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MOHAMMED BIN RASHID SPACE CENTRE

Payload Hosting Initiative (PHI)

PHI Platform User Guide

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1.0 SCOPE

This document has been developed by Mohammed Bin Rashid Space Centre to provide insights about the capabilities of PHI platform and its modular specifications. The entities which are aiming to apply for hosting their payloads in PHI platform shall ensure the compatibility of the interfaces based on this document.

2.0 OVERVIEW

The Mohammed Bin Rashid Space Center (MBRSC) in Dubai, the United Arab Emirates (UAE), is soliciting proposal from relevant companies, universities and research centers worldwide to provide new technologies as hosted payloads for an upcoming Payload Hosting Initiative (PHI) mission. The Mohammed Bin Rashid Space Center was established by Decree Number 2 in 2006 by H.H. Shaikh Mohamed Bin Rashed Al Maktoum to inspire scientific innovation, technological advancement, and to advance sustainable development in UAE. As part of this vision, MBRSC is leading the effort to build space innovative technologies with challenging its capability to design, manufacture and test small satellites in short period of time with verifying hosted payloads.

To achieve a successful mission, MBRSC will handle the development; operation and launch of the satellite bus while the hosted payload entity will handle the development and testing of the payload then hand it over to MBRSC to be integrated with PHI platform. Additional information on MBRSC can be found online at www.MBRSC.ae.

3.0 Platform General Description

The PHI platform design allows for the maximization of volume available for the payload up to four units. The design also ensures robust power properties and various power distribution lines with protection. The satellite has a centralized data system where the OBC will gather all the telemetries via multiple data communication protocols. Also, the platform provides attitude and control system with high level of stability and accuracy. The design provides modular data, power and mechanical interfaces between the hosted payloads and the platform. The thermal design of the payloads can be analyzed based on thermal sensitivity and operation of the payloads. Figure (1) shows the general interfaces between all subsystems in the platform. Table (1) shows the general specification of PHI satellite design.

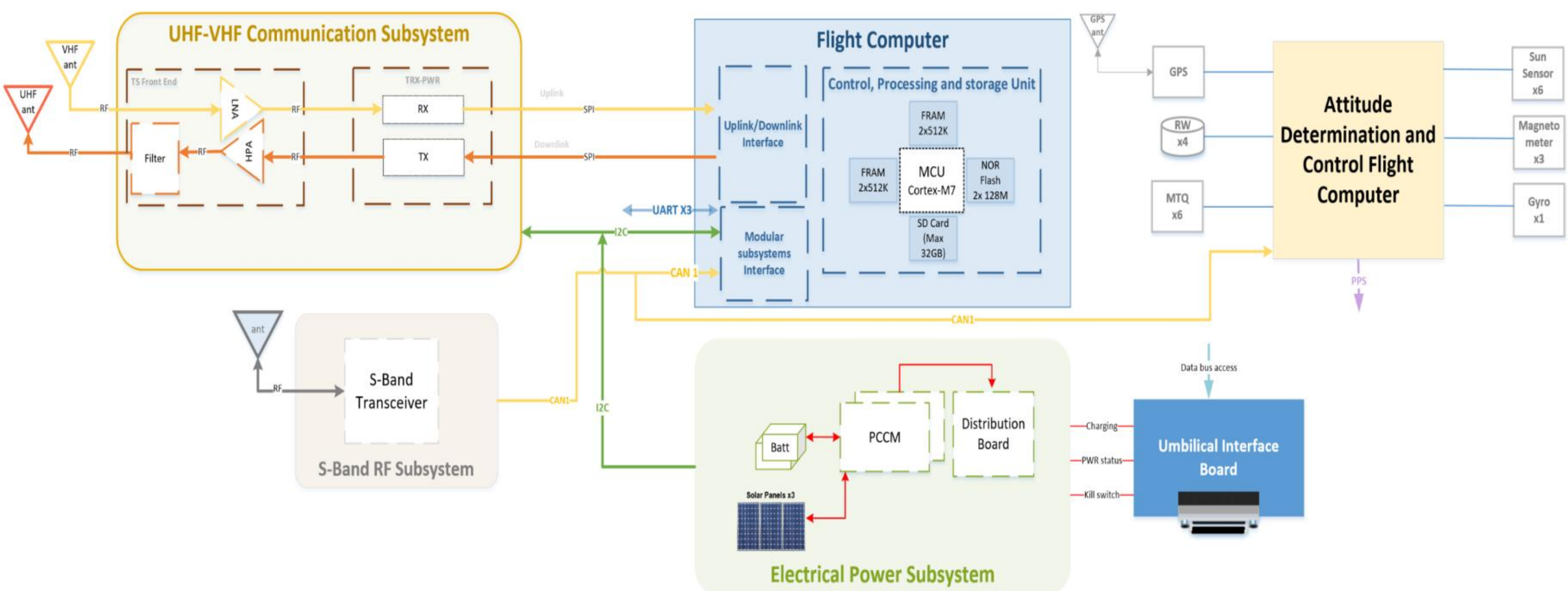

Figure 1: PHI archticture

Table 1 : PHI general specifications

Specifications	Value
Lifetime	1 ~ 2 years
Orbit Type	Sun Synchronous Orbit
Orbit Altitude	500 Km - 600 Km
Satellite Mass	18Kg
Power Generation	38W
Bus Voltage	14.8V
Communication Bands	UHF, VHF, S-band
Downlink Data Rate	9.6kbps to 1Mbps
Control Accuracy	5 deg
Data Interface	I2C, CAN, UART, SPI
Maneuver speed	90 degrees in 160 seconds

4.0 Satellite Bus Design and Interfaces

4.1 Electrical Power Interface

The Electrical power subsystem (EPS) is modular high-power system that is designed by MBRSC. It consists of Power charge and control module and power distribution modules with protection with the following specifications:

- Unregulated voltage rail: 13.0 ~ 16.4V
- Output channels:
  - Up to 6A output current for 13.0 ~ 16.4V unregulated voltage lines
  - Buck regulated power channels
    - Up to 3A output current for 3.3V switch lines
    - Up to 3A output current for 5V switch lines
    - Up to 4A output current for 12V switch lines

- Over-current and reverse-current protection in hardware
- Over-voltage protections
- Turn on voltage ramp control (soft start)
- Accurate voltage, current and power sensing on each channel

The payload subsystem can be connected to one or multiple switchable power lines depending on their operations. It is recommended to connect each module in the payload subsystem to one switchable power line to control the turn ON/OFF and ensure the protection of the power distribution line supplied from EPS to the payload. The typical power connector and pin allocation is shown below:

Table 2: Regulated power pin assignment

Description	Pin	Wire Gauge
Payload _3v3_5v_12v_PWR1	1	22~24 AWG
Payload _3v3_5v_12v_PWR2	2	22~24 AWG
GND	3	22~24 AWG
GND	4	22~24 AWG

Table 3: Unregulated power pin assignment

Description	Pin	Wire Gauge
Payload _un.reg_PWR1	1	22~24 AWG
Payload _un.reg_PWR2	2	22~24 AWG
Payload _un.reg_PWR3	3	22~24 AWG
Payload _un.reg_PWR4	4	22~24 AWG
GND	5	22~24 AWG
GND	6	22~24 AWG
GND	7	22~24 AWG
GND	8	22~24 AWG

If the payload is PCB stacked following PC/104 standard, it can use the following power interfaces and pin assignments as specified in Table (4). The remaining pin assignments in the header are reserved for other subsystems in the platform.

Table 4: Stacking power pin assignment

Connector	Pin	Description
H1	50	3V3_EPS_Input
H2	13	5V_EPS_Input
H2	25	5V_EPS_Input
H2	26	5V_EPS_Input
H2	27	3V3_EPS_Input
H2	28	3V3_EPS_Input
H2	29	GND
H2	30	GND
H2	31	GND
H2	32	GND
H2	45	V_BATT
H2	46	V_BATT

The maximum power consumption allocated for the payload is 20 W for 20 minutes operation per orbit in sunlight (21% duty cycle). If the payload requires higher power consumption, MBRSC can assess the power budget later and provide higher power consumption depending on mission operations.

4.2 Grounding Interface

The platform is following star grounding scheme where all ground points will be returned to the EPS subsystems. The EPS does not provide secondary ground and isolation for sensitive subsystems. The payload should consider ground isolation from load side if required.

4.3 Data Interface

The satellite bus is a collection of four different buses that connects the different subsystems' interfaces with the main Flight Computer. In the first modular satellite mission, four protocols will be used which are:

1. Inter-Integrated Circuit (I^2C)

Table 5: I2C specifications

I2C	**Min**	**Typical**	**Max**	**Unit**
Voltage	0	-	3.3	V
Pull-up resistors	-	2.2	-	kΩ
Frequency	-	100	400	kHz

The payload can be connected to I^2C bus as a slave. The address of the payload will be given later. Pull-up resistor of 2.2 kΩ is added from master side. Payload shall remove any pull-up resistor from their design to interface with the platform I^2C bus.

2. Serial Peripheral Interface (SPI)

Table 6: SPI specifications

SPI	**Min**	**Typical**	**Max**	**Unit**
Voltage	0	-	3.3	V
Frequency	-	187	-	kHz

3. Controller Area Network (CAN)

Table 7: CAN specifications

CAN	Min	Typical	Max	Unit
Dominant Differential Output Voltage	1.6	-	3	V
Recessive Differential Output Voltage	-0.05	-	0.1	V
Bit-rate	-	125	1000	Kbit/s

The payload can be connected to CAN bus as a slave. The address of the payload will be given later. CAN termination resistor of 120 Ω is added from master side. Payload shall remove any termination resistor from their design to interface with the platform CAN bus.

The platform provides another option to use the CAN interface to send a CSP packet. The CubeSat Space Protocol is an open-source C-program network layer delivery protocol used for communication between subsystems in small satellites and with ground station. This protocol is based on a 32-bit header that contains the transport and network layer information.

Table 8: CSP packet structure

	Header (4 Bytes)										Data
Bit	**2**	**5**	**5**	**6**	**6**	**4**	**1**	**1**	**1**	**1**	**1640**
Name	Priority	Source	Destination	Destination Port	Source Port	Reserved	HMAC	XTEA	RDP	CRC	Data

The figure below shows CSP packet over CAN packet structure.

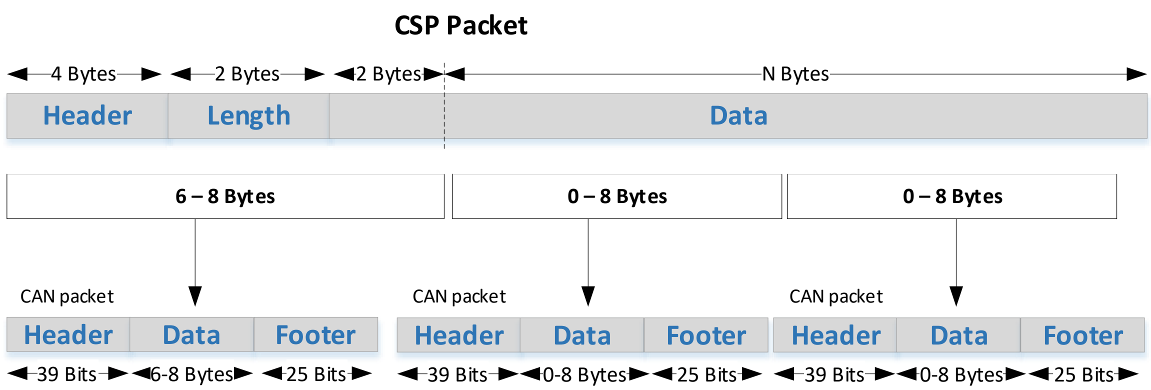

Figure 2: CSP Over CAN Interface Packet Structure

The first CAN packet must include CSP packet header and length of the CSP data. If there is any CSP data, up to 2 bytes of is added to the first CAN data packet. All the other CAN data packets contain only CSP data as shown in the figure above.

4. Universal Asynchronous Transmitter Receiver (UART)

Table 9: UART specifications

UART	Min	Typical	Max	Unit
Voltage	0	-	3.3	V
Baud-rate	-	-	12.5	Mbit/s

The platform can provide PPS signal from the GPS. The Table (10) presents the pin assignment of data lines and PPS that can be provided through PC/104 stacking connector.

Table 10: Stacking data pin assignment

Connector	Pin	Description
H1	1	CDH_CAN_L
H1	2	CDH_PPS

H1	3	CDH_CAN_H
H1	17	UART_RX
H1	18	UART_TX
H1	41	I2C_SDA
H1	43	I2C_SCL

The typical data auxiliary connectors and pins allocation are shown below for I2C, UART, CAN and SPI:

Table 11: I2C pin assignment

Description	Pin	Wire Gauge
I2C_SDA	1	26 AWG
I2C_SCL	2	26 AWG
GND	3	26 AWG

Table 12: SPI pin assignment

Description	Pin	Wire Gauge
SPI_SEL	1	26 AWG
SPI_CLK	2	26 AWG
SPI_MISO	3	26 AWG
SPI_MOSI	4	26 AWG

Table 13: CAN pin assignment

Description	Pin	Wire Gauge
CAN_H	1	26 AWG
CAN_L	2	26 AWG

Table 14: UART pin assignment

Description	Pin	Wire Gauge
UART_TX	1	26 AWG
UART_RX	2	26 AWG

4.4 Data storage

The on board computer will provide 30 GB storage in SD card for payload data. On the other hand, the payload can store its data in the payload subsystem and download it directly to the ground station during payload scheduled passes.

4.5 RF Interface

PHI platform provides two communication subsystems to uplink tele-commands and download telemetries and payload data to the ground station:

- UHF-VHF communication subsystem
- S- band communication subsystem

The main transceiver for telemetry download and tele-command upload during LEOP is a full duplex UHF downlink VHF uplink transceiver consisting of a UHF transmitter and a VHF receiver developed in-house. The main UHF/VHF transceiver is designed to transmit and receive at 9.6kbps. The S-band transceiver will be used to downlink large size of data and uplink software files and tele-commands. Table (15) and Table (16) shows the specifications of the communication subsystems:

Table 15: UHF-VHF specifications

Specifications	Value
UHF Downlink Frequency	436.5MHz
VHF Uplink Frequency	145.806MHz
UHF/VHF Data Rate	9.6kbps
Modulation Scheme	BPSK
Transmission Mode	Full Duplex

Table 16: S-band specifications

Specifications	Value
UHF Downlink Frequency	2230 MHz
VHF Uplink Frequency	2050 MHz
Data Rate	1Mbps
Modulation Scheme	QPSK
Transmission Mode	Full Duplex

The payload can download about 30 MB per contact using S-band link considering 8 min contact time.

The payload can be connected to S-band.

4.6 Mechanical Interface

PHI platform is a 12U structure designed by MBRSC following CubeSat standard size and volume

- X and Y dimensions (mm): 246.3 ± 0.1

- Z dimension (mm): 340.5 ± 0.3

The platform provides around 5U equivalent volume to host the payload with its harness and a mass that should not exceed 5 kg.

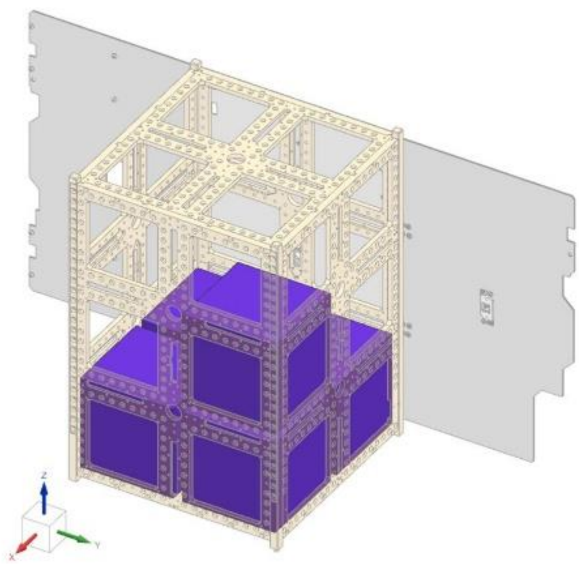

Figure 3: Payload 5U volume

The mechanical structure is designed to host the payload in both forms electronic PCB and mechanical box. The electronic PCB should follow CubeSat PCB Dimension: 95.5 mm * 90.17 mm. The stackable approach uses PC/104 connectors that placed on the subsystem boards, and the subsystem boards connect to each other. PHI platform provides extra volume in the stacking structure. Figure (4) and Figure (5) shows the reserved location and height for payload PCB. The dimension of the PCB with the location of mounting holes and stacking connector presented in details in Figure (6).

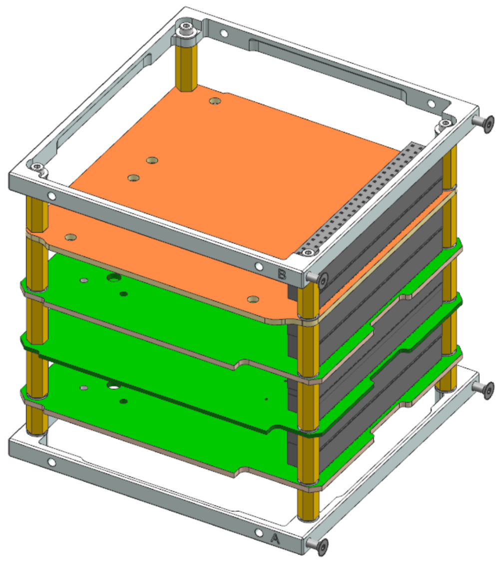

Figure 4: Payload PCB reserved location

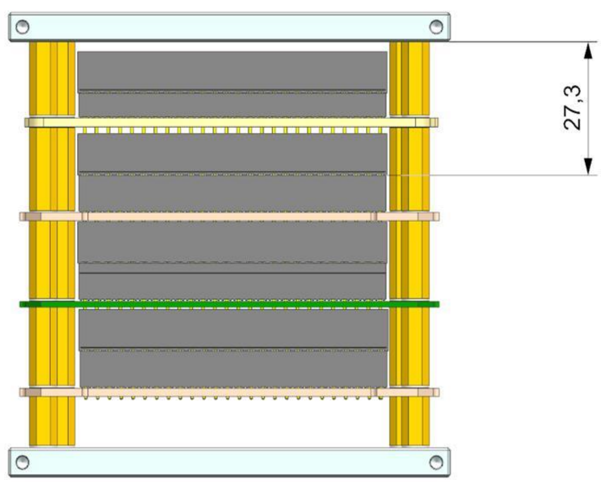

Figure 5: Payload PCB reserved max height

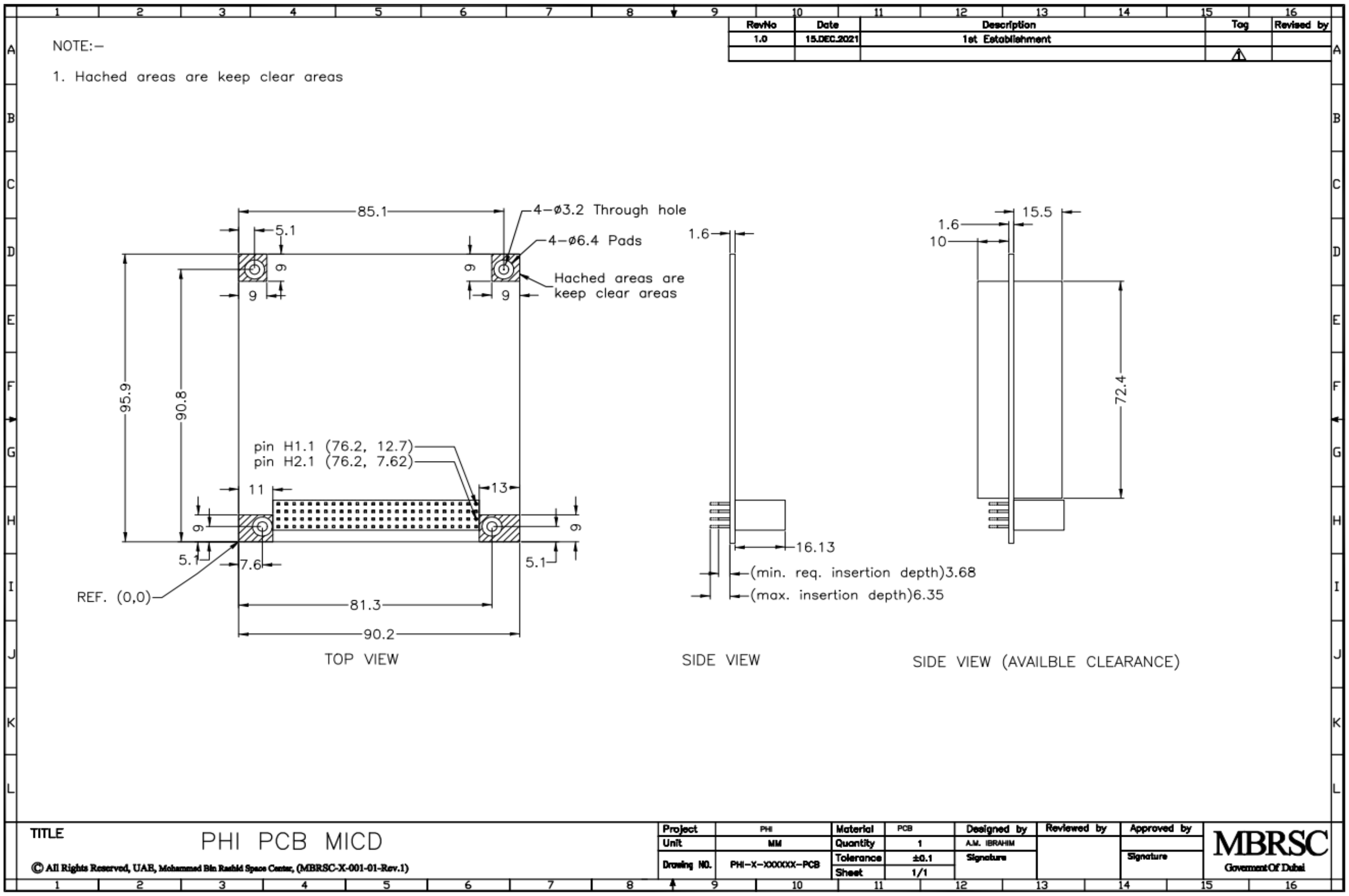

Figure 6: PCB MICD

In case the payload has a customized PCB design, the hosted payload can customize the mechanical support and bracket for their PCBs to be placed anywhere in the 5U provided volume. Figure (7) and Figure (8) show the mechanical structure frame with the mounting holes locations. It indicates the pattern that the hosted payload should follow in designing the customized PCBs or payload boxes otherwise the payload should design a bracket to interface between the platform mechanical structure and their boxes.

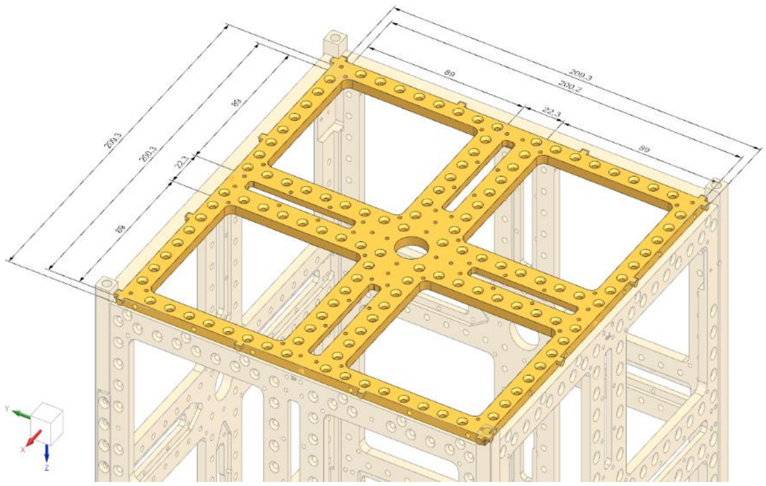

Figure 7: Payload box interface

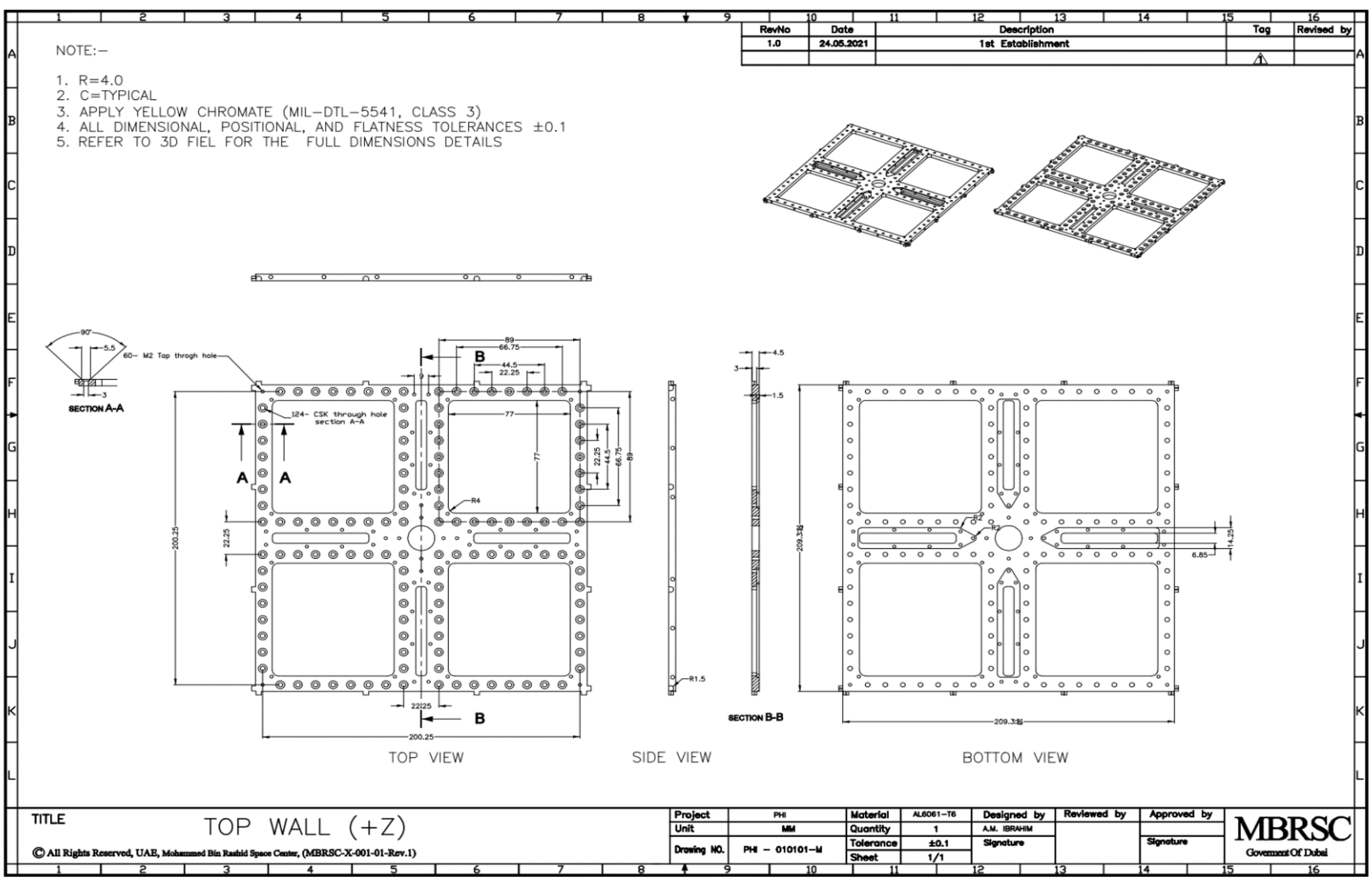

Figure 8: Structure wall MICD

4.7 Thermal Interface

The platform thermal design is highly affected by the orbit parameters, payload selected and operations that varies based on the mission. The satellite consists of passive and active thermal control. The platform can provide thermal insulation or heat path for the payload to maintain the temperature within acceptable range. External heaters will be provided by PHI platform if needed which requires customization of heaters based on the power. The platform will control the external payload heater by switching them ON/OFF using hardware or software control. The platform can provide two flexible heaters for the payload if needed. If the payload includes its own internal heaters as part of their subsystem, the power and control of the heaters should be managed within the payload. In addition, the platform can provide four reserved analog thermistors that can be allocated in the outer structure of the payload to read the temperature telemetries by OBC.

4.8 Attitude Control System Interface

ADCS uses priority-based pointing for its operation as the user can set the priorities. The ADCS provide different pointing modes depending on the mission and payload requirements. More details are presented in Table (17).

Table 17: ADCS specifications

Specifications	Value
Attitude determination performance in Sunlight	1.35° (1σ)
Attitude determination performance in Eclipse	3.55° (1σ)
Maneuver performance	115 degrees in 120 seconds
Pointing modes	▪ Sun pointing ▪ Nadir pointing ▪ Target tracking ▪ Delta-V pointing
Standalone flight control software	The flight software is running on its own ADCS board and not part of the main OBC
Used hardware	▪ ADCS board ▪ Reaction wheels ▪ Magnetic torque rods ▪ Sun sensors ▪ Gyroscopes ▪ Magnetometers ▪ GPS

5.0 GROUND STATION

The ground segment includes the Ground Station Network (GSN) and the Mission Operation Center (MOC). The GSN is located in MBRSC. UHF band will be used for downloading telemetries while the VHF band will be used for uplink the telecommands. The S band network will be used to download the payload data and upload large files. The payload operators can be at MBRSC during payload operation or can have a remote access during payload operation to download payload data. MBRSC operation team will schedule the contacts over a specified ground stations and define the payload contacts in advance to download payload data. More details about operation will discussed with the selected payload later.

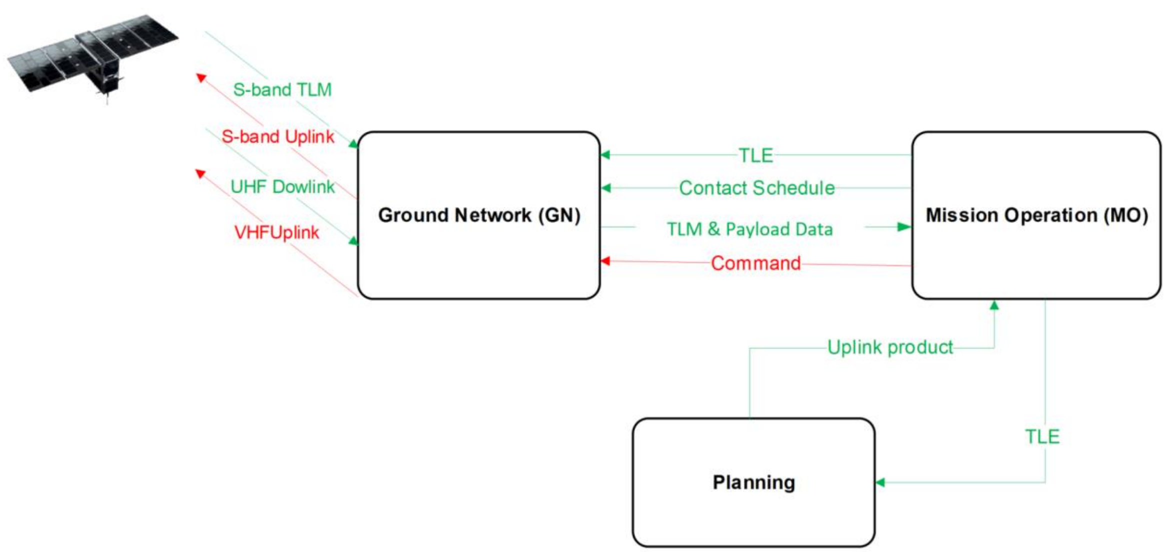

Figure 9: Ground station diagram

6.0 SAFETY AND QUALITY

6.1 Safety

Safety and quality of the payload require planning and controlling to avoid mission failure. One of the recommended approach is Preliminary Hazard Analysis (PHA). It is one of the essential cornerstone of health and safety management system for any mission. By following a systematic approach, hazards can be identified and managed so people are not harmed in the course of their work. Moreover, implementing such approach will help in preserving the facility, environment and the project. PHA can identify any hazards in the payload that will affect the S/C and its operation.

6.2 Material

The below are some aspects for evaluating materials in accordance to their relevance application:

1) Outgassing:

   Every non-metallic material that is not hermetically sealed shall be assessed based on its outgassing acceptance criteria:

   - Total Mass Loss (TML) ≤ 1%
   - Collected Volatile Condensable Materials (CVCM) ≤ 0.1%

2) Flammability

   Evaluation of materials flammability shall be done especially to materials that are used in hazardous environment during satellite launch or storage as examples. Flammable materials are to be avoided when possible.

3) Resistance to thermal cycling

   All materials shall be assessed if they have thermal degradation in performance or possible cracks after exposure to long cyclic stresses included in thermal cycling or TVAC tests.

4) Resistance to radiation:

All materials which are located on the external surface of the satellite including but not limited to; thermal blankets, thermal insulation systems and thermal paints shall be evaluated to check if any performance degradation can occur once exposed to radiation. The evaluation shall include the assessment of particle and ultraviolet radiation if needed and according to the expected radiation levels during the mission lifecycle.

5) Vacuum:

Materials shall be assessed if they will cause any problems under vacuum conditions. Mainly, vacuum conditions can increase the outgassing of certain organic materials used.

6) Stress Corrosion Cracking (SCC):

Materials used in structural applications shall always be screened to prevent failures resulting from SCC. Also, these materials shall endure long term storage and environmental testing exposed on the satellite.