MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

MethaneSAT Mission
Operations Control Centre and Support
Implementation Plan

Prepared by Moller Pollard Consulting Ltd
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New Zealand Government

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

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MBIE combines the former Ministries of Economic Development, Science + Innovation, and the Departments of Labour, and Building and Housing.

This document was commissioned from Moller Pollard Consulting Ltd by the New Zealand Ministry of Business, Innovation and Employment (MBIE) for the purposes of outlining the technical baseline, project structure, and implementation approach to meeting New Zealand's MethaneSAT mission commitments.

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1 Project Overview

1.1 Introduction

Methane is a potent greenhouse gas that is responsible for a quarter of the warming we are experiencing today. Reducing methane emissions from the oil and gas industry is the fastest, cheapest and best opportunity to slow the rate of global warming. Yet, until recently, policymakers and business alike have ignored methane. To fully understand the problem and hold corporations and governments accountable for the commitments they are making, we need more and better data about the extent and source of methane emissions.

MethaneSAT, LLC, a wholly owned subsidiary of the Environmental Defense Fund (EDF), is developing a new, low-cost, purpose-built satellite — MethaneSAT — to map and measure oil and gas methane emissions worldwide, with the potential to assess emissions from the full range of man-made sources. Following launch, targeted for Q3, 2022, MethaneSAT will quantify and publicly report ground-level methane emission rates, monitoring at least 80 percent of global oil and gas infrastructure — including facilities where on the ground measurements are not feasible — to understand the extent and nature of emissions. All data will be made available to the public so that companies, investors, governments, and interested citizens have a clear understanding of the extent of emissions across geographies and facilities, and thus the climate impacts. EDF will use this information to advocate for policies and practices to effectively reduce oil and gas methane emissions, and to measure progress against reduction commitments made as a consequence of this campaign.

1.2 Objectives

1.2.1 Overall Program Objectives

While the focus of MethaneSAT is on oil and gas supply chain emissions, the mission also has the potential to assess emissions from a range of anthropogenic methane sources, including agriculture. Processed data generated by MethaneSAT, as well as derivative data products, are planned to be made publicly available. EDF plans to use the data from the MethaneSAT satellite with a goal of catalysing reduction in methane emissions from oil and gas supply activities by at least 45 percent by 2025.

A joint declaration of intent was signed between MethaneSAT LLC and the Ministry of Business, Innovation and Employment (MBIE) of the New Zealand government. Under this declaration, the two entities have committed to a strategic collaboration with guiding principles including:

a) Using remote sensing to the benefit of life on Earth through quantifying, mapping and building scientific understanding of greenhouse gas emissions;
b) A commitment to open data and science;
c) A commitment to protecting intellectual property; and
d) Adhering to national and international laws governing cooperative collaborations and Earth remote sensing satellite operations.

1.2.2 New Zealand Objectives

The partnership between MBIE and MethaneSAT LLC is the first publicly funded international space collaboration for New Zealand, and is an important step for the growth of the New Zealand space industry.

To that end, MBIE has committed to contribute to the MethaneSAT mission by funding and managing the following mission aspects:

- Prime role in the design, construction, equipping, staffing, and operation of the MethaneSAT Mission Operations Control Centre (MOC);
- Support role in ground station commissioning and interfaces; and
- Prime role in the development and validation of the plans, procedures and operator skills to safely and efficiently conduct the MethaneSAT mission operations for a minimum of launch + 1 year, with an expected mission lifetime of 5 years.

MBIE will provide project management resources for technical oversight of New Zealand's contribution. The NZ project management team will also coordinate NZ institutional and public engagement with the MethaneSAT mission.

MethaneSAT will support MBIE in delivering the mission contribution laid-forth by this plan, including through information exchange and personnel mentoring, and in so doing will support MBIE's objectives of growing New Zealand's space industry and research capacity.

1.3 Document Purpose and Outline

The purpose of this document is to outline the approach and practices in the implementation of the New Zealand portion of the MethaneSAT mission. This document outlines the technical baseline, structure of the project, and implementation approach.

2 Technical Baseline

2.1 Mission Overview

With reference to the MethaneSAT Design Reference Mission: the Tier 1 goal for MethaneSAT is to determine the emission rates of methane (CH4) from the most significant source regions to the atmosphere across the globe, within two years of operations. The Tier 2 goal is to identify major point sources within the regional scale target areas for which emission rates are obtained. MethaneSAT is a versatile imaging spectrometer operating at two bands:

1. Methane Band allowing determination of the total column of CH4 along the optical path from the sun to the ground, reflected back to the satellite. The CH4 total column is retrieved from the absorption spectrum of CH4 in the wavelength range 1630 – 1690 nm using a combination of fast spectral fitting to determine airglow and detect clouds and a full-physics algorithm to determine final XCH4.
2. Oxygen Band to determine the total column of dry air, using the absorption spectrum of O_2 in the $^1\Delta$ bands (1249 – 1289 nm).

The MethaneSAT mission will image major source areas ("targets") for emission of methane to the atmosphere, emphasizing oil and gas extraction, processing, transportation, and use, as well as emissions from coal mining. MethaneSAT will also select targets in other source areas, representing a variety of emission processes, including: cities, landfills, dairies, wetlands, tundra, rice fields, feedlots, manure disposal, and more.

MethaneSAT will normally select targets each day using the MethaneSAT Target Selection Tool (TST) which uses an algorithm to select the targets according to a value assigned by its expected methane emission rate, forecast cloudiness, and probability of being observed (climatological cloudiness, seasonal factors at high latitude). A target represents a region where we expect significant emissions of methane, for example, an oil and gas field, a complex of refineries, or a major coal mining area. Targets for MethaneSAT may cover only a few kilometres or extend up to 200 km.

Targets will be sequenced into a coordinated mission observation plan. MethaneSAT will fly in a sun-synchronous low-Earth orbit (LEO) and perform slewing and pitch manoeuvres to acquire identified targets. Further, daily on-board dark current and radiometric calibrations and periodic health checks of the focal plane array (FPA) (e.g. looking at the night sky) are required.

2.2 Technical Baseline for the New Zealand Contribution

The NZ contributions will conform to the MethaneSAT mission's existing technical and schedule/milestone requirements. Their commitment to a mission critical system, the MOC development, commissioning and its operation and interface with support infrastructure and services (e.g. ground stations, terrestrial links and tracking and collision avoidance services (TCAS)) impose rigor and traceability in the implementation. At a high level, the MOC will:

- transform the targets identified by the TST and compile them into a sequence of payload acquisitions, instrument calibration and coupled spacecraft manoeuvres;
- Verify the sequence does not violate payload and/or satellite limitations;
- Verify compliance with data downlink capacity;
- Generate and upload the payload and satellite command sequence;
- Monitor MethaneSAT health and safety via telemetry and TCAS services; and
- Ensure ground transmission for archiving of science and calibration information.

Figure 1 shows an overview of the system elements that comprise the entire MethaneSAT mission operations and responsibilities. The NZ MethaneSAT contributions, comprises all elements in blue (designated as primary). This includes:

- Payload Operations (with the exception of the Science Data Processing);
- Satellite (Observatory) Operations Management;
- Mission operation support services including TCAS and contracting terrestrial communication links; and
- Ground station contracting and management

While at present no Science Data Processing is allocated within the NZ Project, at the discretion of MBIE, as the key stakeholder, and the NZ Project Manager, NZ-specific science interests may be allocated a dedicated interface with the MOC. This project goal would serve NZ educational, research, and technology interest, but is not mandated by the MethaneSAT Mission or the MOU, and thus not presently included in this document.

2.2.1 Mission Operations Control Centre Baseline

The MOC provides a set of functional capabilities for command, control, and support of the space vehicle and its payload. The MOC shall span two security zones: high and moderate.

The high security zone shall be a physically separated set of information technology (IT) infrastructure and computing devices that ensure the safety, reliability, and availability of the MOC controlled spacecraft and payload. The high security zone portion of the MOC shall perform commands uploads to control MethaneSAT.

The moderate security zone shall allow for science calibration, non-critical observatory maintenance, and science data download sequencing. The moderate security zone also shall assess payload and spacecraft engineering telemetry for nominal performance and health.

Both zones shall allow for compliance review prior to upload of any commands.

Uninterrupted Mission Operation services will be provided for a minimum of one year of operation with continuation through mission life probable. During commissioning the NZ-MOC will conduct 24/7 shadow operations, with actual operations being performed by Ball from a US-MOC. After commissioning, during routine operations the MOC will be staffed seven days a week with staffing hours that enable interchange between MOC personnel and the science team generating the daily plan. On-call support and support by special request is to be provided as required to meet special peak or critical periods of activity.

For contingency operations, Backup Control Center (BCC) capabilities and services shall be provided for each major MOC subsystem element or function. As such, an environment in both a high security zone and a moderate security zone is provided to enable BCC operability and ensure un-interrupted Mission Operation services for the life of the mission. Responsibility and hosting of the BCC will be determined by the Programme Manager and is subject to approval of MethaneSAT LLC.

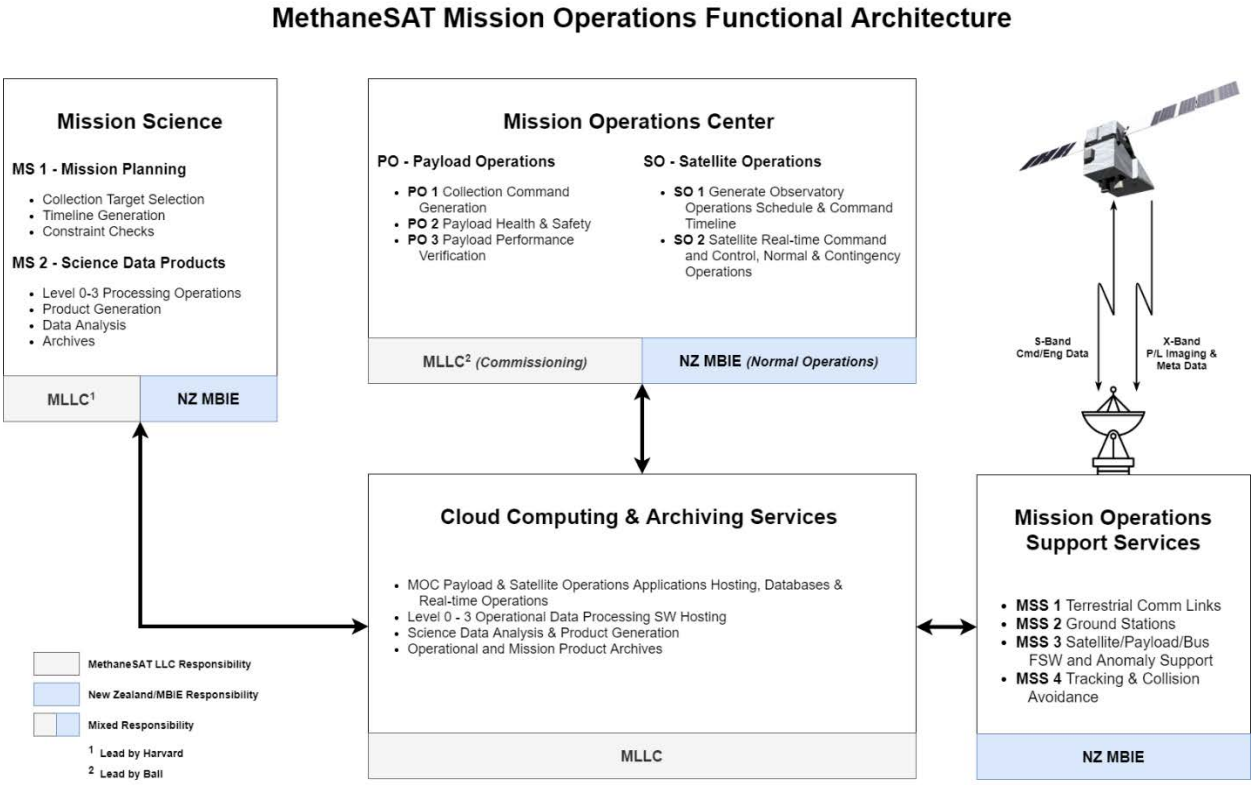

Figure 1: MethaneSAT mission operations architecture and responsibilities.

2.2.1.1 Payload Operations Baseline

Payload operations receives the target list from the TST and generates a target collection command sequence integrating spacecraft pointing manoeuvres along the orbit path and integrating necessary instrument calibrations (PO1). Constraint checking verifies compliance with spacecraft and payload safe limits in addition to meeting science and calibration data-downlink limits.

Payload telemetry is monitored to ensure operation within identified ranges and health and safety of the integrated payload/spacecraft assembly (PO2). Procedures for health and safety maintenance as provided by the contractor companies will be performed.

In addition to payload health and safety, payload performance/quality will be monitored in terms of the low-rate engineering data downlink (PO3). These metrics and assessments will be prescribed by the payload developer (Ball).

2.2.1.2 Spacecraft Operations Baseline

The MOC is an integrated spacecraft command and control facility. The MOC provides payload and spacecraft trajectory commands to support mission operations and received health and safety telemetry. A mission operations room within the MOC will provide the physical location from which flight controllers support and operate the MethaneSAT mission and vehicle.

TCAS services will be contracted and engaged for the agreed duration of New Zealand's mission participation including commissioning.

2.2.2 Ground Station Segment

Ground station services will be contracted and managed**.** The baseline requirement is S-band up/down and X-band downlink services (meeting KSAT X-band lite capabilities) for a minimum of 20 contacts per day. Note however that this capability may expand in order to meet NZ science requirements once they are defined. Managing cost, scope and priority will fall under the Programme Manager's responsibility.

2.2.3 Terrestrial Communications Segment

Terrestrial communications links to support both commissioning and mission operations will be provided for integrated testing, commissioning and a minimum of one year of operation.

3 Project Management, Governance Structure, and Key Roles

3.1 Project Authority and Governance Structure

MBIE will appoint an internal NZ MethaneSAT Programme Manager who assumes overall responsibility for the New Zealand contributions, including allocation of budget and schedule resources.

The NZ MethaneSAT Programme Manager (see Section 3.2) forms the primary programmatic interface with MethaneSAT LLC. In cases of discrepancies in scope, schedule, or other major

aspects of the programme, a Joint Steering Group (JSG) consisting of senior representatives of MethaneSAT LLC and MBIE shall be formed to adjudicate those discrepancies.

Figure 2 shows the NZ/MethaneSAT programme organization and reporting structure.

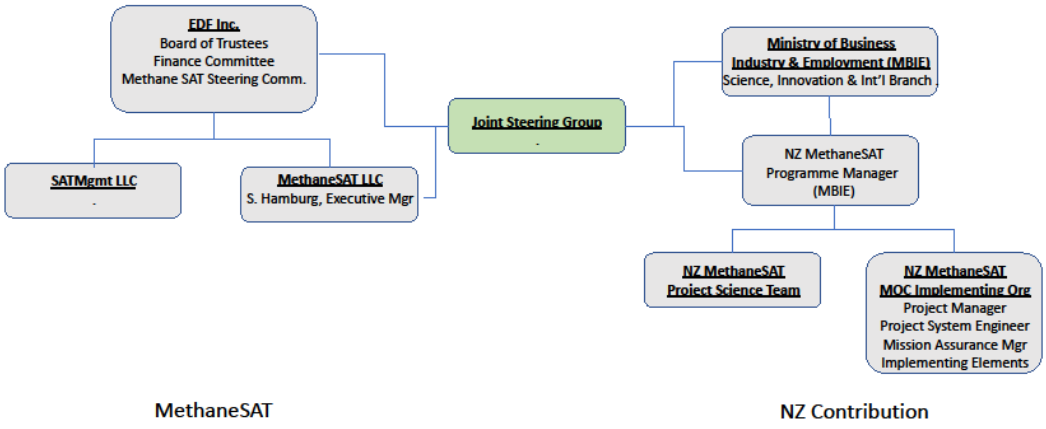

Figure 2: Top-level organization of the NZ MethaneSAT contribution, and makeup of the Joint Steering Group.

3.2 Key Roles

The NZ MethaneSAT implementation structure calls for the following key roles:

NZ MethaneSAT Programme Manager: Responsible for overall implementation of all NZ deliverables, including the management, administration, organization, direction, coordination, and approval processes for the New Zealand portion of the project. Also within the goals of the NZ MethaneSAT project is the generation of new scientific research within New Zealand, and to that end the NZ Programme Manager shall interface and coordinate with the NZ Science Team leader in the formation and management of a Project Science Team. The focus of the Science Team includes providing scientific expertise to aid in project decisions; generating new scientific research related to New Zealand agricultural practices; and providing educational and research opportunities at New Zealand universities, laboratories, and schools. This position will be within MBIE.

NZ MethaneSAT Project Manager: Responsible for overall implementation, coordination of the MOC development and operations and service support subcontracts. The Project Manager is the prime technical interface with the US MethaneSAT project, and reports directly to the MBIE Programme Manager. This position will be staffed independently within the prime MOC implementing agency.

NZ MethaneSAT Project System Engineer: the overall project technical lead, responsible for the balance of performance and risk to meet the requirements baseline. The Project System Engineer is also responsible for configuration control of the project documentation; management of the project requirements; planning for, implementation of, and documentation of validation and verification activities; technical assessment of project technical waivers; technical interface to the US MethaneSAT Project; and coordination of the overall project technical activities. This position will be staffed within the prime MOC implementing agency. At the discretion of the implementing agency it is acceptable for the Project Manager and the Project System Engineer roles to be served by the same person.

NZ MethaneSAT Mission Assurance Manager: the independent safety and mission assurance technical authority, the Mission Assurance Manager (MAM) is responsible for hardware and software Quality Assurance, including independent assessment of technical compliance; technical inspection; and independent risk assessment. The NZ MAM coordinates directly with the US MethaneSAT Mission Assurance organization. The Mission Assurance Manager may be staffed independently within MBIE, a second entity, or within the prime MOC implementing agency.

3.3 Customer and Stakeholder Definition

The key customer for the NZ portion of MethaneSAT is EDF. The EDF is a non-governmental organization that will use the data and findings from the MethaneSAT mission in advocacy to reduce global methane emissions.

MBIE, as the funding agency, represents the key stakeholder in the implementation of the NZ portion of MethaneSAT. MBIE is a New Zealand government ministry that will draw upon the data and findings of MethaneSAT to inform broader NZ government climate change policy including inter-governmental climate change efforts. MBIE's additional objectives is to use the NZ MethaneSAT partnership to grow the NZ space industry and research capacity to include public outreach and education.

4 Implementation Approach & Project Dependencies

4.1 Implementation Approach

As the funding agency, MBIE is responsible for the implementation of the NZ MethaneSAT project, and as such the Programme Manager is created as an MBIE position.

The implementation of the key element, the MOC and associated services, is to be awarded via contract to a NZ entity by MBIE. Given the national importance of this key element, the overall, ranked criteria for selection of the implementing entity are:

1. Demonstrated experience with the development and operations of low-Earth orbiting science satellite missions including vehicle and payload health and safety and overall requirements compliance (i.e. overall program credibility);
2. Schedule compliance and credibility;
3. Technical compliance and credibility;
4. Programmatic compliance and credibility (cost); and
5. National benefit and impact.

Once a key organization for MOC implementation is selected, the staffing and affiliation of the other key implementing roles (PSE, MAM) can be decided by the Programme Manager, although it is envisioned that those roles would be best contained within the implementing organization.

A strong objective of NZ's partnering and contribution to MethaneSAT lies with education and space-sector capacity development. To this end, the physical location of the MOC shall be at a tertiary educational facility within New Zealand. Participation of students in non-mission critical operational support, subject to security requirements compliance and international regulation compliance, is highly desirable as are publicly visible facilities and operations as permissible within security constraints.

At a minimum of 6 months prior to contract end (and post commissioning), the MOC implementation agency will deliver a proposal to support transition of mission operations and MOC responsibility to the host facility. This proposal will include 1) ongoing support the level of which will be determined based on experience gained during MOC development and 2) host personnel training.

The formation of the Project Science team is expected to maximize national impact, including selection of range of participants from varying organizations.

4.2 Project Dependencies

Successful implementation of the MOC and associated services (TCAS, ground-station and terrestrial communications) have a number of dependencies. The integrated sensor/satellite MethaneSAT system will be commanded and sequenced by the MOC and the MOC will be responsible not only for operations, but also health and safety including insurance of operations that fall within safe limits for the hardware. Therefore, knowledge of the MethaneSAT hardware and critical interfaces and constraints is essential for the MOC development. The NZ MOC developer will work with Ball Aerospace, MethaneSAT LLC (MLLC), Blue Canyon Technologies (BCT, Bus Provider) and Harvard/SAO to ensure a complete understanding of the Flight Systems operational design, test, nominal and contingency operations requirements.

Ball has the lead responsibility to develop and validate the systems, databases, engineering tools and procedures for on-orbit commissioning of MethaneSAT. Ball will make these available prelaunch as they are developed and formally transition these to NZ MethaneSAT at the conclusion of the commissioning phase.

These project dependencies are itemized in Section 11.3.

5 Program Baseline

5.1 Requirements Baseline

The following subsections summarize the baseline requirements for the NZ responsible elements. The MethaneSAT Mission Operations Ground System Architecture, Requirements and Responsibilities document is the controlled overarching reference for the MethaneSAT requirements for mission operations. These requirements are repeated below for convenience.

Changes or modifications to these requirements by MethaneSAT LLC that result in a change in MBIE overall scope will be subject to review for impact by the PSE and PM. Similarly, any non-compliance in ability to meet a requirement will be subject to review and reporting consistent with Project Control Plan and if necessary will be raised to the JSG for assessment and adjudication.

5.1.1 Payload Operations (PO)

PO 01 Target Collection Command Sequence Generation

- **PO 1. 1** Access Geo-located Targets and Collection Lists
- **PO 1. 2** Generate Geo-located time sequenced Target Lists with Collection Modes for up to 24 hours of operations
- **PO 1. 3** Identify and Eliminate Constraints
- **PO 1. 4** Update Target Request Collection History
- **PO 1. 5** Transmit Geo-located time sequenced Target Lists with Collection Mode no later the 12 hours before execution of the first command
- **PO 1. 6** Access and update new Target Collection timelines as late as 6 hours before the first update Target.

PO 02 Ensure Payload Health and Safety

- **PO 2. 1** Access, Decrypt and display in Real-time Bit Sync'd Raw engineering data during Ground Stations contacts for up to a total of 30 minutes per orbit
- **PO 2. 2** With < 100ms of delay calibrate & perform computations to convert Raw engineering data to engineering units and enable call up of any engineering data parameter for display
- **PO 2. 3** Provide the computational tools to monitor Payload performance including the capability to trend all engineering data either from the real-time data stream, archived data or simultaneously using both
- **PO 2. 4** Provide the ability to define and for automated detection & display of High & Low, Red & Yellow limits for engineering parameters
- **PO 2. 5** Archive and enable recall < 1 minute all raw and converted engineering data for at least 30 days
- **PO 2. 6** Archive of all Raw data with command, telemetry, calibration and conversion data bases for at least 6 years after MethaneSAT Launch
- **PO 2. 7** Provide the ability within a Ground Stations contact to issue Payload real-time commands or call up Payload command sequences stored on the Satellite to maintain safety and or execute real-time operations for the flight systems

PO 03 Assess & Maintain Payload Spectroscopic Performance Quality

- **PO 3. 1** Access Calibrated Level 0 and Level 1 Payload Data
- **PO 3. 2** Access all Payload calibrations and operational scale factors
- **PO 3. 3** Provide tools and computational capability compare and analyse Payload Calibration Images, target acquisition scale factors and generate updates for on-board and science data processing systems the Payload Flight Software

5.1.2 Satellite Operations (SO)

SO 01 Generate Satellite Operations Execution Schedule & Command Timeline

SO 1. 1 Maintain Current knowledge of Satellite Orbit ephemeris correlated to GMT to <10ms and ± 20 m along and in cross track.

SO 1. 2 Maintain knowledge and models to project of Satellite resource capacity needs, availability and constraint avoidance

SO 1. 3 Maintain knowledge and model of Satellite orbital altitude, and the tools to generate orbital manoeuvre commands and track propellant usage

SO 1. 4 Generate and validate orbit adjust manoeuvres

SO 1. 5 Ingest Geo-located Target and Calibrations lists, and Calibrated Payload and Collection Mode Command Sequences

SO 1. 6 Generate a constraint free Satellite schedule defining Pointing, Payload Operations, Calibrations, Housekeeping Operations, Data Collects, Storage, and Downlinks needed

SO 1. 7 Request X/S Band Ground Station support and iterate with Satellite schedule as required

SO 1. 8 Generate the Command Sequences, verify they do not violate and constraints and restrictions, package and encrypt them for uplink

SO 02 Satellite Real-Time Command & Control Nominal and Contingency Operations

SO 2.1 Ingest and store for uplink the daily Satellite operations command sequences and associated Ground System support schedules

SO 2.2 Capability to automate or manually establish bi-directional communications link between the Satellite Mission Operations Management Centre and the ground stations for commanding and engineering data, and hi-rate links from the Ground Stations to Science Data Processing for science data

SO 2.3 Capability to automate or manually command the Ground Stations to acquire S and X Band links to the Satellite, Command Data Dumps and issue Real-time nominal and contingency commanding

SO 2.4 Uplink to the Satellite and verify command successfully stored on -board

SO 2.5 Ingest and display in Real-time Bit Sync'd Raw engineering data during Ground Stations contacts for up to a total of 30 minutes per orbit

SO 2.6 With < 100ms of delay calibrate & perform computations to convert Raw engineering data to engineering units and enable call up of any engineering data parameter for display

SO 2.7 Provide the computational tools to monitor Satellite systems performance including the capability to trend all engineering data either from the real-time data stream, archived data or simultaneously using both

SO 2.8 Provides updated Spectrometer Focal Plane Radiometric and Boresight Alignment data and Ephemeris data files every TBD days

SO 2.9 Provide the ability to define and for automated detection & display of High & Low, Red & Yellow limits for engineering parameters

SO 2.10 Archive and enable recall < 1minute all raw and converted engineering data for at least 30 days

SO 2.11 Archive of all Raw data with command, telemetry, calibration and conversion data bases for at least 6 years after MethaneSAT Launch

SO 2.12 Provide the ability within a Ground Stations contact to issue Payload real-time commands or call up Payload command sequences stored on the Satellite to maintain safety and or execute real-time operations for the flight systems

5.1.3 NZ Mission Operations Support Services (MSS)

MSS 01 **Terrestrial Communications Services -** HI Rate Payload data ≥100Mbs and Low Rate Data 1Mbs communications capability for Prelaunch, Commissioning and L+ Normal Operations as needed between Ball, Harvard, the NZ MOC and Remote Ground Stations starting at approximately 6 months before launch

MSS 02 **Remote Ground Stations** - S Band up/down and KSat-Lite X Band Downlink services a minimum of 20 contacts per day

MSS 03 **Flight Software and Anomaly Support** - Establish on-call Time and Material support agreements for Satellite/Payload/Bus Anomaly Support and Flight Software Maintenance with the Ball and Blue Canyon Technologies

MSS 04 **Orbital Tracking and Collision Avoidance – E**stablish Tracking and Collision Avoidance Service Contracts for Commissioning with a Commercial Service

5.1.4 NZ Operational Readiness **(OR)**

OR 01 Transition from Ball Commissioning to NZ Normal Operations – Operations Systems, procedures and tools developed and validated for MethaneSAT Commissioning by Ball of MethaneSAT, will be provided as a deliverable to NZ. NZ is required to provide any required additions to Software Systems/Applications, Data Bases, Operations Procedures/Handbooks, Simulators, Analysis Tools conduct Normal Operations.

OR 02 NZ Operations Interfaces - Demonstrate compatibility between all NZ Mission Operations systems and flight to ground interfaces

OR 03 Operations Software, Data Base and Procedure Validation –Validate all NZ developed Normal Operations Software, Data Bases and Procedures. NZ with flight systems and/or using certified simulators.

5.2 Schedule Baseline

The working baseline MethaneSAT integrated project schedule including key milestones and reviews is shown in Figure 4. Figure 5 shows the baseline NZ MOC development and operations schedule, inclusive of the associated NZ-responsible elements. This baseline schedule is designed for compliance with the mission schedule and includes key mission milestones in addition to MOC specific milestones.

The integrated project schedule, key milestones and reviews shown in Figure 4 are referenced from the MSWG MethaneSAT Mission Systems Integration and Launch Readiness Plan. These dates are based on an August 2022 Launch Date and 30 Day Commissioning period. The launch window that has been contracted for is 6 months starting Q3 2022 through Q1 2023. MLLC Plans to assess the most likely launch date by Q1 2021. At that time MLLC will work with the MethaneSAT Partners and Contractors to adjust the milestones with the intent of completing the development and launch readiness to support the most probable launch date within currently available resource budgets and establish a process to address any future changes.

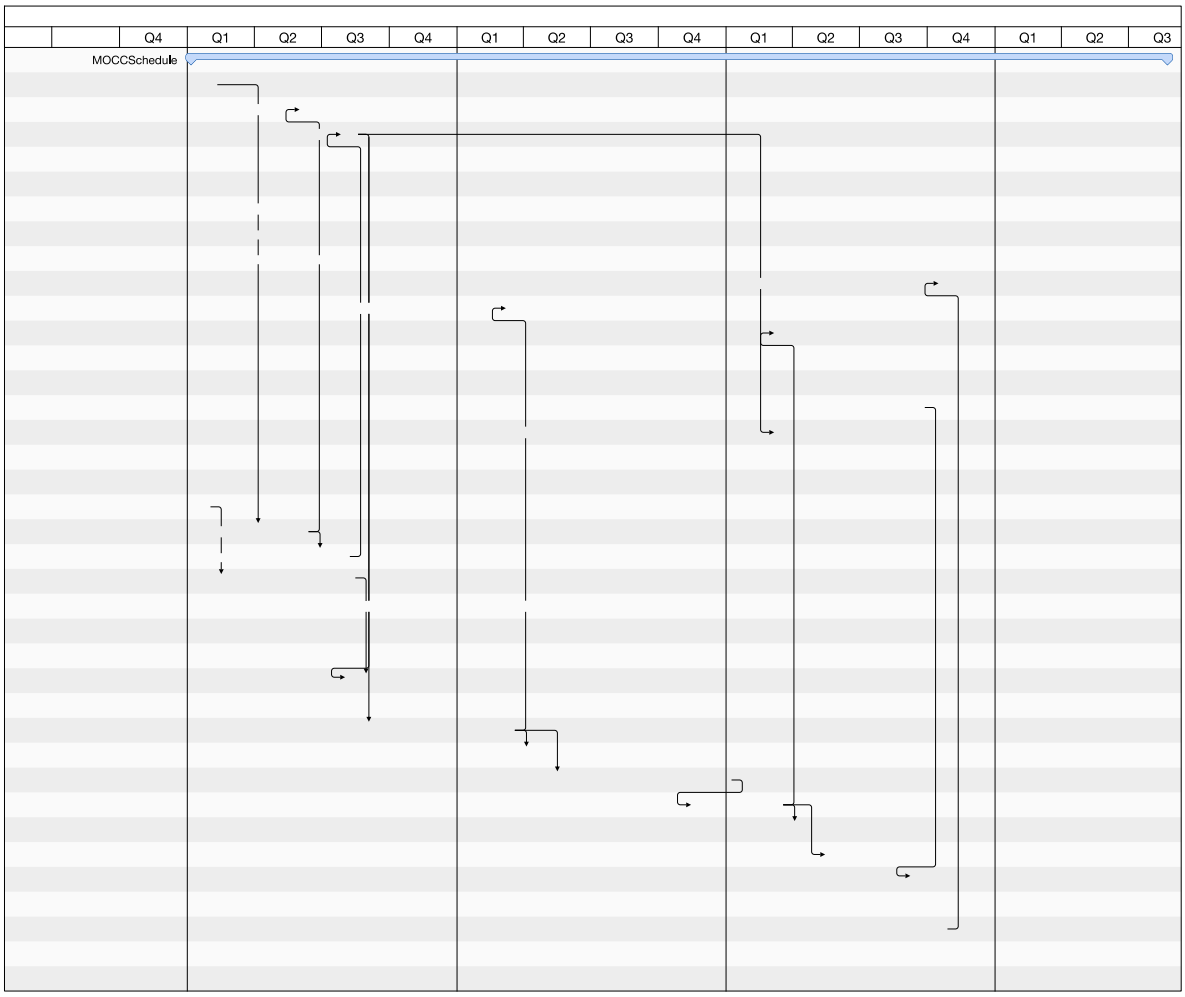

Figure 4: New Zealand MOC and ground system support development schedule.

An itemized list of deliverables (ref: MethaneSAT Mission Operations Statement of Work) that correspond to the timeline of Figure 4 is given in Table 1.

Table 1: Scheduled list of deliverables for MOC development.

Program Milestone	MBIE Deliverable	Date
Flight systems PDR	Gnd Station Users Guide	01/20
Commissioning & Mission Ground Systems/Operations Requirements Review	Preliminary Msn Ops Requirements, Ops Concepts & Development Plans/Schedules	04/20
Flight System CDR	Msn Ops Sys & Normal/Contingency Ops Design, Interfaces, Test and Validation Requirements	Q2/20
Commissioning & Mission Ground Systems/Operations PDR	Preliminary Msn Ops Sys & Normal/Contingency Ops Design, and the Development, Test and Validation Plans/Schedules	06/20
Monthly Progress Reports	Monthly Reports on Progress against Development, integration, Test, launch Readiness of the Msn Ops, Ground Systems, Operations Tools and Staff	Q3/20 – Post Commissioning
NZ & MLCC Msn Ops Contracts in-place	NZ - MOC, Msn Ops, Gnd Stations (MLCC-Cloud Services)	Q4/20
Commissioning & Mission Ground Systems/Operations CDR	Msn Ops Sys & Normal/Contingency Ops Design, and the Development, Test and Validation Plan	02/21
Msn Sys Ops Review # 1	MOC inputs to paper simulation of the execution of ops in support of the DTTL verify that Gnd Sys and Ops Functions and Performance capabilities will meet Msn needs.	Q2/21
Commissioning & Mission Operations Infrastructure Review	Commissioning & Msn Ops Cloud, Communications Links and Ground Station Design. Operations, Development and Validation Plan Review	Q2/21
Msn Ops Development Sys On-line	NZ MOC development system in-place with MLLC Cloud instance of COSMOS and Communications Link in-place	Q2/21
Mission Operations Development	Development of the Mission Operations Health, Safety, Planning, Scheduling and Engineering Analysis Operations Procedures	Q2/21-Q2/22
Msn Sys Ops Review # 2	MOC inputs to paper simulation of the execution of ops in support of the DITL verify that Gnd Sys and Ops Functions and Performance capabilities will meet Msn needs.	Q4/21
Msn Ops Staffing/Training Plans	Msn Ops Staffing and Training Plan	Q4/21
Msn Ops Sys, Procedures & Data Base Validation	Develop and Deliver End-to-End Msn Ops Sys Test and Flight to Ground RF, Cmd, and Data Compatibility Test & Verification Procedures	Q4/21
Delivery Msn Support Services	Validate operational readiness of the MOC, Terrestrial Communications, Ground Stations RF Compatibility and Tracking/Collision Avoidance Services to support Integration, Test, Launch Site Operations, Launch, Commissioning and Mission Operations	Q1/22

Program Milestone	MBIE Deliverable	Date
Operation Readiness	Complete NZ Mission Operations Procedure Development, Validation, Staffing, Training, Operator Certifications and Flight-to-Ground System Verification	Q2/22
Pre-ship, Launch and Mission Readiness Review Inputs	Gnd Station's, Communications Links, Tracking/Collision Avoidance Services, Mission Operations Team	Q2/22
Mission Rehearsals	Activity Plans and Procedures for Mission Rehearsals	Q2/22
Special Mission & Science Operations Commissioning Activities	Desired Operational Commissioning and Calibration Sequences	Q3-Q4/22
Launch and Mission Rehearsals	Provide Mission Operations Systems, Services and Personnel for Launch Rehearsals and Mission Simulations	2Q-3Q/22
Operations Readiness Review	Operations Validation, Simulations and Training Results Review that demonstrates MBIE Systems and Services Readiness to support Mission Operations	2Q/22
Mission Operations Support Services	Provide Terrestrial Communications, Ground Stations and Tracking/Collision Avoidance for post Launch Vehicle initial communications link acquisition, and for commissioning and Mission Operations	3Q/22
Msn Ops Transition To NZ	• Conduct shadow operations from the NZ MOC during Commissioning Operations Q3 Demonstrate readiness for handover and transition MethaneSAT Operations responsibility from Ball to the NZ MOC	Launch (no earlier than Aug 2022)
Mission Operations Commissioning	Demonstrate operational proficiency of the Mission Operations Systems and Team with Ball in the Shadow mode	Launch (no earlier than Aug 2022)
Mission Operations	• Staff MOC to conduct MethaneSAT Mission Operations o Health, Safety and Science Mission Operations 7 Day/Week, 24 Hours/Day Planning & Scheduling 7 Days/Week with hours that enable interchange between MOC personnel and the science team generating the daily plan.	Minimum of Launch (no earlier than Aug 2022) + 1 Year
Msn Services	Provide Terrestrial Communication, Ground Stations and Tracking/Collision Avoidance for initial post Launch Vehicle separation communications link acquisition and for Commissioning and Mission Operations	2Q/22 – Minimum of Launch (no earlier than Aug 2022) + 1 Year
Daily Operations Reports	Reports of Mission Operations Performance against Plans, Anomalies and Operations Proficiency	Post Comm'g
Anomaly Reports	Anomalies, disposition and supporting analysis	Weekly

Program Milestone	MBIE Deliverable	Date
Flight Systems Performance	Flight Systems trend analysis, such as Battery Depth of Discharge, Wheel Currents, Propellant usage, Star Tracker to Boresight Alignment/Scale Factors, and other TBD parameters with any recommendation for changes in operations to prolong MethaneSAT operational lifetime and/or mitigate potential loss of uptime	Monthly
Operator Certifications	Replacement Operator Training and Certification Reports	As Needed

5.3 Resource Baseline

Funding to the order of NZ$18M has been allocated to support the MOC development and operations and includes allocation for the contracted support services. The funding level has been assessed via independent estimates generated by the MethaneSAT project personnel and through obtaining service quotes.

5.3.1 Facility Baseline

The MOC shall be hosted at a tertiary educational facility. This facility will commit to the provision and maintenance of premises that satisfy the physical and IT security and redundancy requirements of Section 2.2.1.

5.4 Acquisition Management

The MOC development and operations will occur under contract to MBIE. MBIE will identify suitable candidates based on the prioritized criteria of Section 4.1. Those entities will be asked to submit a proposal for the work effort along with documentation of demonstrated LEO science mission development and operations support. This will be technically and programmatically reviewed by MBIE. The evaluation process will be expedited in accordance with the mission timeline.

Technical support contracts are to be established by MBIE with MethaneSAT LLC for: 1) Ball Aerospace to provide deliverables as itemised in Table 1; and 2) BCT to provide deliverables as itemised Table 2.

Service and support contracts are to be established and managed by the MOC developer for 1) ground-station services; 2) TCAS; and 3) terrestrial communications to meet Mission operations requirements.

The operational MOC host entity will be selected under a competitive process led and negotiated by MBIE. That contract will be managed by the Programme Manager.

6 Mission Assurance Approach

In keeping with the goals of developing New Zealand's role in the international space community, MBIE commits to a formal Mission Assurance approach for the NZ MethaneSAT mission. The implementation of that role is assigned per the definitions in Section 3.2, and shall include, at a minimum, independent requirement verification auditing, hardware inspection, software review, problem/failure disposition, and risk assessment aspects of mission assurance. The Mission Assurance Manager reports independently and directly on those aspects of the project to MBIE as the key stakeholder.

The Mission Assurance Manager shall document the overall approach in a Safety and Mission Assurance Plan, to be approved by the MBIE Programme Manager and other key stakeholders within MBIE.

Review of the contents and disposition of problem/failure reports, risk database entries, and other plans or procedures by the US portions of the project, namely MethaneSAT LLC or its contractors/partners, may be limited to items directly impacting the interfaces between entities. The authority on what NZ items shall be shared with MethaneSAT LLC or its partner's lies with the NZ MethaneSAT Programme Manager subject to the governance structure laid out in this Plan.

7 Project Control Plans

The MOC prime implementing agency shall be responsible for the development and implementation of the following control plans, deliverable to and approved by the NZ MethaneSAT Programme Manager:

- Risk Management Plan, which includes the formation, tracking, and reporting practices of the NZ MethaneSAT risk database;
- Problem/Failure Reporting Plan, which includes the formal approach to track and disposition problem/failure/anomaly reports;
- System Engineering Implementation Plan, which includes the overall organization of the NZ MethaneSAT System Engineering team, approach to formal requirements tracking, approach to formal validation and verification of requirements; and
- Configuration and Software Management Plans, including approach to document and software configuration, as well as software development and validation approaches.

The authority as to the extent to which these plans extracts, or their resultant products are shared with MethaneSAT LLC is held by the NZ MethaneSAT Programme Manager.

8 Project Review and Interchange Approach

8.1 Project Review Support

The NZ MethaneSAT will support all major reviews by the US MethaneSAT project, including:

- Project Critical Design Review
- Project Operational Readiness Review
- Project Commissioning and Handover

The NZ MethaneSAT Programme Manager will coordinate with the review convener to ensure that the appropriate representation from New Zealand are available and ready to support those reviews, as well as any additional reviews required.

8.2 Joint Technical and Program Interchange

In keeping with the goals of mentoring, as well as to facilitate the necessary flow of information, MBIE commits to a minimum of quarterly, in-person Technical Interchange Meetings with US counterparts as appropriate.

MBIE also requests monthly project-level meetings between NZ and US counterparts to ensure coordination on all key programme deliverables.

8.3 Internal Reporting & Reviews

The NZ MethaneSAT Programme Manager is responsible for creating the project reporting structure, which shall include at a minimum monthly reviews and reports with all key NZ stakeholders. Those reports should include at a minimum the current status of key deliverables, resources, as well as a reporting of the top items in the risk database and the status of all key problem/failure reports.

In addition, MBIE expects to commission appropriate internal technical or programmatic reviews of the NZ MethaneSAT project, particularly prior to key US Project Reviews or deliverables. Such reviews are convened by MBIE and shall include an independent board of Subject Matter Experts in addition to key stakeholders.

9 Export Control

MBIE requires that the NZ MethaneSAT Project comply with all appropriate export control laws of all project entities, including at a minimum New Zealand and the United States. The responsibility for this compliance is assigned to the NZ MethaneSAT Programme Manager.

As successful implementation of this programme is dependent on the necessary exchange of information, MethaneSAT LLC will apply for and obtain a Technical Assistance Agreement governing the relations between entities in the US and New Zealand.

10 Other Items

10.1 Lessons Learned

At the conclusion of the NZ MethaneSAT program, the NZ Programme Manager is responsible for producing a Project Lessons Learned document, deliverable to MBIE that details key lessons learned, outcomes, and recommendations for improvements learned throughout the project lifecycle.

10.2 Data Handling

The science data handling is not the responsibility of NZ, however mission time-line sequences, including vehicle and payload commanding and calibration activities must be archived and maintained for the entirety of mission operations in addition to anomaly reports and flight system performance reports. MLLC will provide Cloud Based Compute and Archiving Services for NZ for the life of the Mission and for the post-operational Mission Data Archive. Creation of a data-management plan is the responsibility of the NZ PSE. Formats and meta-data will be agreed with the MethaneSAT mission. Furthermore, the MOC contracted entity will create and maintain a project document repository to ensure revision control of critical documents. These include but are not limited to:

- Processes and procedures.
- Agreements and protocols.
- Interface Control Documents (ICDs).
- Security plans.
- Training documents
- TIMs and review packages.
- Ground segment schedules.
- Security protection documentation.

10.3 Education and Outreach

The MethaneSAT Project addresses diverse external audiences and will engage those audiences via a variety of tools. EDF itself intends to use data from the mission for advocacy in emission reduction with both political and public outreach and publicity.

With respect to NZ's participation, outreach and community engagement will be supported raising awareness of impacts of anthropogenic activities on climate-change and influencing evidence-based policy decisions. Press releases, social media and web-site development will all be utilised to provide continued and up-to-date information to the scientific community, decision and policy makers, and the public.

The NZ participation in MethaneSAT is intended to inspire the next generation of scientists and engineers. Hosting the MOC at an educational institution is an intentional mechanism to maximise that potential. Once routine operations are achieved, student engagement in non-mission critical support staffing is intended. Furthermore, there will be an active engagement in educational activities such as speaking at local schools and tertiary educational institutions by ST members. The Programme Manager will work with MBIE public affairs to develop press releases and participate in interviews with local and national media outlets. Informational materials such as white papers and fact sheets are developed to convey key messages to targeted audiences.

11 Appendices

11.1 Acronym List

AI&T Assembly, Integration, and Test
ATP Authority to Proceed
BCT Blue Canyon Technologies
BCC Backup Control Centre
CDR Critical Design Review
CDRL Contract Deliverable Requirements List
DITL Day in the Life
ICD Interface Control Document
IOT In Orbit Test
IRD Interface Requirements Document
IIRR Instrument Integration Readiness Review
ITS Information Technology Systems
KSAT Kongsberg Satellite Service
LS Launch Services
LRR Launch Readiness Review
LV Launch Vehicle
MBIE Ministry of Business, Innovation and Employment
MLLC MethaneSAT Limited Liability Company
MOC Mission Operations Control Centre
MO Mission Operations
MSS Mission Operations Support Services
NZ New Zealand
OOM Observatory Operations Management
OR Operational Readiness
PDR Preliminary Design Review
PM Project Manager
PO Payload Operations
PSE Project System Engineer
PSR Pre-Ship Review
RF Radio Frequency
SO Spacecraft Operations
ST Science Team
TAA Technology Assistance Agreement
TCAS Tracking and Collision Avoidance Services
TRR Test Readiness Review
TST Target Selection Tool