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Precision – A very-high resolution imager – Design through to manufacture

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Precision – A very-high resolution imager – Design through to manufacture

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ABSTRACT

Precision is a very high resolution earth observation imager that delivers high quality and high area coverage for pan-sharpened imagery and has been developed by SSTL as part of a ESAs Incubed programme. Over the last few years the development has been progressing through the design phase and development phase and is now undergoing PFM manufacture and test.

An overview of the instrument design is presented alongside the key design decisions that led to the overall specification. This resulted in a compact design that utilises a novel sensor and innovative opto-mechanical techniques to achieve a swath of >9.5km and a GSD in panchromatic channel of 0.6m native. The PAN channel is used to sharpen four 1.2m GSD multi-spectral channels and through post-processing sub 0.5m GSD is achievable. This allows for its integration into compact spacecraft in order to support affordable operations as a stand-alone unit or in constellations providing higher temporal resolution. Anticipated applications include mapping, surveillance, infrastructure and asset monitoring, disaster monitoring, insurance and loss adjustment. The ability to achieve improved resolution through processing lends itself to high performance small satellites with capabilities for on board processing to allow near real time feature recognition and the use of ISL' for high availability to meet the customer needs of today.

Keywords: High Resolution, imager, payload, VHRI, small satellite

1. INTRODUCTION

The continued and increasing demand for Earth Observation (EO) data coupled together with the driving requirement to have lower latency and higher resolution data means that constellations of very high resolution imagers are required. In order to minimise the cost of such constellations the imager performance for any given size needs to be maximized. The SSTL-300 S1 imager (TripleSat constellation) achieved sub-metric performance but the overall imager size at nearly 2m and innovative, but somewhat complex to align design, results in higher costs than the current market desires. Leveraging both new technology and optimizing the design for manufacture allows for a more compact system that is enabled for rapid and cost-effective production. SSTL has been developing a system to achieve a high performance-to-cost ratio imager that provides excellent capability.

2. PRECISION PAYLOAD DESIGN

The Precision payload is a pushbroom imager that leverages new developments in detector technology as well as employing efficient opto-mechancical design and assembly techniques. This enables rapid and cost effective production of flight models, these are therefore suitable to enable the deployment of a high resolution constellation. The optical design is based on a Ritchey-Chretien (RC) Cassegrain telescope with focus lenses at the back to make an overall compact design. While other designs were considered the axisymmetric arrangement of a two mirror RC allows for a simple mechanical arrangement and alignment strategy.

Fundamental to any high resolution imager design is the selection of the overall clear aperture sizing which dictates the limitation to the theoretical performance. For any given aperture it is then the challenge to maximize the information content this can be achieved by minimizing losses due to aberrations but useful information is also lost due to aliasing at higher spatial frequencies.

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While the first may be seen as a function of alignment the main contribution is from the aberrations of the mirrors and distortion needs to be minimized by design. For the RC design the primary mirror can be the largest contributor and ensuring that thermoelestic distortion is not introduced is key to an effective design. Control of this can be achieved through active heating of such components but at the penalty of power and therefore impacting on the overall platform system sizing. Precision has therefore been designed as a passive athermal design with this aspect of the design being controlled through a compensated mount whos complexity is minimized by the production technique employed. Secondly we can look to recover and make use of all the higher spatial information. This can be achieved by using a detector with ½ pixel shifted PAN pixels where the information can be recovered through processing that would normally be lost through aliasing.

An aperture size of 420 mm was selected which when combined with the focal length of 4200 mm offers a compact solution while carefully balancing the ability to make use of the ½ pixel sampling. Additionally the ability of the imager to achieve a high SNR while maintaining a wide dynamic range is achieved. The detector is based on CMOS detector technology with on-chip Time Delay and Integration (TDI). The sensor offers 4 ½ pixel shifted PAN channels and 4 multispectral (MS) channels

As part of understanding the performance improvement that can be achieved with the design and subsequent processing simulated imagery is produced based upon the optical parameters. This helped to specify the overall value of the wavefront error that would be acceptable.

The overall imager performance is given in Table 1. It is important to note that this is as built optical performance accounting for all thermal effects that are expected during operation on orbit

Table 1. Precision optical specification for nominal altitude 500km.

Image properties	Specification
PAN GSD (m)	0.6m PAN native, 0.3m PAN sampling <0.5m post processed,
MS GSD (m)	1.2 m native
Bands	PAN, Red, Green, Blue, Near-Infrared
Swath (km)	>9.5km
MTF	>8 % PAN, >17% MS
SNR (all bands)	>100:1

The opto-mechanical design utilizes a bulkhead for mounting the primary mirror, lens assembly and focal plane, and a truss metering structure for positioning of the secondary mirror. The majority of the structural components are metallic while straylight components are made from light-weight carbon composites. The focal plane of the imager is attached to the focus mechanism which is secured between it and the bulkhead.

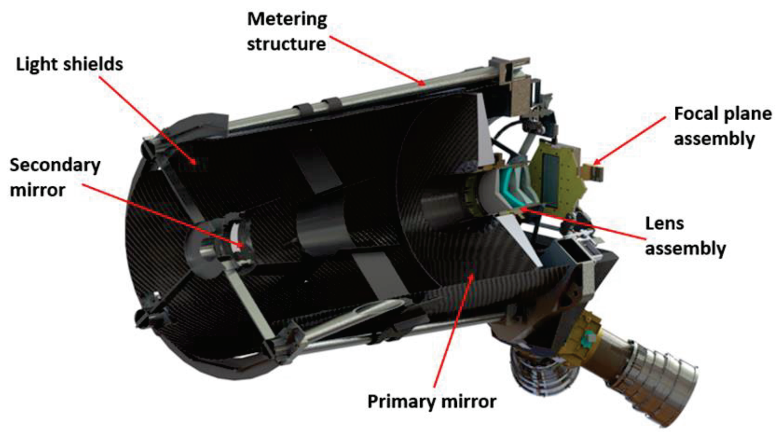

Figure 1. Precision opto-mechanical design

While SSTL has significant imager heritage in designs based upon the use of high performance carbon composites the metallic truss structure has been selected due to the ability to use readily available and machinable materials. These can be procured on shorter timescales and avoid issues associated with high performance resins such as minimum order quantities, long lead times and can only be stored for a limited shelf time in refrigerated conditions.

A passive thermal control system is implemented to prevent excess thermos-elastic stress in the case of the mirrors and minimize the bowing of the detector during operation. The imager is nominally radiatively isolated from its environment using MLI blankets and a radiation shield that additionally provides stray-light control. Thermal control of key components has been included as a risk mitigation but baseline performance is achieved without its use.

Table 2. Precision mechanical specification.

Image properties	Specification
Mass (kg)	< 55kg
Volume	<610 mm Diameter <1250mm Height
Mechanical Interface	Four point mount with anti-vibration interface

The Front-End Electronics (FEE) design is based upon heritage established from other missions that use CMOS technology sensors. The FEE interfaces to the sensor mounted on a headerboard which connects via a flexi cable. The FEE is capable of performing some processing of pixel data before transmitting out over 4 x 5Gigabit CoaXpress outputs. As well as a higher specification FPGA for dealing with image data a second supervisor FPGA is responsible for monitoring the functionality.

An imager services module is based on generic input and output circuitry, allowing it to take on diverse sensor and actuator roles across a variety of payloads. Its flexible and banked design allows telemetry sensor and actuator channels to be added to the system. For Precision the services module is responsible for providing the following functionality: Heater power, Temperature monitoring, Active thermal control logic, Motor drivers, Kill switch logic and Encoder operation

Table 3. Precision electrical specification.

Image properties	Specification
Power (W)	< 45W normal imaging
Data Interface	CoaXpress protocol at 5GHz
Electrical Interface	Power : 28V ±7V TM/TC: CAN-SU2 protocol at 388 kbps

3. PRECSION DEVELOPMENT

The development philosophy was to use feature breadboards and EM models to trial and de-risk key new elements while completing qualification on the PFM model. The lean but successful development philosophy has allowed a smooth transition into the PFM manufacture of the payload.

Breadboard activities have been used to trial new processes particularly where new materials have been used, this has included brazing processes, unique baffle manufacturing, test of primary mount compensator technology.

EM units were used to qualify the main structure and focus mechanism. The EM structure was thermally cycled, vibrated and shock tested which allowed correlation with the analysis. A number of updates to the manufacturing processes could be made from carrying out the work which would prove beneficial for the PFM.

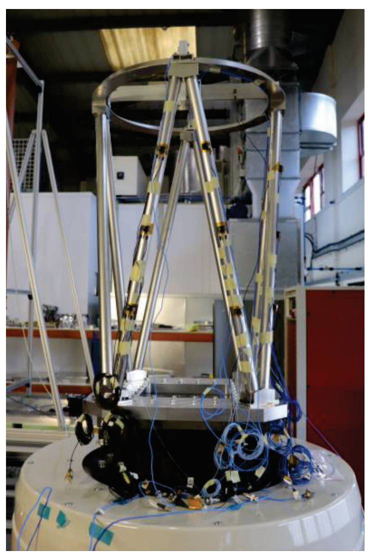

Figure 2. EM structure undergoing vibration testing

The EM focus mechanism underwent a number of additional tests pre and post environmental testing to characterize its behavior with a dummy load, these included step resolution, translation speed, travel, torque margin, tilt after movement, cycles and backlash to demonstrate compliance to the design requirements

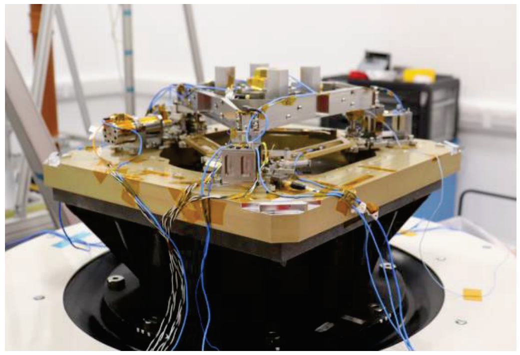

Figure 3. EM focus mechanism undergoing vibration testing

An EM unit of the FEE has allowed for testing of an EM sensor at an early stage as well as providing the platform to develop the firmware and software. This approach was also taken with the services module.

4. PRECSION PFM MANUFACTURING

The PFM hardware is currently undergoing manufacture and key sub-assemblies have already been assembled. All mechanical pre-alignment has taken place and the installation of thermal hardware onto the main assembly, secondary mirror assembly and focal plane has taken place. The secondary mirror has been aligned and bonded into its assembly with associated baffle and the lens assembly is nearing completion.

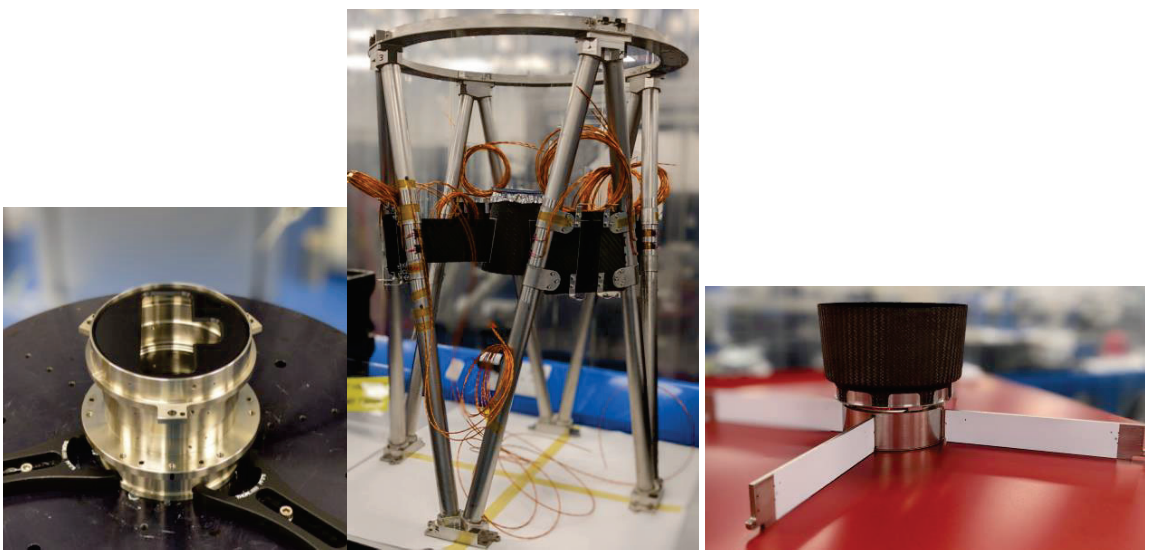

Figure 4. Left to right: Lens Assembly, Truss with central baffle and thermal hardware, Secondary mirror assembly with baffle installed.

The final assembly and integration of the primary and secondary mirrors takes place within a build tower with the imager orientated vertically. The tower provides both a stable enviornment for carrying out inteferometric alignment in an efficient and reproducible manner.

Either side of environmental testing the perfromance of the imager is characterised so that any chnages in alignment or perfromance will be detected. The Modulation Transfer Function (MTF) of the imager integrated with the sensor and electronics is measured at points across the field using a large collimating projection system. Additionally radiometric measurements will be carried out using a 1.5m integrating sphere with tunable light source and spectroradiometeric measuring system.

5. COMMON BUILDING BLOCKS

During the Precision development a number of key technologies and processes that have been demonstrated and qualified have been transferred to other product developments. This has enabled these developments to be carried out on accelerated timescales and with an added level of confidence.

It was the intention at the outset to develop some common building blocks that can be used across a range of products. An obvious example of this is the services module which can easily be re-configured for use on other imagers where there are different mechanisms and thermal control requirements.

The truss structure has also been incorporated into the next generation of SSTLs carbonite imagers, this not only allows for simplification of the design phase but also allows a level of commonality during build and test where only small modifications are needed to ground support equipment. This is demonstrated through the use of the standard build tower which can be reconfigured for 4 different imager products, this gives flexibility to managing AIV schedules across multiple projects.

6. CONCLUSION

An overview of the Precision – Very High Resolution – instrument has been presented along with the design rational and route to the PFM imager. The instrument achieves the aims of providing a compact high resolution payload which maximizes new detector technology and incorporates efficient manufacturing processes.