculture, disaster relief, cartography, national security and Earth Sciences; meeting both humanitarian and scientific needs. It also meets system business needs by providing a highly flexible and responsive platform for permuting constellation capabilities with fast turn-around timescales for system upgrade, augmentation and optimisation. Larger space systems typically have their capabilities restricted to only a small number of purpose-driven satellites where the provision of rapid system adaption and future compliance comes at a significantly high price in cost, time, effort and resources. The proposed low-cost system will provide major cost savings with comparably minor reductions in performance which are readily accountable by new paradigms in space technology.

Mission Objectives

The system aims to achieve the following mission objectives:

- Provide an initial operational constellation with two or more satellites each of mass <15 kg within a 2-year development timescale and budget not more than $6M excluding launch procurement costs (it is assumed that £1 ~ $1.5).
- Demonstrate the acquisition of medium resolution (<32m) multispectral Earth imagery with nano-satellite technology.
- Provide a sustainable system allowing replacement and replenishment of its elements with augmentation and upgrade capabilities in response to market needs of not more than 1 year from identification to launch.
- Acquire multi-spectral images of Earth land regions to be downloaded within a timescales commensurate with those necessary for the imagery purpose.
- Achieve imaging site revisit and response time of not more that three days.

Concept of Operations

The mission consists of a constellation of two-channel medium resolution Earth imaging satellites supported by a network of ground stations. The ground segment consists infrastructure for requesting data products; scheduling and tasking of the space segment; and data acquisition and dissemination. Upon initial deployment, spacecraft operations will be performed from SSTL's ground station facilities in Guildford, UK which will support regular data downlink opportunities. Interested partners will benefit from the data products as *juste retour* for the provision of ground station infrastructure where possible in order to increase system capacity and reduce data acquisition latency.

The space segment provides image acquisition, storage and downlink capability. The system must take advantage of all possible opportunities to downlink data owing to contrasting high data volumes and a low-rate downlink. This is the key factor that demands robust and effective downlink infrastructure with three possible modes for data downlink. *Trickle downlink* would use low rate data direct from imaging satellite to a single ground station requiring multiple passes per data product; *hopping downlink* has a sufficiently populated ground network to allow each imaging satellite to download the data product across multiple sites for reintegration upon receipt; and *high speed relay* uses inter-satellite links to transfer data to a dedicated relay satellite with high data rate capacity. With a relay satellite placed in the same orbit plane and altitude, data may be continuously streamed from the imager satellites, throughout the obit, for high speed downlink at the next opportunity. The system can support up to four imagers per relay satellite.

Collaborative efforts with international ground stations provide mutual benefits for example imagery of Australia or South Africa is down-linked in Japan, or the UK respectively. Other image/downlink partner combinations include Japan/Chile, Argentina/Thailand and New Zealand/UK.

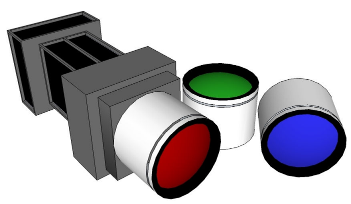
Key Performance Parameters

The success of the mission depends on how the system is able to meet user needs in terms of product data/information density and product delivery time. These correspond to the following technical performance parameters: End-user resolution/GSD – the system offers to provide 22 m GSD imagery at the user interface. No loss of fidelity should occur between site imaging and product delivery; Revisit/Response Time – the system should be sufficiently robust to meet product delivery times guaranteed to the user by means of orbit maintenance and operational downtime - proposed as 75% upon initial deployment.

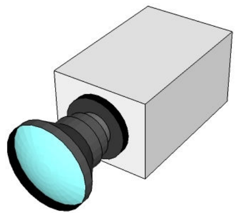
Space Segment Description

The space segment consists of several satellites performing Earth imaging, data storage and download. Relay satellites are proposed to provide high rate data storage and downlink capacity with system augmentation. Each satellite is a 3U x 3U Cubesat platform, each carrying one of a selection of imaging payloads. The system makes use of both heritage and COTS equipment where possible whilst allowing opportunity for modification where necessary. The 'worst-case' total mass of the satellite, dependent upon the selected payload is 13 kg and maximum power load of 22 W.

There will be a choice of two payloads available at initial deployment. Firstly, the SSTL Multispectral Imager (MSI) (shown right with a choice of filters) is a channel-filtered panchromatic digital optics system providing 22m GSD imagery from an altitude of 686 km in the



red, near-infrared, green and blue spectral bands. With its heritage as part of conventional complement of six imagers, it is able to function independently providing a swath width of 300 km and each 300 km x 300 km image produces ~100 MB of data. Secondly, the Surrey Space Centre Microbolometer (left) uses two commercial-off-the-shelf (COTS), un-cooled microbolometer arrays in push-broom configuration to provide 300 m GSD sampling with a 96 km swath width in the Mid-wave Infrared (3μm - 5μm) and Thermal Infrared (8μm - 12μm).



The structure accommodates two imager units in any combination of microbolometer or MSI imager (which can be adapted at very low cost to image in the spectral band of interest). This allows new satellites to be rapidly added to the constellation according to spectral imagery market needs.

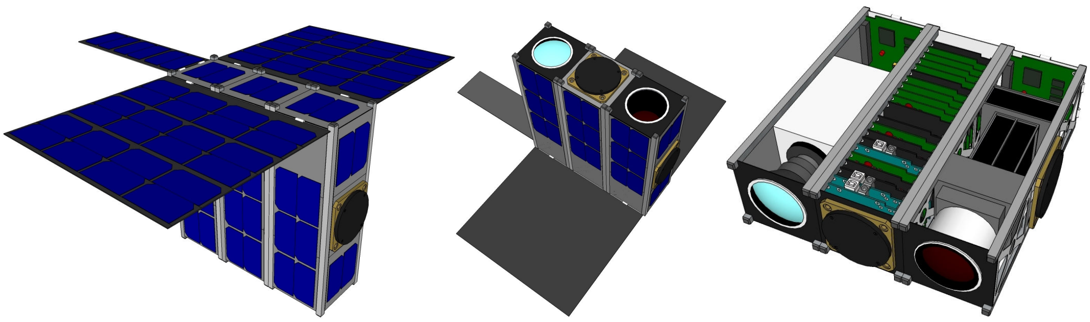


Figure 1 – Imager spacecraft configuration with Multi-Spectral Imager and microbolometer payload.

Two MSI units flown on a single satellite produces data at a rate of 36Mbs^{-1}, acquiring a 300 x 300 km^2 in 45 seconds. Data is stored on two dual redundant 16 GB SD memory cards. A single S-Band transmitter, currently under development at SSTL is proposed to provide a downlink rate of ~1 Mbs^{-1} with the use of a nadir pointing heritage S-Band Patch antenna. A second patch antenna is fitted along the flight vector for inter-satellite links when data relay satellites are launched to augment the system.

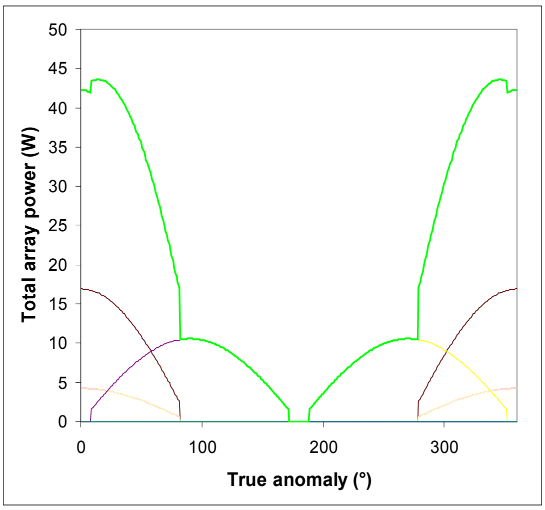


Figure 2 – Spacecraft power profile

The power system consists of body-mounted and deployable solar panels with a total photo-sensitive area of 0.24m^2 supplied by 90 emcore™ triple junction PV cells with 28.5% BOL efficiency. The system maintains an orbit average power of 16W with 7 Ah COTS battery capacity whilst maintaining nadir pointing during imaging. This can be improved by adopting sun-pointing attitude rates when the imagers are not in use.

The Attitude control system consists of a 3-axis nano reaction wheel and pulsed plasma thruster (PPT) system – currently under development – with a suite of magnetorquers, magnetometer, and sun- and nadir-sensors. Primary propulsion is by the PPT and a micro-butane thruster providing delta-V~2 m/s driving constellation acquisition time.

Orbit/Constellation Description

A 686 km Sun-Synchronous Orbit with a 10:30am Local Time of Ascending Node (LTAN) provides excellent lighting and cloud mitigated imaging conditions. This altitude has been selected to ensure a 22m GSD from the MSI imager and to eliminate issues of atmospheric orbit decay. The satellites are separated by 30° true anomaly, corresponding to 8 minutes separation over the ground. This mitigates safe separation, minimal fuel burn for LEOP, minimum time between image acquisitions between imagers and establishes the geometry necessary for operation with a relay satellite. Future satellites may be deployed into a second orbit plane with a 2:00pm LTAN to provide a daylight revisit time of less that four hours whilst maintaining acceptable lighting conditions. The constellation shall be deployed via several rollout phases:

Phase 1: Constellation Initial Deployment - Two spacecraft launched in tandem and deployed

Phase 2: Continued Constellation Deployment - Additional imagers launched. Potential for relay satellites

Phase 3: Constellation Augmentation and Upgrade- Additional satellites target specific needs of both the constellation (upgrade, redundancy, replacement) and the business needs (e.g, imagery in specific bands, and revisit and response times).

Sun-synchronous orbits are a popular choice for future missions and opportunities piggy-back launches exist with such launchers as Dnepr, Vega, and Minator.

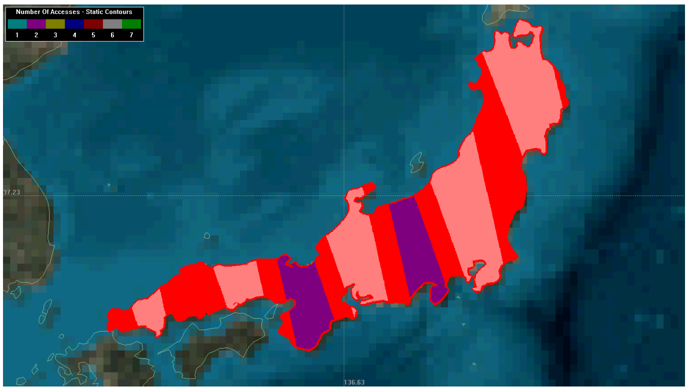


Figure 3 – Coverage for Japan showing access opportunities (between 1 & 7) in one week.

The selected constellation provides a revisit and response time of not more than two days. Figure 3 shows the number of access opportunities to Japan within a 7 day period. The average revisit times may be optimized as the number of satellites in orbit increases.

Implementation Plan

SSTL's extensive experience of delivering low cost, high performance space systems on budget and on-time will ensure that the project has every chance of success. SSTL proposes to design, develop and perform assembly and integration activities in–house. Thermal, EMC and vacuum tests will require external facilities at Astrium UK, National Physical Laboratory and the Rutherford Appleton Laboratory. SSTL proposes, also to utilize its own ground station facilities to deploy, calibrate and operate the system throughout its early life (right). Partners and/or customers are warmly invited to provide ground segment facilities to provide downlink capacity

Life Cycle Costs	£k
Non-Recurring Engineering	650
Recurring Engineering (per sat.)	900
Ground Network	1000
Phase 1 Flight-Ready	**2450**
Launch Campaign	2000
Phase 1 Operational	**4450**
Ground Operations (Per Year)	150

such that the system may operate effectively and efficiently.

The project shall be organised to provide a critical review of user needs, system requirements and design trade-offs. This will be followed in tandem with the design and development of new and current solutions with a strong emphasis upon system verification. Intermittent design reviews at both the work package and project level will ensure system integration, compatibility with partners and performance validation. SSTL's experience is procuring launch campaigns will seamlessly integrate development and operational phases. PDR and CDR provide opportunities to make payload combination selections, however a payload interface budget shall allow payload selection to be made as late as possible to provide fast time response to user needs.

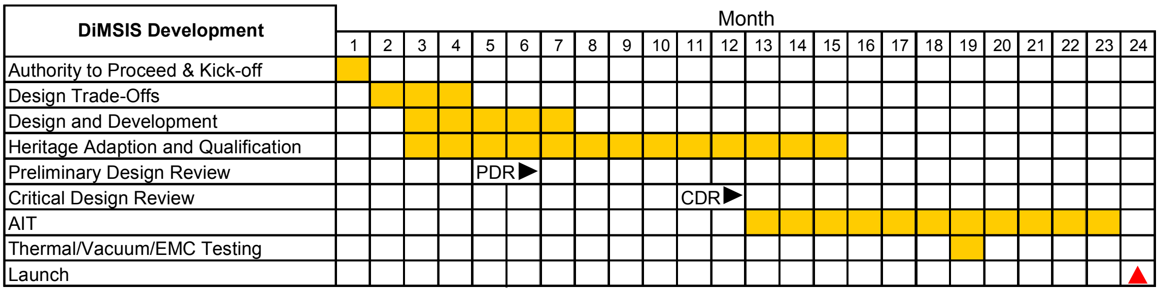


Figure 4 – Implementation and deployment schedule for initial operation

This sustainable solution provides a baseline system that is continuously upgraded, augmented and modified throughout the piece-wise life-cycle of all its elements. Spacecraft disposal will typically occur with the provision of replacement spacecraft and after two years individual lifetime. Disposal is intended to be via atmospheric re-entry with the necessary delta-V provided by a low-thrust pulsed plasma thruster. The five most significant risks to the system development are:

1. Non-development of new hardware and software within time and budget. Much of the equipment selected for the mission has significant heritage on larger platforms and provides surplus performance. An adaption and redesign campaign is thus required.
2. Non-delivery of products and services from partners, subcontractors and suppliers including EMC, thermal and vacuum testing at external facilities.
3. Issues in development and qualification of structure and launch vehicle adaptor system. The modifications made to the 9U Cubesat structure as well as development of a complementary deployer will require significant testing, verification and validation.
4. The S-Band transmitter is currently under development with actual performance unknown. This poses risks to the resulting downlink rate affecting operations and data dissemination to the customer as well as power loading and thermal effects on the spacecraft.
5. Loss of revenue if the system under-performs. Potential withdrawal of investors for system augmentation.

References

[1] *Applications of the Disaster Monitoring Constellation* – SSTL Internal

[2] *SSTL Multispectral Imager Specifications* – SSTL Internal