GEISAT PRECURSOR MISSION FOR METHANE DETECTION AND QUANTIFICATION: CAL/VAL AND DATA DEMONSTRATION ACTIVITIES WITHIN THE CCM FRAMEWORK

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ABSTRACT

GEISAT Precursor is a 16U CubeSat successfully launched in June 2023, and selected for the Copernicus Contributing Mission (CCM) programme. The GEISAT Precursor boards an iSIM-90 camera developed by Satlantis, specifically designed for methane emissions detection and quantification.

The GEISAT methane detection method is the Multispectral Differential Photometry (MDP) consisting of taking images with several filters and, using the different signal values measured at different wavelengths, to obtain the methane absorption. Additionally, for the VNIR images, Satlantis can apply its proprietary Ultra High-Resolution (UHR) algorithm for spatial resolution enhancement obtained without artificial intelligence. Given this, GEISAT Precursor can deliver two main data products, i.e., UHR and MDP product for methane applications.

The contract awarded as CCM Category 1 includes the definition and implementation of a rigorous in-orbit CAL/VAL campaign, supported by ESA, with the aim of ensuring optimal quality. Also, a series of data demonstration activities linked with the Copernicus Services to unlock the complementarity of GEISAT Precursor, and the Sentinels are foreseen.

This work presents the GEISAT Precursor mission and its status, the main technological features for CH4 emissions detection and data processing, and a summary of the CCM activities implemented up to date.

1 INTRODUCTION

Methane is the second most abundant greenhouse gas, with a warming potential 28 times that of CO2 over 100-year period, as such it is considered one of the greatest contributors to global warming. It is estimated that anthropogenic activities are responsible for most methane emissions, accounting for nearly 60% of the total [1]. The energy sector is the second largest contributor after agriculture, with 40% of emissions from human activity coming from oil and gas. Therefore, reducing methane emissions from this sector is essential to mitigate climate change.

In recent years, several initiatives related to fight against global warming and GHG in particular have kicked-off, with various dedicated specifically to methane, both at governmental and private levels, e.g., Global Methane Initiative (GMI) and the Oil and Gas Methane Partnership (OGMP). The global aim – as set at the Global Methane Pledge (GMP), launched during COP26 in 2021 – is to reduce 30% the methane emissions by 2030 from 2020 levels.

To support and bring forward such initiatives, different methods and approaches have been explored and adopted, and satellite monitoring has emerged as a powerful tool for detecting and quantifying methane emissions, particularly from oil and gas operations ([2][3]). Indeed, in the framework of the

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Global Methane Pledge, the Methane Alert and Response System (MARS), a satellite-based methane detection system, supports the International Methane Emissions Observatory (IMEO) to acquire relevant data for stakeholders [4]. Compared to ground-based methods, satellite-based measurements provide global coverage and continuous monitoring [5], for large emissions. Large emissions could be contributing significantly to the overall budget [6].

As a result, satellites targeting methane have increased, varying in sensitivity and complexity [7]. These satellites can be classified as areal flux mappers and point source imagers, which are suitable for detecting large-scale and small-scale emissions, respectively. Point source imagers, with higher spatial resolution (4-60 m), allow for better detection of smaller plumes and more precise location of emissions [8]. In turn, these can be classified into hyperspectral (0.3-10 nm) and multispectral instruments (50-200 nm), with hyperspectral imagers able to retrieve finer absorption lines but suffering from higher photon noise and greater complexity, while multispectral instruments being general-purpose, simpler, and cost-effective but may produce more false positives [9]. However, multispectral imagers used for methane detection (Sentinel-2, Landsat-8/9, and WorldView-3) are general-purpose instruments. Hence, SATLANTIS is developing a cost-effective constellation of satellites called GEISAT, with high-resolution multispectral imagers specifically designed to detect and quantify greenhouse gas. SATLATIS is iterating with the relevant Institutions and key players in the Oil and Gas sector (e.g., ENAGÁS) to ensure the alignment of goals. This initiative aims to support both commercial and public stakeholders to meet the goals of the international methane agenda.

2 METHODOLOGY AND MISSION

2.1 Technological starting point

SATLANTIS' endeavour towards methane emissions detection and quantification is based upon the proprietary technology iSIM (integrated Standard Imager for Microsatellites), a family of multispectral imagers with high and very high spatial resolution developed for Earth Observation and Universe Exploration. iSIM cameras have a binocular configuration (i.e., two channels) with a diffraction-limited optical system. Three spherical optical surfaces (modified Maksutov-Cassegrain design) point the light rays towards 2D Commercial Off-the-Shelf (COTS) Complementary Metal Oxide Semiconductor (CMOS) sensors modified to withstand vibrations, thermal, and radiation hazards. Custom filters in front of the sensors selectively transmit light of specific wavelengths to capture data in discrete spectral bands. SATLANTIS has developed and tested two versions of the camera called iSIM-90 and iSIM-170, suitable for 12-16U CubeSats and 50-100kg Microsatellites, respectively. The iSIM-170 (Figure 2-1) has a larger aperture diameter and focal length than the iSIM-90, resulting in a smaller ground sampling distance (~4 vs. ~7 m in the SWIR at 500km orbital height) but narrower swath (4.27 vs. 8.25 km per channel in the SWIR at 500km orbital height). SATLANTIS has validated the iSIM-170 and iSIM-90 technology on the International Space Station (ISS) with IOD [10] and CASPR missions in 2020 and 2021. Since then, SATLANTIS was able to launch other three missions, i.e., ARMSAT1 in May 2022, equipped with a VNIR iSM-90 camera for environmental and agricultural applications; GEISAT Precursor in June 2023, the subject of this work and detailed below; HORACIO in March 2024, embarking a VNIR+SWIR iSM-90 camera and considered the second satellite of the GEISAT constellation (Section 5). The company also provided a VNIR iSIM-90 camera to the MANTIS mission, developed within an ESA InCubed programme, in orbit since November 2023. A third version of the camera, iSIM-300, is currently under development for Minisatellite platforms.

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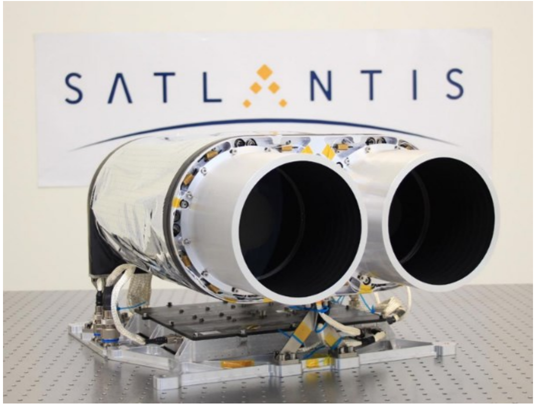

Figure 2-1: iSIM-170 optical payload.

The iSIM cameras can acquire images at a high rate, up to 60 frames per second (FPS) in the SWIR. Filters are strategically positioned perpendicular to the direction of the satellite's travel, allowing for a consistent scanning of specific areas (Figure 2-2). The iSIM observation strategy enables two technological benefits: (1) the enhancement of the signal-to-noise ratio with the acquisition of overlapping frames, and (2) the camera's ability to capture sharp images while changing its pointing direction along or across track. Both enable two observation modes for methane detection (Figure 2-2): agility i.e., tracking non-linear features, such as gas pipelines, and back-scanning, fixing an observation target in the satellite trajectory to increase the exposure time and the number of frames captured over punctual locations. These features make iSIM a suitable tool for monitoring oil and gas facilities.

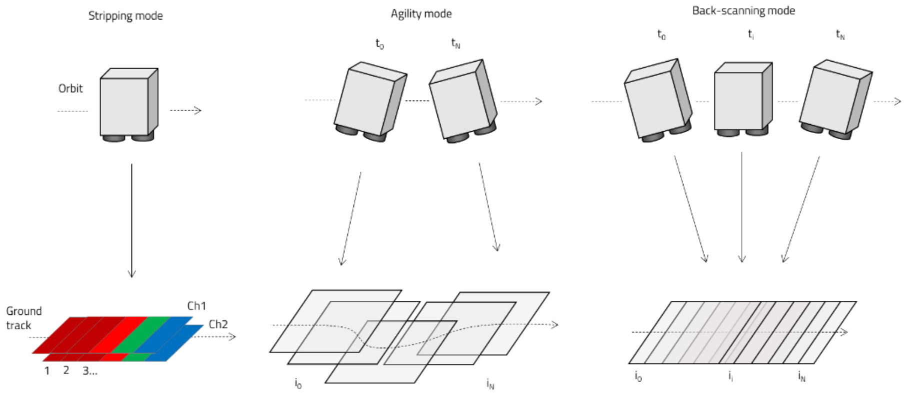

Figure 2-2: Observation strategies of iSIM for methane monitoring in oil and gas facilities. Left: acquiring at nadir, in striping mode. Centre: tracking non-linear features, in agility mode. Right: pointing continuously over a target, in back-scanning mode.

2.2 Payload for methane emissions detection and quantification

The GEISAT Precursor mission carries an iSIM-90 camera, incorporating VNIR (400-600 nm) and SWIR (700-1700nm) channels. The specific model builds upon certified core technologies from previous iSIM, featuring enhanced elements for high-resolution imaging such as:

- CubeSat-optimized mechanical structure.
- Improved thermomechanical design.
- Enhanced optical design and performance.
- Multispectral capability, with 5 filters in VNIR channel and 5 filters in SWIR channel.
- New generation of Electronic and Control Systems.
- New generation of VNIR detector proximity electronics.
- Implementation of SWIR detector.

The iSIM-90 VNIR+SWIR uses a modified Maksutov-Cassegrain optical design with a focal length of 775 mm and an effective aperture diameter of 77.5 mm. The imager is designed to provide diffraction-limited images between 450 and 1700nm over the entire 1.8º FOV in VNIR and SWIR spectral bands, with a spatial resolution of 2 m in VNIR (13 km swath @500 km altitude) and 13 m in SWIR (8.25 km swath @500 km altitude). The VNIR and SWIR channels provide simultaneous observations of the facilities for both visual inspection and methane monitoring. At a height of 500km, the ground sampling distance (GSD) of the VNIR and SWIR channels with the Ultra-High-Resolution algorithm (UHR) [11][12] leads up to ~2m and ~4m. For methane detection, the SWIR channel is binned at the sensor level up to 13m to improve SNR and gain sensitivity to methane.

This instrument – shown in Figure 2-3 below – was launched onboard the GEISAT Precursor 16U CubeSat in June 2023, and is currently operational (Section 2.5).

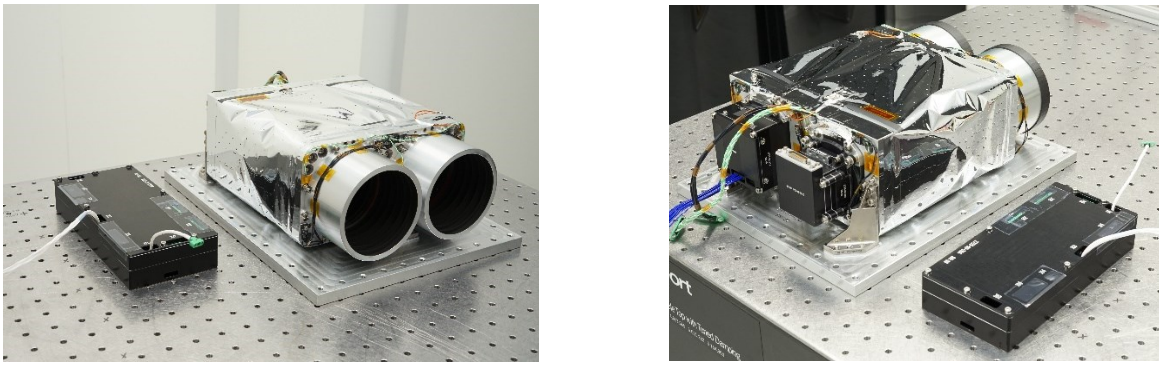

Figure 2-3: Flight model opto-mechanics of the iSIM-90 and ECS box.

2.3 Methodology for Methane retrieval

The technology presented above leverages a specific methane retrieval technique called Multispectral Differential Photometry (MDP). The algorithm pipeline detects and quantifies methane in 6 steps (Figure 2-4).

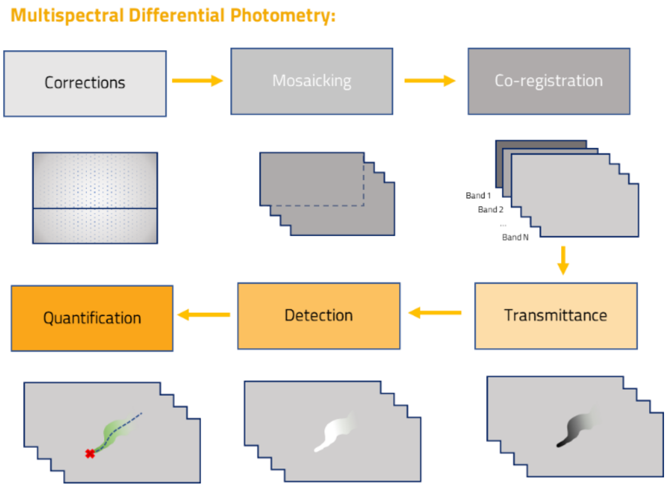

Figure 2-4. Flowchart of the Multispectral Differential Photometry (MDP) algorithm.

First, raw frames undergo corrections that (1) mitigate sensor artefacts due to temperature, read-out patterns and pixel-to-pixel variations using darks and flats and (2) counteract the distortion viewing geometry distortion by reverse the warping according to the distortion profile. Second, the processing pipeline aligns a sequence of frames based on the cross-correlation between overlapping areas. The alignment provides the total and relative shifts between frames, which are then combined in a single mosaic. Integrating several frames in a single image increases the SNR and expands the extension of the image. Here, the algorithm bins the image to sacrifice spatial resolution for higher SNR, depending on the application and configuration settings. Third, the spectral bands are aligned in a co-registration phase, so features in different spectral bands overlay.

Fourth, the algorithm estimates atmospheric CH4 light attenuation by comparing the CH4-sensitive band with an estimate of the same band without methane (CH4'), derived from additional spatial, spectral, and temporal data. In the fifth step, Light attenuations statistically different from the background are classified as methane once the noise has been reduced with several combinations of low-pass filters. Finally, the pipeline solves for the column density on a pixel basis using a look-up table derived from the runs of a simple forward atmospheric model. Then, the algorithm calculates the flowrates considering the mass of methane traversing the plume cross-sectional area and the local wind-speed data. When local data is not available, the algorithm retrieves and interpolates from NOAA GFS [13] or ERA5 [14][14] reanalysis data. The algorithm and the individual steps were validated through simulations and experiments and are currently under implementation on data collected from orbit by GEISAT Precursor.

2.4 Roadmap towards GEISAT constellation

SATLANTIS' methane detection project has been ongoing for some years and involved the development of camera prototypes before the launch of GEISAT Precursor. These prototypes were assessed and improved through a combination of lab, field, airborne, and simulation experiments [15]. The launch of the GEISAT Precursor mission is allowing SATLANTIS to validate the technology – from focal plane assembly to processing chain – in orbit and with data retrieved from space through real scenarios. This mission is conceived as the first satellite of the GEISAT constellation, that includes HORACIO, launched in March 2024 and currently in commissioning phase, and two microsatellites to be launched between Q4 2024 and Q1/Q2 2025. The objective of the GEISAT constellation is to have various satellites in orbit for increased revisit and coverage, but also to pursue the expansion of the spectral capabilities of the constellation, reaching up to 2500 nm through improved designs, with new detectors and cryocooling. For this, SATLANTIS is planning to launch by 2026-2027 more satellites based on the microsatellites under development. All of these missions will contribute to creating a tasking capability for the GEISAT constellation.

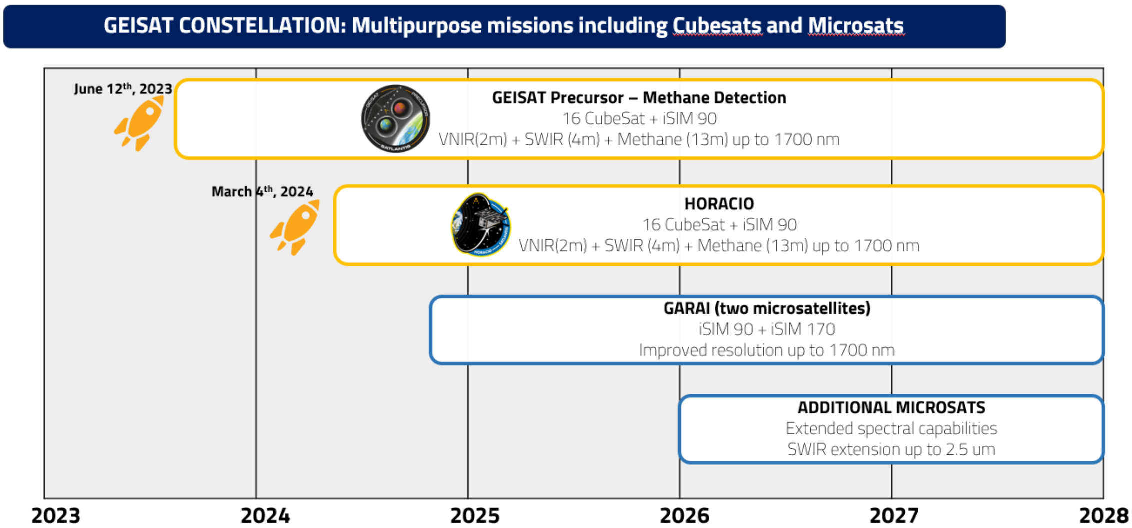

Figure 2-5: Roadmap of GEISAT Constellation.

It is important to note that GEISAT Precursor – like the future assets of the constellation – cannot only provide simultaneous imagery in VNIR and SWIR, with the specifications presented above, but also offers other innovative features like (i) the Ultra-High resolution algorithm developed and proprietary of SATLANTIS to enhance resolution without applying artificial intelligence; (ii) the Multi-spectral capability without loss of spatial resolution independently of the number of bands; and

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(iii) the Agility to acquire images while the satellite observes both across and along its orbit thus allowing to continuously monitor non-linear structures on ground.

With respect to the future constellation, it is also worth noting that SATLANTIS aims at advancing satellite technology by proposing new solutions that include:

- Extending the Short-Wave Infrared (SWIR) bands up to 2500nm, to enhance the capabilities for applications like methane detection or forest fire monitoring, providing more detailed and accurate data.
- Onboard Data Pre-processing Chain, to reduce data latency, ensuring that valuable information is processed and delivered more quickly to ground.
- Use of polarimetry, to mitigate background and aerosol effects in methane measurements from space. This research contributes to improved accuracy in detecting and monitoring methane emissions.

These initiatives showcase SATLANTIS's dedication to innovation and the continuous enhancement of satellite technology, which, in turn, benefits a wide range of applications, including environmental monitoring, resource management, and scientific research.

2.5 GEISAT Precursor Mission

GEISAT Precursor is a technology demonstrator for methane emissions detection and quantification.

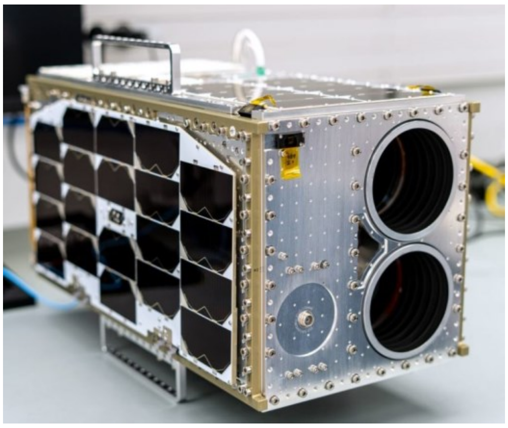

Figure 2-6: GEISAT Precursor mission 16U CubeSat. Image Courtesy of Nanoavionics.

It was launched with SpaceX on board the Falcon 9 Transporter 8 mission on June 12th, 2023, targeting a 500-550km SSO orbit with a local descending time of 13:00. The commission of the mission have been successfully completed and currently the mission is consolidating its operational phase. Table 2-1 describes the main aspects of the mission.

Table 2-1: GEISAT Precursor mission characteristics.

Constellation	**GEISAT**
Mission Name	GEISAT Precursor
Primary Use	Methane emissions
Satellite	16U CubeSat
Instrument	iSIM-90
Launch	12th June 2023
Mission orbit	SSO
Nominal altitude	530 km

The GEISAT Precursor's instrument is an iSIM-90 camera, with the specifications listed in Table 2-2.

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Table 2-2: GEISAT Precursor's iSIM-90 specifications.

Parameter	Description
Spectral range (nm)	450 – 1700 [1]
Effective aperture (mm)	77.5
Focal length (mm)	775
Spatial resolution (m)	~2 (VNIR) [2] ~13 (SWIR) [3]
Note 1: Note that the effective spectral range is limited by the quantum efficiency of the panchromatic detector. Note 2: After UHR. Note 3: For methane product.	

GEISAT Precursor delivers two main data products referred to as UHR and CH4. UHR-Precision products provide TOA radiance (L2A) and surface reflectance (L2B) high-resolution multispectral imagery for generic purposes. L2 CH4 is the product resulting from the MDP, with an image of the estimated methane column densities over background concentrations (CH4) and the uncertainties associated to the estimates (CH4U). Table 2-3 shows an overview of the characteristics of these products.

Table 2-3: GEISAT Precursor's Data Products.

Property	**Product type**	
Product category	UHR-Precision	CH4
Target applications	Generic applications	Methane point sources
Spatial Resolution (m) [1]	VNIR: ~2 SWIR: ~4	~13
Processing level	L2A (TOA Radiance) L2B (BOA Reflectance)	L2 CH4 (Column density)
Product Data Format	GeoTIFF	NetCDF
Note 1: To be confirmed after tests with UHR applied to the SWIR bands.		

2.5.1 GEISAT Precursor Ground Segment

The data provided by GEISAT Precursor will be available through the data access infrastructure developed by SATLANTIS. SATLANTIS has developed, implemented, and validated a Ground Segment infrastructure devoted to the management of the multiple EO missions of the company. GEISAT Precursor mission was already integrated into this infrastructure, adding new functionalities and features, specially designed for the new methane products generated by the mission. The high-level architecture of the Ground Segment is composed of: (1) Ground Station Network (GSN), (2) Mission control Centre (MCC) and (3) Data Hub or Payload Data Ground Segment (PDGS).

The Ground Station Network (GSN) is the worldwide distributed high coverage network of antennas use for satellite-to-ground (telemetry and payload data) and ground-to-satellite (commands) communications. GSN of GEISAT Precursor Mission includes four antennas provided by Kongsberg Satellite Service (KSAT-Lite) and located in Puertollano (Spain), Svalbard (Norway), Awaura (Australia) and Hartebeesthoek (South Africa). The Mission Control Centre (MCC) is the infrastructure from where satellite operators plan and control all the satellite activities, by using the Mission Control Software (MCS), which allows to perform satellite tasking, GSN scheduling and monitoring, satellite TT&C, etc. The Data Hub or Payload Data Ground Segment (PDGS) is the infrastructure that manages all the payload data received from the satellite.

3 COPERNICUS CONTRIBUTING MISSION (CCM)

GEISAT Precursor Mission was selected for the Copernicus Contributing Mission programme in 2023. The Copernicus Contributing Missions (CCMs) play a vital role in Earth observation, delivering data that complements the output of the Copernicus Sentinel missions. Comprising missions from European and international third-party operators, these satellites help cover the needs of Copernicus Service Providers. The CCMs are therefore an essential additional source of data not

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only to Copernicus Services, but also to EU institutions & bodies, research projects funded by EU and public authorities. More details about the Copernicus Programme and user groups are available in [16].

Facilitating on-boarding of European New Space missions to supply data to Copernicus Services is one of the principles of the CCM element. The European Emerging Copernicus Contributing Missions comprise a group of new space start-ups, scale-ups and small and medium sized enterprises developing commercial missions with the objective of delivering data to Copernicus. The European Emerging CCMs encompass various emerging commercial data domains including hyperspectral, thermal infrared, atmospheric composition, and multispectral domains. Presently, ESA and associated expert teams are collaborating closely with European Emerging CCMs companies to ensure the delivery of high-quality data [17] [18].

3.1 GEISAT Precursor CCM Category 1

GEISAT Precursor Mission was selected as Emerging CCM Category 1 for Atmospheric Composition domain in 2023. This domain focuses on the EO sensors that retrieve atmospheric composition measurements such as the greenhouse gases, air pollutants, and cloud & aerosol information with better spatial and/or temporal resolution than the current atmospheric satellite instruments.

The contract awarded as CCM Category 1 encompasses the definition and execution of a meticulous in-orbit CAL/VAL campaign, reinforced by ESA's support, aimed at ensuring optimal data quality. In addition to this, the activities within the CCM also involve a series of data demonstration activities linked to the Copernicus Services, coordinated by ESA. These initiatives are intended to reveal the synergies between GEISAT Precursor and the Copernicus Sentinels satellites, unlocking their complementarity and harnessing higher spatial and temporal resolution for enhanced performance.

In terms of impact, the CCM Category 1 contract has played a pivotal role in solidifying SATLANTIS as a Medium-sized Company, reinforcing its capabilities beyond an optical payload provider to becoming an end-to-end mission provider. Additionally, the transformative influence of being acknowledged as a Copernicus Contributing Mission has acted as an accelerator, enhancing credibility, and playing a crucial role in attracting new clients and contracts. This recognition further solidified SATLANTIS' reliability and strengthened the trust placed in the company by stakeholders.

4 CAL/VAL AND DATA DEMONSTRATION ACTIVITIES

The CCM Category 1 contract involves meticulous planning and execution of an in-orbit CAL/VAL campaign, aimed at ensuring the highest standards of data quality to fulfil the needs of Copernicus users. This is done under the supervision and support of ESA's professionals and a dedicated Atmospheric Mission Performance Cluster (ATM-MPC), which provide guidance and support as well as an independent data quality assessment/validation, further ensuring a delivery of data of the highest quality to Copernicus. Moreover Satlantis, together with ESA and ATM-MPC, are all actively taking part in regularly scheduled meetings and workshops, notably the VH-RODA workshop [19] and the CCM Cal/Val Checkpoint [20]. Additionally, activities under the CCM encompass data demonstration initiatives associated with Copernicus Services, as a demonstration of the capabilities of the mission.

4.1 Calibration and Validation activities

The data quality assurance of GEISAT Precursor encompasses the following activities:

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- **Pre-flight calibration campaign:** The pre-flight calibration campaign includes the comprehensive characterization of the camera components, including the detector, filters, and optical system, as well as the entire system. The assessment is conducted across multiple phases of the assembly process to effectively identify and address potential issues, ensuring the integrity and optimal performance of the instrument.
- **In-orbit CAL/VAL campaign:** The in-orbit CAL/VAL of GEISAT Precursor comprises various activities, such as dark , flat , spatial , geometric , and radiometric calibration. The plan includes estimates of clear-sky satellite revisits considering the constraints in the requirements for each activity. Each activity will be repeated periodically with frequencies according to their relevance for the mission. The periodic assessment will enable tracking the evolution of the performance of the imager and address any issue at shortest notice.

Within the CCM framework, in-orbit CAL/VAL plan has been meticulously defined for each activity, accompanied by corresponding quality metrics and assessment criteria. Dark and flat calibration techniques are employed to estimate noise contributions and rectify detector biases. Geometric Calibration measures image properties like ground sample distance (GSD), swath, optical distortion, and optical central axis. Spatial Calibration evaluates optical quality, Point spread Function (PSF), and Modulation Transfer Function (MTF), while Radiometric Calibration ensures accuracy in radiometric measurements. Figure 4-1 provides images acquired by GEISAT Precursor of geometrical, spatial and radiometric calibration sites.

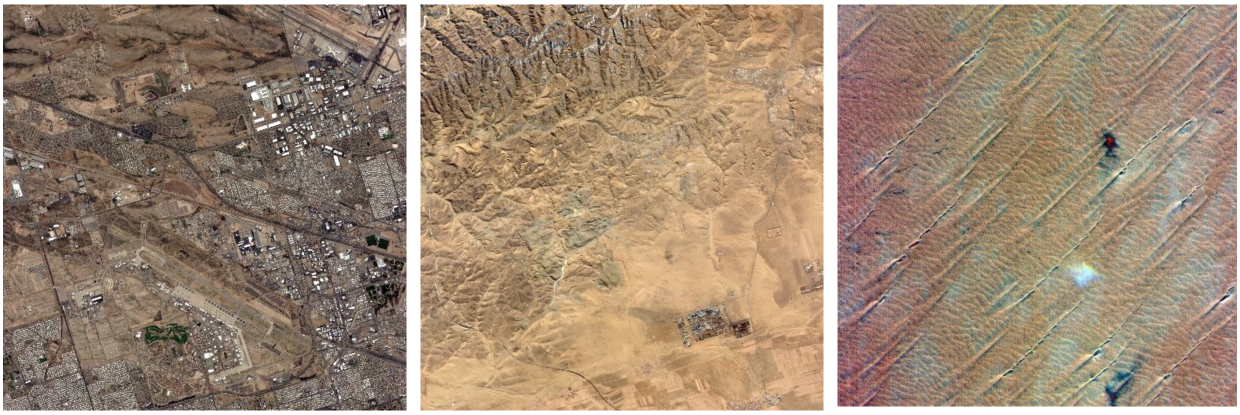

Figure 4-1: RGB images of geometric (left), spatial (centre) and radiometric (right) calibration sites captured by GEISAT Precursor.

4.2 Methane calibration measurements

The CAL/VAL activities for GEISAT Precursor's methane data products involves several quality assessment and validation processes that will be carried out gradually with the goal of verifying the data quality of the methane product. The first step is the comparison of methane measurements between GEISAT Precursor and another instrument, such as Sentinel-2, over a well-characterized persistent emitter. This cross-validation involves processing with the MDP both GEISAT Precursor and a third-party sensor's images and assess their consistency in terms of (1) methane column densities and (2) emission flowrates. Column densities can be visually compared by examining images with minimal latency from both sensors [21]. The discrepancy in flowrates can be quantified by comparing time series of measurements, as done in [22].

Identifying persistent emitters is an ongoing critical step. The persistent emitter must (1) sustain the emission over a sufficiently extended period, (2) have concentrations large enough to be measured by GEISAT Precursor and the third-party sensor, and (3) be observed under favourable observation conditions such as clear-skies, and reduced viewing and solar zenith angles. Different candidate

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locations have been identified across sectors (i.e., O&G, coal mines, and landfills) and multiple latitudes, to avoid constraints in illumination conditions. These locations will be systematically observed during the lifetime of GEISAT Precursor, to monitor the methane retrieval performance over time.

Figure 4-2 provides an image of a methane plume detected by GEISAT Precursor over an Oil and Gas facility in Algeria.

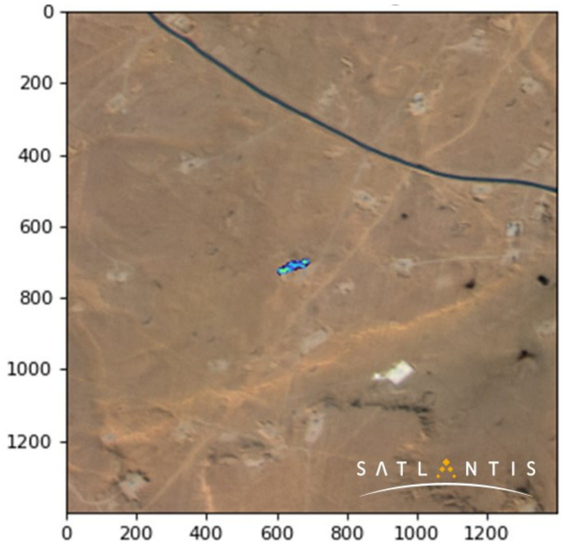

Figure 4-2: Methane plume detected over an Oil and Gas facility close to Hassi Messaud in Algeria, with the corresponding RGB image from GEISAT Precursor.

4.3 Data demonstration Activities

The CCM Category 1 program entails planning and executing demonstration activities, with the aim of (1) proving compliance with data quality standards, (2) showing the usefulness of the data in specific use cases for the Copernicus Services, (3) and assessing capabilities of data delivery.

SATLANTIS has proposed for phase 1 three distinct demonstration activities, developed collaboratively with the Copernicus Services and coordinated by ESA. These activities include:

- Tipping and cueing between Sentinel 5P and GEISAT Precursor.
- Monitorization and Verification of EU Strategic Areas.
- Methane emissions Detection and Quantification in O&G industry.

4.3.1 Tipping and Cueing

Tipping and Cueing is the coordinated use of complementary sensors to enhance and optimize persistent monitoring processes over large areas of interest. The combination of complementary image resolutions and/or spectral bands facilitates the generation of valuable information for different applications such as the monitoring of methane hotspots and air quality control.

In this data demonstration initiative, SATLANTIS proposes combining Sentinel 5P data (daily revisit, 2600 km swath, 5x7.5 km2 resolution) with GEISAT Precursor (~3 day revisit, 8 km swath, 13 m resolution) (Figure 4-3). This Tipping and Cueing approach showcases the combination of the complementary advantages to timely pinpoint the precise location of a point-source methane emissions, which is valuable for the Copernicus Atmospheric Monitoring Service.

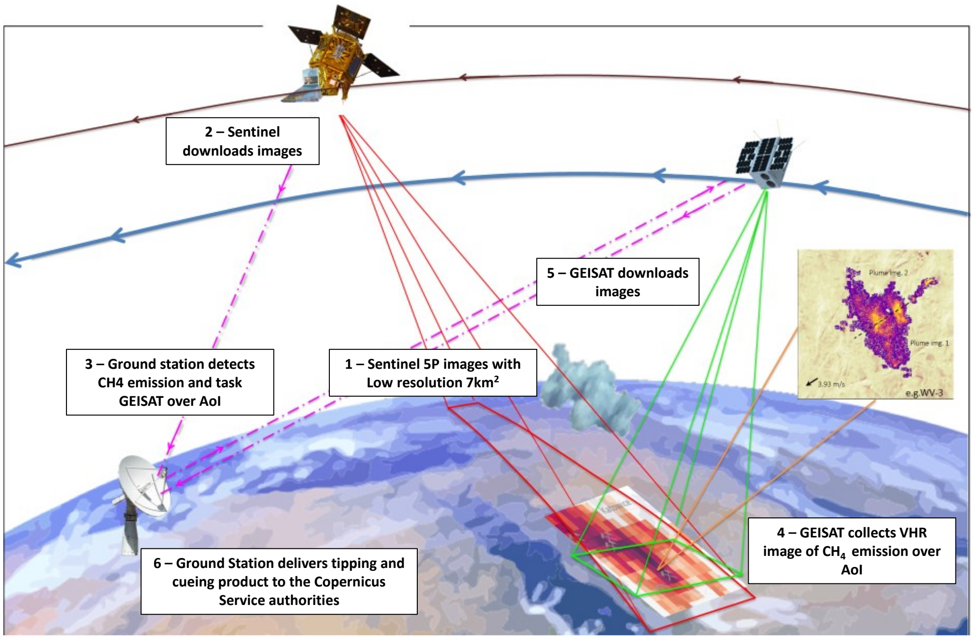

Figure 4-3: Tipping and Cueing concept combining Sentinel 5P and GEISAT Precursor.

SATLANTIS is responsible for overseeing the overall Tipping and Cueing process, which includes the semi-automatic detection of methane hotspots from TROPOMI's images. In a preliminary face, the experiment on emitters from O&G industry located in Turkmenistan, Algeria, Iran, and Iraq. The analysis of TROPOMI's images is repeated daily, reviewing the suggestions from the algorithm and defining the definitive coordinates. SATLANTIS plans the acquisition and uploads the commands to the GEISAT Precursor satellite to observe during the next pass available.

4.3.2 Monitorization and Verification of EU Strategic Areas

The aim is monitoring critical infrastructure for the EU concerning natural gas supply. Monitoring involving not only detecting potential methane emissions, but also the visual inspection of the facilities with the simultaneous VNIR and SWIR channel of GEISAT Precursor. These capabilities offer significant benefits, including enhanced spatial detail and frequent observations, which could yield benefits for various users, with the Copernicus Security Services being the primary target audience.

The data demonstration activity involves systematic acquisitions and processing of GEISAT Precursor data over the Areas of Interest (AoIs). Several quality metrics are calculated and assessed including acquisition capacity, and image quality in terms of GSD, Singal-to-Noise Ratio (SNR) and georeferencing accuracy. For the initial phase, Algeria was selected as the primary Area of Interest. Algeria is the fourth-largest gas exporter, and it the second most important to the EU gas imports after Norway. Algeria plays critical geopolitical role for the EU [26]. This activity is currently underway.

4.3.3 Methane emissions Detection and Quantification in O&G industry

The main goal of this initiative is to validate the quantification of methane emissions provided by GEISAT Precursor. The activity is proposed to be conducted in collaboration with ENAGÁS, the Technical Manager of the Spanish Gas System and the main carrier of natural gas in Spain.

Field campaigns consider both programmed emissions of natural gas and controlled releases. These emissions are synchronized with the revisit of GEISAT Precursor to capture satellite images during venting, coordinating SATLANTIS and ENAGAS technical teams. The experiment started in February 2024 as part of CCM Category 1 contract.

Over the 19 compression stations controlled by ENAGAS, the selected target is a compression station in Catalonia, Spain. Compared to others, this station is the most suitable option based on (1) the amount and number of potential emissions, (2) the probability of cloud cover, and (3) average surface windspeeds. Various acquisitions have been conducted with GEISAT Precursor, distributing the releases over 5 different days to maximize the probability of clear skies.

Furthermore, an additional field campaign involving controlled methane releases is being designed. The experiment will be conducted using on-ground equipment to control and quantify the flow rates that will be compared against GEISAT Precursor measurements. Additionally, various in-situ sensors may be considered as third-party measurement devices. These sensors will offer additional ground truth data for assessing GEISAT Precursor retrievals.

5 CONCLUSIONS

Satellites, with their systematic data acquisition capabilities, high spatial resolutions, and global coverage, can enhance security by acquiring information on strategic facilities. Specifically, GEISAT Precursor, equipped with VNIR and SWIR capabilities, enables the simultaneous visual inspection of targets and the detection methane emission anomalies potentially affecting suppliers. Hence, GEISAT Precursor can positively impact various aspects, including energy security, infrastructure protection, safety, and monitoring regulation compliance.

Moreover, the combination of Sentinel 5P data with GEISAT Precursor acquisitions can provide accurate information concerning the location of the leaks, and this will contribute to the unambiguous identification of the methane emitters.

The methane emissions related to oil and gas industry come from a wide variety of sources along the value chain. Some of these emissions are unintentional, while other emissions are planned, often carried out for safety reasons or due to the design of the facility or equipment.

GEISAT Precursor Data can serve to promptly identify the methane leak, and the data can be used to inform companies or sites responsible for these emissions in order to fix the problem as expediently as possible. This quick detection and action are a key point to mitigate global methane emissions.

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