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INNOONBOARD for Improved Image Handling in Airborne Coastal Reconnaissance – a Project Presentation

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Abstract

Aerial reconnaissance produces vast volumes of data, and downlink capabilities have difficulties to keep up. One way to handle this problem is to decrease the amount of data by selecting the most important data already on board, then further selecting data for priority download. The INNOONBOARD project combines these methods, creating a data management solution for coastal reconnaissance aircraft.

The project is supported by Innovair, the Swedish Strategic Innovation Programme for Aeronautics. It is carried out by three Swedish SMEs; Spacemetric, Unibap, and ST Airborne Systems, and will be reported by the end of 2022.

Spacemetric recently developed its Bluestone technology, building on its Bluestone software suite. Using only limited bandwidth to send an overview image and metadata to the ground, Bluestone users, in near real-time, get an overview of the data on board one or more aircraft, experiencing that the data is “on the user’s hard drive". Using high-performance miniature computers on Unibap's platform with data collected onboard the aircraft of ST Airborne Systems mini-computers on board aircraft, users can select on-board data, and can also select on-board data for priority download, enabling rapid image analysis.

Building upon an earlier Innovair project, INNOONBOARD will go from "lab capability" to demonstrator.

The project aims to:

- increase the efficiency of Spacemetric's image data processing software;
- increase Spacemetrics and Unibap's ability to assist integrators of flight monitoring systems, UAV manufacturers and operators of flight and UAV systems with their technologies; and
- strengthen the Swedish aviation industry.

TRL-wise, Bluestone will be placed in Unibap's SpaceCloud platform (TRL 6), which will then be tested and flown on board ST Airborne Systems’ flying assets, whilst some image quality improvement algorithms will be at slightly lower TRL levels.

In early September 2022, when ICAS takes place, some preliminary project results are expected to be available for presentation.

Keywords: On-board Image Handling, On-board Image Selection, Data Selection for Priority Download, Airborne Reconnaissance, Solving Bandwidth Limitations.

1. Introduction

Aerial reconnaissance sensors produce an ever-increasing volume of data, whilst data downlink capabilities have difficulties to keep up with the data flow. One way to deal with this problem is to decrease the amount of data already at source, that is to make a selection on board, avoiding data which carries little interest. Another way of getting around the data downlink problem is to try to select the most important data for priority download, and de-select less important data. The INNOONBOARD project aims to combine both these methods to create an optimal data management solution for coastal reconnaissance aircraft.

Below is found a description of the project and its methods. The INNOONBOARD project is supported by the Swedish Strategic Innovation Programme for Aeronautics, Innovair (hence the first four letters of the project name). INNOONBOARD is carried out in co-operation between the three Swedish SMEs Spacemetric, Unibap, and ST Airborne Systems.

The INNOONBOARD project will be reported to Innovair by the end of 2022.

2. Project Partners

The Swedish SME Spacemetric (www.spacemetric.com) is one of the world leaders in advanced image data management, with many customers among satellite, aerial, and UAV operators and integrators.

Since 2013, the Swedish SME Unibap (www.unibap.com) has been at the forefront of cloud-based, intelligent data processing and sensor management in resource-limited environments in aerospace and smart industrial automation. Unibap's radiation-tolerant hardware and its OpenCloud-based SpaceCloud framework provide a flexible infrastructure for application development and software reuse.

The Swedish SME ST Airborne Systems (https://airbornesystems.se) has a long and successful track record within aerial reconnaissance, i.a. supplying its MSS 7000 system for airborne maritime surveillance to the coast guard authorities in several countries.

Figure 1 - ST Airborne Systems has equipped aircraft such as these for ocean surveillance for a number of countries around the world. These are in daily use by the National Aerial Surveillance Program for monitoring the more than 5 million square km of Canadian waters. Photo credit: Transport Canada

ST Airborne Systems has equipped aircraft such as these for ocean surveillance for a number of countries around the world. These are in daily use by the National Aerial Surveillance Program for monitoring the more than 5 million square km of Canadian waters. Photo credit: Transport Canada

Spacemetric and ST Airborne have long discussed the integration of Bluestone into ST Airborne System's platforms, whilst Spacemetric and Unibap have already worked together in satellite-related projects. All three companies can now look back on more than six months of corporation within the INNOONBOARD project and perceive that there will be great synergies resulting from this project.

3. Project Description

Spacemetric has recently developed its Bluestone technology further, increasing its practical usefulness further. In short, Bluestone users, using only limited bandwidth to send an overview image and metadata to the ground, in near real-time, are able to obtain an overview of the data on board one or more aircraft. The user experience is that the data is “on my own hard drive", and not on board a far-away aerial vehicle. The INNOONBOARD project will use this Bluestone technology to select on-board data for priority download. Using the downloaded selected data, Bluestone users can then quickly start to analyse images, make decisions, and start production and / or evaluation.

The INNOONBOARD project builds upon an earlier Innovair-supported project leading up to Bluestone “lab capability”. INNONBOARD will develop and use these earlier results. The Bluestone image data management will now be used on board aerial platforms, enabling selection of key data and de-selecting of data of less interest, thereby decreasing the data volumes to be handled downstream. This will be done using minicomputers on board the aircraft, going from "lab capability" to “demonstrator”.

The Unique Selling Point of the project, which lies within Innovair's theme of "Intelligent Systems and sensors", is the use of Bluestone on board an aerial vehicle in the air – a first for this Spacemetric-patented technology.

Within the INNOVAIR project, the goal is to further develop Bluestone's functionality for image management with high-performance miniature computers and test this on Unibap's SpaceCloud platform with image data collected on board the aircraft of ST Airborne Systems.

The project aims to:

- increase the efficiency of Spacemetric's image data processing software;
- increase Spacemetric's and Unibap's ability to assist integrators of flight monitoring systems, UAV manufacturers. and operators of flight and UAV systems with their technologies; and
- strengthen the Swedish aviation industry in general.

The project is expected to have a major effect on Spacemetric's competitiveness and to increase Spacemetric's attractiveness with Swedish and foreign integrators, whilst Unibap sees great opportunities in increased use of SpaceCloud for flexible distribution of software applications and reuse of software – applications can now be moved to where they are best utilised. Edge calculations and AI / ML will also enable autonomy, providing opportunities for complex intelligent systems. Finally, ST Airborne Systems sees great value in being able to add INNOONBOARD's capabilities to its already strong aerial reconnaissance offer.

As stated above, the project is a collaboration between Spacemetric, Unibap and ST Airborne Systems. Spacemetric is responsible for project management and for the actual development of Bluestone functionality, e.g., image quality improvement and ground surface identification. Unibap will contribute its SpaceCloud hardware platform, where the Bluestone functionality is used, whilst ST Airborne will primarily assist with functional needs and validation in practical tests with data collected on board coastal reconnaissance aircraft.

The iX5-100 processing solution shown in Figure is designed by Unibap and will be used within the project. The solution is designed for advanced and data-intensive processing tasks in extreme environments. The unit is designed as a heterogeneous computer solution that can support intensive processing tasks, either airborne or in space.

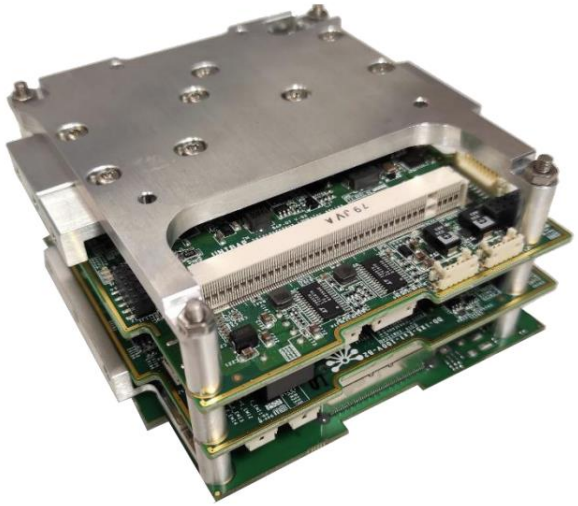

Figure 2 - Photograph of SpaceCloud iX5-100 radiation-tolerant cloud computing solution.

An overview of the integrated processing solution is presented in Table 1, giving information on the key elements of the iX5-100 solution.

Table 1- Overview of the iX5 heterogeneous compute solution

Processing and Memory	
Intelligent processing core	AMD® Embedded G-series SOC Series HD RADEON GPU, 2 CU (Up to 77 GFLOPS)
FPGA	Microsemi® SmartFusion2™ with ARM® Cortex™-M3 MCU
RAM	2 GB DDR3 ECC (CPU/GPU), 0.5 GB DDR3 ECC (FPGA) ECC on Flight Models
Heterogeneous interconnect	PCIexpress® x2 lanes v2.0, 10 GT/s (AMD SOC <-> FPGA) mini-PCIe slot
Storage	Up to 240 GB M.2 Solid State Drive (SSD) SLC nandflash type Up to 2.8 TB M.2 Solid State Drive (SSD) TLC/MLC nandflash type 64 GB eMMC / Micro-SD card

The hardware is combined with Unibap's SpaceCloud Operating System (SCOS) and -Framework (SCFW) that allows for a full cloud experience on the edge. This is combined with the SpaceCloud radiation mitigation framework called SafetyChip / SafetyBoot, that allows for the system to detect and mitigate single event radiation upsets in the system in a resilient manner. A graphical presentation of the SCOS and SCFW is shown in below.

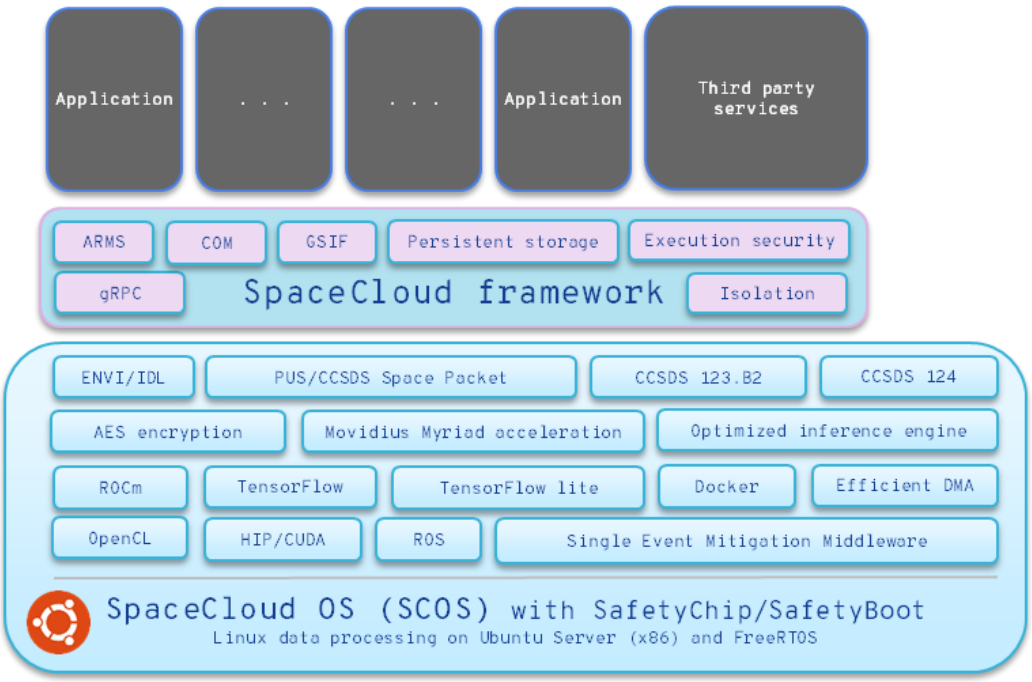

Figure 3 - SpaceCloud OS and -Framework with integrated functionality.

SCOS and SCFW allow for operators of the system to orchestrate AI/ML applications on the edge using tools like TensorFlow, Docker, ROCm, and other well-known tools on the ground. In addition to this, AMD G-Sereis GPU carries an x86 processing architecture that allows for porting of existing software onto the system with minimum effort to either implement new functionality or adjust and tweak existing applications. 3rd party software can be added to the toolbox, tools like Spacemetric Bluestone software suite or ENVI from L3 Harris (where, incidentally, the ortho and the 3D modules are delivered by Spacemetric.)

SCFW provides a generic sensor interface (gSIF) that is designed to map out different connecting units for easy integration and communication, allowing talking data into the system from various sensors and sending it back out again to communication links on ground as an example. In addition to this, there is also a scheduling system available to manage and schedule operations, access to persistent storage, isolation between multiple users, and other features needed.

4. "Neighbouring" Project Examples

Unibap is working with Spacemetric to provide an integrated payload utilising a Simera Sense HyperScape50 imager, shown in Figure 3 below, to acquire images in space, process them in space, and filter data from the imager in Space. The main objective is to filter out cloudy images and compress the remaining data to push as much usable data as possible to the ground through a capacity-limited downlink.

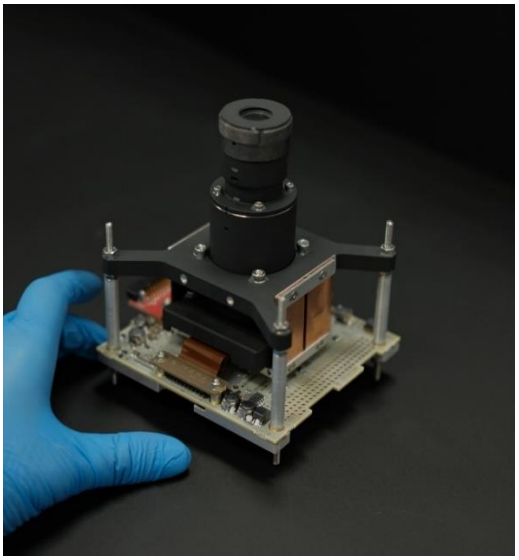

Figure 4 - Simera Sense HyperScape50 imager

Table 2 - Simera Sense HyperScape50 specifications.

Optics	
Focal Length	93.9 mm ±1 mm
Aperture	11.75 mm
Full Field of View	13.68° (across-track);
Imaging	
Configuration	Push-broom
Sensor Technology	CMOS Global Shutter
Resolution	4096 pixels
Pixel Size	5.5 µm
Pixel Depth	12-bit
Spectral Bands	Up to 32 bands user-selectable, including: - Hyperspectral bands with user-selectable central wavelength in 1 nm steps - Panchromatic band
Spectral Range	Hyperspectral Bands: 442 nm to 884 nm Panchromatic band: 500 nm - 750 nm

As the need for more spectral data in the infrared spectrum is increasing, the data output from especially multi- and hyperspectral sensor continues to grow. This, in combination with the

increasing output from the development of COTS EO sensors, will demand an increase in the ability to filter data close to the sensor, as has been the case for a wide variety of EO sensors applied on ground.

When designing a processing system for satellites there are several architectures available including CPUs, FPGAs, and GPUs. They all come with different advantages when applied: the CPU offers flexibility with the ARM Cortex-series is a popular choice, whilst the FPGA offers speed and high output with the Xilinx 7000-series that has, for the last decade, been the popular choice for complex and demanding computing tasks in orbit. The GPU brings the latest addition to space-based processing i.e., hardware acceleration with multiple offerings currently being tested in orbit, including Nvidia Jetson, AMD and the Myriad2/X from Intel being demonstrated and characterized in-orbit.

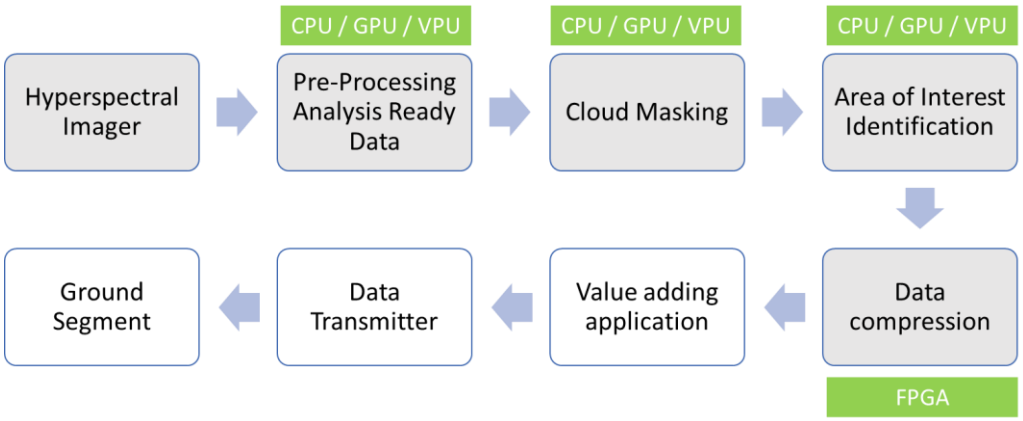

Figure 5 - Heterogeneous processing pipeline implemented to manage data from Simera Sense imager.

As part of the image processing pipeline shown in Figure , where the RAW image data is processed from (using satellite terminology) level 0 to level 1 data, the processing unit performs radiometric corrections in the imager, and geometric corrections, band co-alignment, and geo-location of the raw image data being performed by Spacemetric's Bluestone.

For data reduction purposes, area of interest identification and cloud masking are performed by Craft Prospect, as shown in Figure below, with data being compressed down to as little as 30% of the original size in real-time using an implementation of the CCSDS 123.0-Bb-2 algorithm image compression are implemented by Metaspectral.

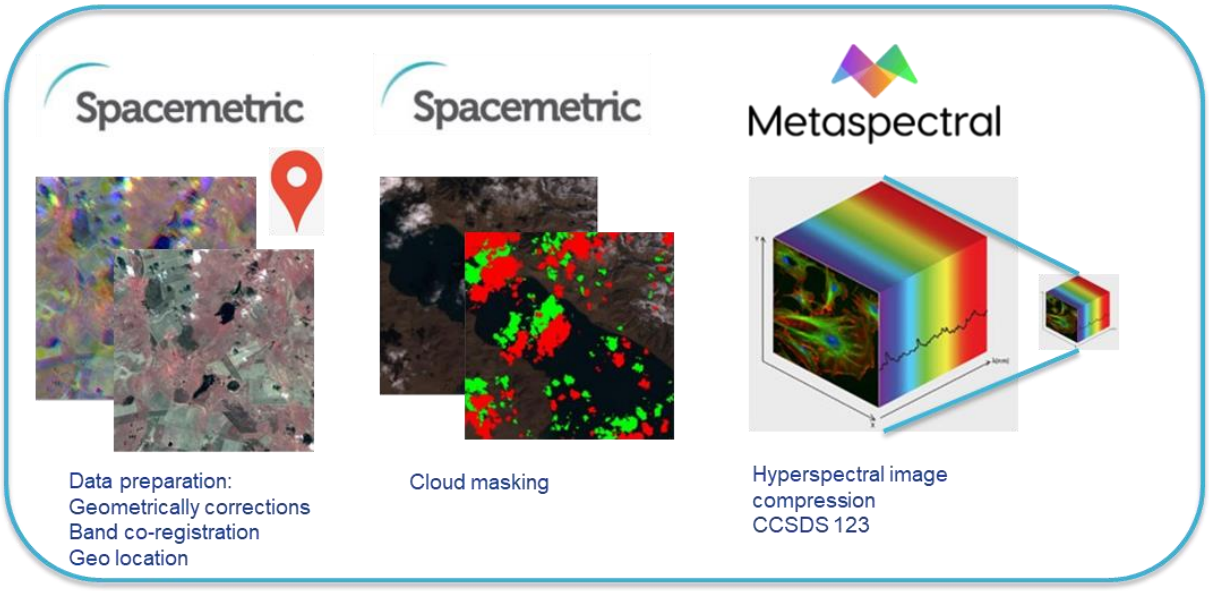

Figure 6 - Processing pipeline with software partners

In another project, Unibap, is working with the Hawaiian Space Flight Laboratory on a NASA-sponsored mission, HyTI, intended to collect hyperspectral thermal images and process those on orbit.

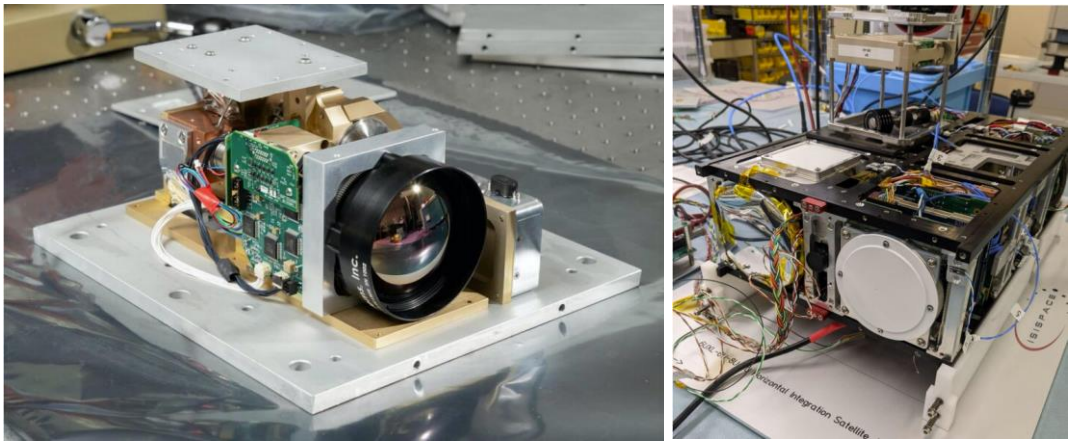

Figure 7 - Left: HyTI payload. Right: HyTI Flat Sat

This mission is focused on capturing long-range Infrared thermal data from the earth's solid surface and atmosphere. The detector captures 45MB per second converted into daily operations 100 GB of data. iX5 reduces the data amount on-board by converting the data from L0 to L1 to by 96% that is downlinked over X-band at 50Mb/sec.

5. Rough Project Outline

The INNOONBOARD project will be run iteratively, but can roughly be divided into a start-up phase, a development and integration phase, and, finally, a demonstration phase.

In the start-up phase, an analysis was carried out of which problems the project is trying to solve, in conjunction with a first iteration of user scenario definition and analysis. These problems were found to lie mainly within the realms of image quality improvement and ground surface identification. The work has therefore proceeded along those lines.

The now on-going development and integration phase consists mainly of development of methods and software, and of integration, both between different hardware units involved and between

hardware and software. The following work packages have been identified (with the lead company stated for each work package):

- Development of image quality improvement and geometric band alignment of image data from a sensor used in the project (Spacemetric);
- Development of image quality key value calculation i.e., methods to assess the amount of image noise, resolution and motion blur (Spacemetric);
- Development of ground surface identification, enabling sending down to the ground only those parts of images where the ground surface is visible, thus saving transmission time and volumes. To separate land from e.g., clouds, several methods will be combined: comparison between the spectral bands of the images, reconstruction of the ground surface / cloud surface, and use of reference image layers. (Spacemetric);
- Refinement and optimisation of software on the SpaceCloud platform. (Spacemetric in collaboration with Unibap);
- Integration between the sensors used by ST Airborne Systems and Bluestone to ensure that the produced data can be used by Keyustone (Spacemetric and ST Airborne Systems); and
- Integration between the SpaceCloud platform and ST Airborne Systems' aerial assets (ST Airborne Systems and Unibap).

Throughout the project duration, efforts will be made to align the project development with the needs of other commercial entities, thereby increasing the possibilities of the project's technology to reach a wider market faster.

The final phase of the project is scenario testing and demonstration of the service, where it will be shown that the development and integration "fit together". Bluestone will be placed in Unibap's SpaceCloud platform (TRL 6), which will then be tested and flown on board ST Airborne Systems' flying assets, whilst the image quality improvement will still be at a slightly lower TRL level.

6. Results so far, and the way forward

Initially, apart from Spacemetric's work with software development, the project has focused on the integration between Unibap's SpaceCloud platform and Spacemetric's Bluestone software. Spacemetric has developed software that can read and manage image data on Unibap's SpaceCloud platform from a hyperspectral Simera sensor, which is a possible future sensor for ST Airborne Systems' flying platforms. Unibap has also performed system tests on the SpaceCloud platform to verify that the integration works. Unibap is now updating its SpaceCloud framework for data acquisition and processing to facilitate the integration of future, additional sensors.

The adaptation of a generic sensor interface will facilitate adaptation and integration with sensors on ST's platform. The integration between Unibap's SpaceCloud platform and ST Airborne Systems' platforms and sensors will now begin. ST Airborne Systems has started by investigating which video files may be suitable for further work.

In early September 2022, when ICAS takes place, some preliminary project results are expected to be available for presentation.

As an important aside, it should be mentioned that since the commencement of the INNOBOARD project, Spacemetric's Bluestone technology has been successfully tested on an in-flight satellite[1].

7. Acknowledgements

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For enquiries regarding the contents of this publication, please contact Mr Daniel Åkerman at da@spacemetric.com .

9. Copyright Statement

[1] For reasons of business confidentiality, no further details can be given at the time of writing, but hopefully we will be able to include more information in the final version of the paper to be submitted by 15 July.