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GOLDS-UFSC Documentation

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SpaceLab, Universidade Federal de Santa Catarina, Florianópolis - Brazil

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Nomenclature

ACS *Attitude Control System.*

EDC *Environmental Data Collection.*

EPS *Electrical Power System.*

GOLDS *Global Open Collecting Data System*

INPE *Instituto Nacional de Pesquisas Espaciais.*

LIT *Laboratório de Integração e Testes.*

OBDH *On-Board Data Handling.*

PCB *Printed Circuit Board.*

TTC *Telemetry, Tracking and Command Module.*

Contents

CHAPTER 1

Introduction

GOLDS stands for Global Open Collecting Data System...
INPE
LIT
PCB

1.1 Mission Description

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1.2 Mission Objectives

1. To serve as a host platform for the EDC payload.
2. Validate the EDC payload in orbit.
3. Validate EDC functionality in orbit.
4. Validate core-satellite functions in orbit.
5. Evaluate the behavior of the core modules.
6. Perform experiments on radiation effects in electronic components in orbit.
7. Serve as relay for amateur radio communications.

1.3 Mission Patch

The mission patch of the GOLDS-UFSC can be seen in Figure 1.1, it is inspired by the FloripaSat-I patch [1].

Figure 1.1: GOLDS-UFSC mission patch.

CHAPTER 2

Mission Requirements

1. The power system shall be able to harvest solar energy.
2. The power system shall be able to store energy for use when GOLDS-UFSC is eclipsed.
3. The power system shall supply energy to all other modules.
4. The data handling system shall communicate with the other modules and store their data.
5. The communications system shall send a beacon signal periodically using VHF radio.
6. The communications system shall send the CubeSat telemetry using UHF radio.
7. The communications system shall be able to receive telecommands and respond to them accordingly.
8. The attitude system shall be able to perform a 1-axis stabilization of the CubeSat.
9. GOLDS-UFSC shall have the capability to receive and execute a shutdown telecommand, therefore ceasing all transmissions.
10. The downlink transmissions shall be done once at a time, either telemetry or beacon.
11. The ground station shall operate under the proper radio frequency communication licenses.
12. GOLDS-UFSC shall comply with international and Brazilian radio license agreements and restrictions.
13. The team shall build and operate a ground station for full communication with GOLDS-UFSC.

CHAPTER 3

Mission Schedule

	Month (2021)											
Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dez
1	■	■	■	■								
2	■	■	■	■								
3	■	■	■	■	■	■	■	■	■			
4	■	■	■	■	■	■						
5				■	■	■	■	■	■	■		
6					■	■	■	■	■	■	■	
7								■	■	■		
8								■	■	■	■	
9									■	■	■	■
10										■	■	
11										■	■	
12											■	
13									■	■	■	■
14											■	■

Table 3.1: Mission schedule.

Each activity of Table 3.1 is decribed below:

1. Acquisition and manufacturing of critical elements and components for the solo platform.
2. Acquisition and manufacture of elements and components critical to the payload.
3. Acquisition and manufacturing of critical elements and components for the solo segment.
4. Compatibility tests between platform and payload in SpaceLab UFSC.
5. Integration of the engineering model in SpaceLab UFSC.
6. Preparation and suitability of the ground segment.
7. Verification and validation of the engineering model at SpaceLab UFSC.
8. Verification and validation of the flight model at SpaceLab UFSC.

9. Data collection platforms installation.
10. Verification and validation tests of Engineering Model compatibility with EMMN in the INPE / CRN in Natal.
11. Environmental tests at the Integration and Testing Laboratory (LIT/INPE).
12. Flight model acceptance and ground segment review.
13. Ground segment delivery.
14. Flight model delivery.

CHAPTER 4

Overall Description

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4.1 General Diagrams

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4.2 General Behaviour

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4.3 Orbit Parameters

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4.4 Power Budget

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4.5 Link Budget

4.5.1 VHF Link

- Direction: **Downlink**
- Frequency: **145,97 MHz**
- Modulation: **MSK**
- Datarate: **1200 bps**
- Output Power: **30 dBm (1 W)**
- Protocol: **NGHam**

4.5.2 UHF Links

Main UHF Link

- Direction: **Downlink and uplink**
- Frequency: **436,9 MHz**
- Modulation: **MSK**
- Datarate: **4800 bps**
- Output power: **30 dBm (1 W)**
- Protocol: **NGHam**

EDC UHF Link

- Direction: **Uplink**
- Frequency: **401.635 MHz**
- Modulation: **BPSK**
- Datarate: **400 bps**
- Protocol: **SBCD**

4.6 PC-104 Bus

4.7 Telecommunication

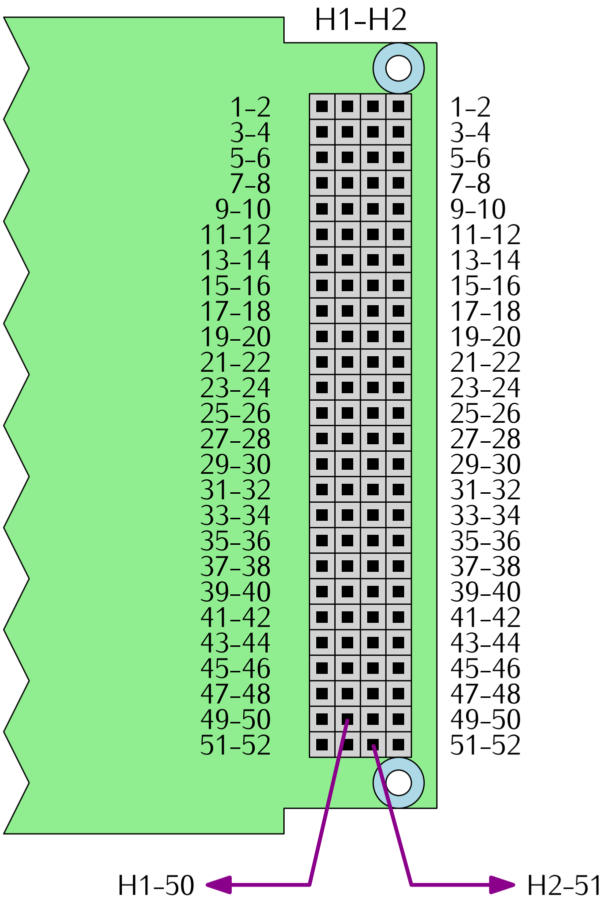

Figure 4.1: Reference diagram of the PC-104 bus.

Pin Row	H1 Odd	H1 Even	H2 Odd	H2 Even
1-2	-	-	-	-
3-4	-	-	EDC_1_EN	EDC_2_EN
5-6	-	-	BE_UART_RX	-
7-8	RA_GPIO_0	RA_GPIO_1	BE_UART_TX	GPIO_0
9-10	RA_GPIO_2	-	-	-
11-12	RA_RESET	RA_EN	BE_SPI_MOSI	BE_SPI_CLK
13-14	-	-	BE_SPI_CS	BE_SPI_MISO
15-16	-	-	-	-
17-18	EDC_UART_RX/TX	PLX_EN	-	GPIO_1
19-20	EDC_UART_TX/RX	GPIO_2	-	GPIO_3
21-22	-	-	-	GPIO_4
23-24	-	-	-	-
25-26	-	-	-	-
27-28	-	-	-	-
29-30	GND	GND	GND	GND
31-32	GND	GND	GND	GND
33-34	-	-	-	-
35-36	RD_SPI_CLK	-	ANT_VCC	ANT_VCC
37-38	RD_SPI_MISO	-	-	-
39-40	RD_SPI_MOSI	RD_SPI_CS	-	-
41-42	PL_I2C_SDA	-	-	GPIO_5
43-44	PL_I2C_SCL	-	-	-
45-46	OBDH_VCC	OBDH_VCC	BAT_VCC	BAT_VCC
47-48	EDC_VCC	EDC_VCC	-	-
49-50	RD_VCC	RD_VCC	EPS_I2C_SDA	-
51-52	BE_VCC	BE_VCC	EPS_I2C_SCL	-

Table 4.1: PC-104 bus pinout.

Signal	Pin(s)	Used By	Description
GND	H1-29, H1-30, H1-31, H1-32, H2-29, H2-30, H2-31, H2-32	All	Ground reference
BAT_VCC	H2-45, H2-46	EPS	Battery terminals (+)
ANT_VCC	H2-35, H2-36	EPS, ANT	Antenna power supply (3.3 V)
OBDH_VCC	H1-45, H1-46	EPS, OBDH	OBDH power supply (3.3 V)
EDC_VCC	H1-47, H1-48	EPS, EDC 1, EDC 2	EDC power supply (5 V)
RD_VCC	H1-49, H1-50	EPS, TTC	Main radio power supply (5 V)
BE_VCC	H1-51, H1-52	EPS, TTC	Beacon power supply (6 V)
RD_SPI_CLK	H1-35	OBDH, TTC	CLK signal of the main radio SPI bus
RD_SPI_MISO	H1-37	OBDH, TTC	MISO signal of the main radio SPI bus
RD_SPI_MOSI	H1-39	OBDH, TTC	MOS signal of the main radio SPI bus
RD_SPI_CS	H1-40	OBDH, TTC	CS signal of the main radio SPI bus
EPS_I2C_SDA	H2-49	OBDH, EPS	SDA signal of the EPS I2C bus
EPS_I2C_SCL	H2-51	OBDH, EPS	SCL signal of the EPS I2C bus
BE_UART_RX	H2-5	EPS, TTC	EPS TX, Beacon RX (UART bus)
BE_UART_TX	H2-7	EPS, TTC	EPS RX, Beacon TX (UART bus)
EDC_UART_TX/RX	H1-25	OBDH, EDC 1, EDC 2	OBDH TX, EDCs RX (UART bus)
EDC_UART_RX/TX	H1-27	OBDH, EDC 1, EDC 2	OBDH RX, EDCs TX (UART bus)
EDC_1_EN	H2-3	OBDH, EDC 1	EDC 1 enable signal
EDC_2_EN	H2-4	OBDH, EDC 2	EDC 2 enable signal
PLX_EN	H1-18	OBDH, Payload X	Payload X enable (GPIO)
PL_I2C_SDA	H1-41	OBDH, Payload X	SDA signal of the payload I2C bus
PL_I2C_SCL	H1-43	OBDH, Payload X	SCL signal of the payload I2C bus
GPIO_N	H2-8, H2-18, H1-20, H2-20, H2-22, H2-42	OBDH	GPIO pin (not used)

Table 4.2: PC-104 bus signal description.

Link	Packet Name	Payload			
		ID	*Source Callsign*	*Data (up to 220 bytes)*	*Size (bytes)*
Beacon	EPS Data	00h	"0" + "PY0EGU"	EPS + TTC data	58
	TTC Data	01h		TTC data	18
	EPS Data	02h		EPS + TTC data	39
	TTC Data	03h		TTC data	18
Downlink	Telemetry	10h	"0" + "PY0EGU"	Flags + OBDH/EPS data	220
	Ping Answer	11h		Requester callsign	15
	Data Request Answer	12h		Req. callsign + data	15 to 155
	Hibernation Feedback	13h		Req. callsign + hibernation in hours	17
	Message Broadcast	14h		Req. + dst. callsign + message	22 to 60
Uplink	Ping Request	20h	Any Callsign	None	8
	Data Request	21h		Data flags + count + origin + offset	16
	Hibernation Request	22h		Req. callsign + hibernation in hours + key	29
	Broadcast Message	23h		Dst. callsign + message	15 to 46

Table 4.3: Telecommunication packets and their content.

CHAPTER 5

Subsystems

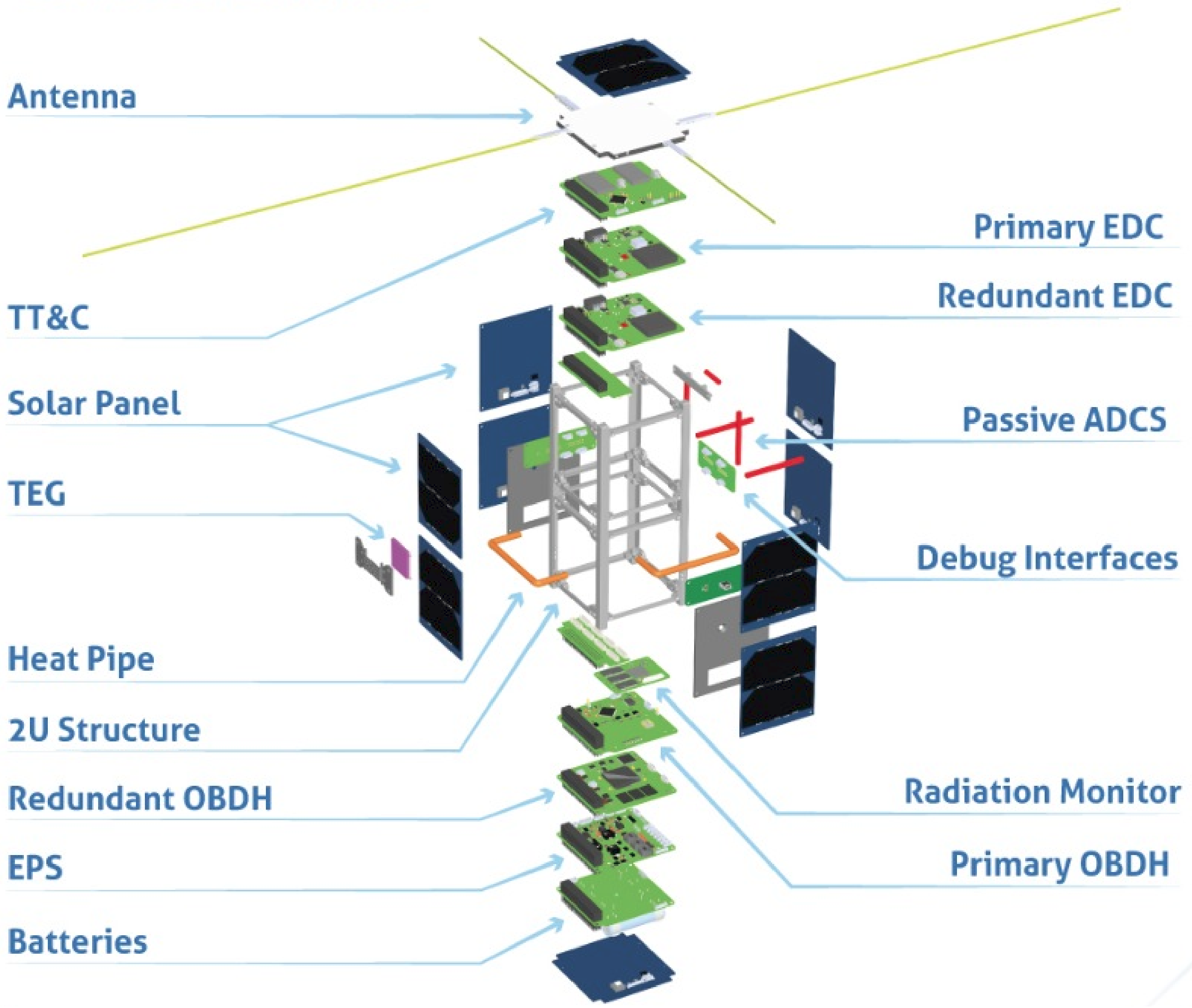

Figure 5.1: Exploded view of the GOLDS-UFSC satellite.

5.1 On-Board Data Handling

The OBDH 2.0 is an On-Board Computer (OBC) module designed for nanosatellites. The module is responsible for synchronizing actions and the data flow between other modules (i.e., power module, communication module, payloads) and the Earth segment. It packs the generated data into data frames and transmit back to Earth through a communication module, or stores it on a non-volatile memory for later retrieval. Commands sent from Earth segment to the CubeSat are received by radio transceivers located in the communication module and redirected to the OBDH, which takes the appropriate action or forward the commands to the target module.

The module is a direct upgrade from the OBDH of FloripaSat-1 [1], which grants a flight heritage rating. The improvements focus on providing a cleaner and more generic implementation in comparison with the previous version, more reliability in software and hardware implementations, and adaptations for the new mission requirements. The board of the module can be seen in Figure 5.2.

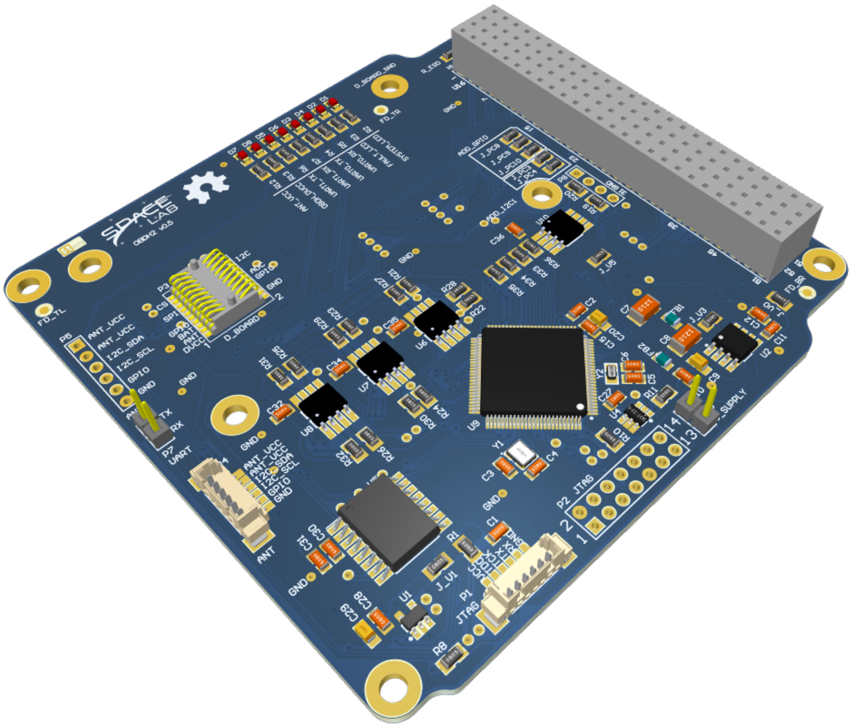

Figure 5.2: OBDH module.

More information about this module can be found in [2].

5.2 Telemetry, Tracking and Command Module

The TTC (or TT&C) is responsible to make the communication between the earth (a ground station) and the satellite, and is divided in two sub-modules: Beacon and downlink/uplink. The beacon is a independent sub-module who transmits a periodic signal containing an identification data (ID) of the satellite and some basic telemetry data. The downlink/uplink sub-module is the main communication device. It has a bidirectional data link to receive telecommands from the earth and transmit all available data back to Earth. The board of the module can be seen in Figure 5.3.

More information about this module can be found in [3].

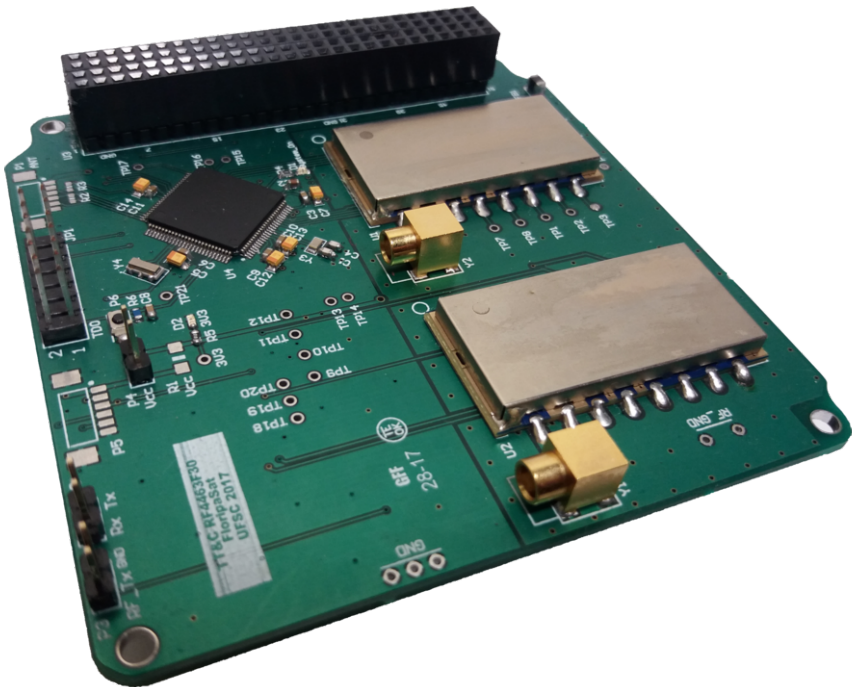

Figure 5.3: TTC module.

5.2.1 Antenna Module

The used antenna module is the CubeSat deployable VHF and UHF antenna from ISISpace [4]. It is a four monopole antenna built with tape strings (up to 55 cm) and compliant with the CubeSat standard (dipole or turnstile options are also available). The deployment method is the burning wire and it can be controlled digitally through a I^{2}C interface. To allow redundancy, there are two independent deployment controllers that can be activated separately. Also, the construction of this module allows the installation of a solar panel at the top side. The RF gain is about 0 dBi.

A picture of the antenna module (with all antennas released) can be seen in Figure 5.4.

The chosen configuration for this mission can be seen below (using Figure 5.5 as reference):

- Configuration: 4 monopoles (1x VHF + 3x UHF)
  - Antenna 1: VHF - 145,97 MHz (beacon)
  - Antenna 2: UHF - 401,635 MHz (EDC)
  - Antenna 3: UHF - 436,9 MHz (downlink/uplink)
  - Antenna 4: UHF - 401,635 MHz (redundant EDC)
- Tuning structure size: 2U
- Mounting position: Top
- Supply voltage: 3,3 V
- I^{2}C control type: Dual bus
  - Primary I^{2}C address: 31h (7-bit address)

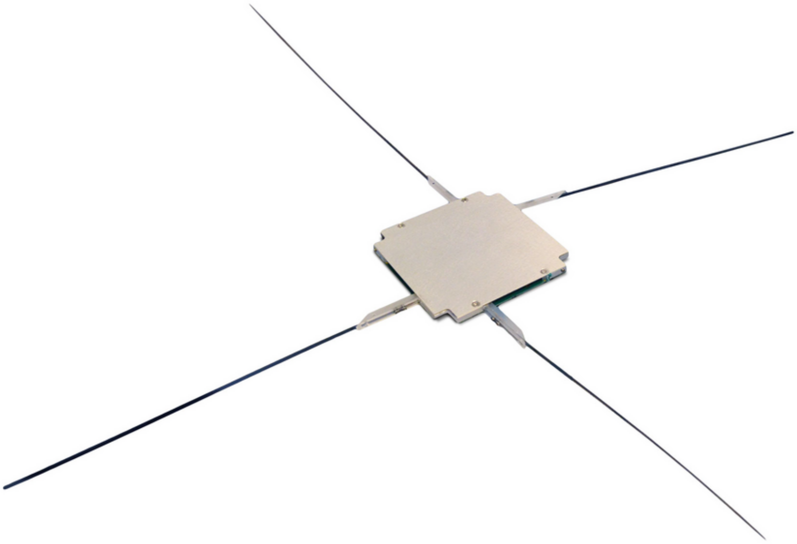

Figure 5.4: Antenna module from ISISpace.

- Redundant I²C address: 32h (7-bit address)

- I²C watchdog: Enabled with a time out of 60 seconds.

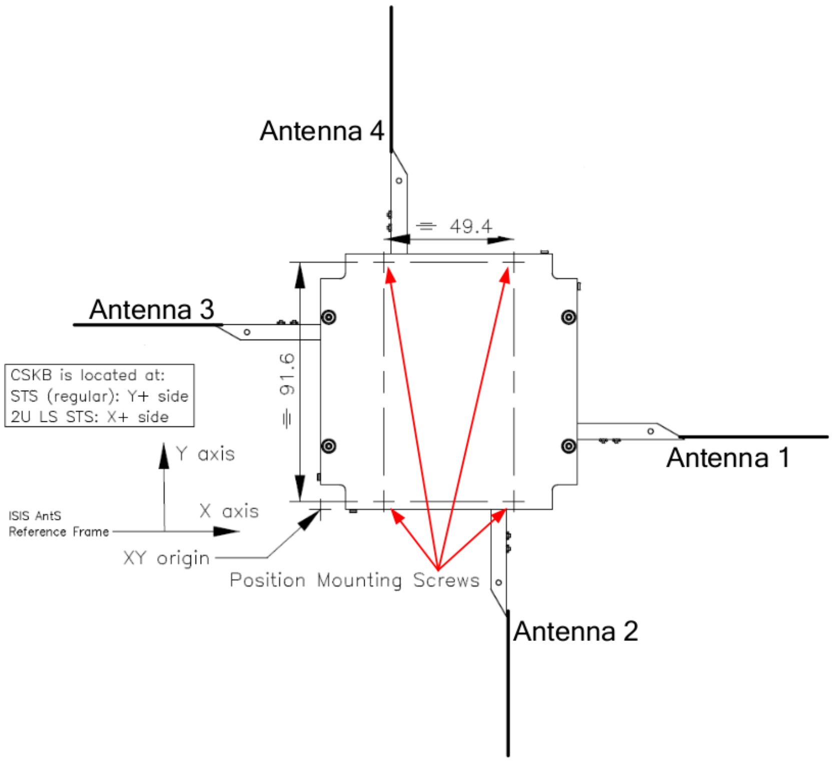

Figure 5.5: Configuration reference of the antenna module.

In the digital interface, a temperature sensor and the state of four deployment switches (1 per monopole) are also available. These switches indicate if a monopole is released or not, and can be used as feedback of the deployment process.

5.3 Electrical Power System

EPS [5]

5.3.1 Battery Module

[6]

5.3.2 Solar Panels

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5.3.3 Kill-Switches and RBF

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5.4 Attitude Control System

The Attitude Control System (ACS) is a passive attitude control system, which depends on the Earth's magnetic field to rotate and stabilize the satellite [7, 8]. The system is composed of one permanent magnet to create a force to align the magnet with the Earth's magnetic field and four hysteresis bars to damp the cube oscillations and achieve stabilization.

When equilibrium is achieved, the permanent magnet aligns itself to the Earth's field lines. The hysteresis bars convert oscillation and rotation energy into heat, maintaining the alignment through magnetic moment. The components are placed in positions as to minimize the magnet's interaction with the hysteresis bars, which limits the magnetic moment of the magnet [9]. Figure 5.6 shows the mounting of the hysteresis bars (green) and the permanent magnet (red) on the mechanical structure. The whole passive ACS was implemented according to [9].

As a passive magnetic attitude control system is used, it is possible to stabilize only one axis, and so, the CubeSat will still slowly (due to hysteresis bars) rotate around this axis, even after stabilized. A N45 neodymium magnet and 4 hysteresis bars of Permanorm 5000 H2 are used (courtesy of Vacuumschmelze GmbH & Co. KG). The material of the hysteresis bar is shaped in order to maximize the stabilization, which is the most important part of the attitude control.

Many conditions impact on the detumbling time, which is the time required for the satellite to stabilize. Magnetic passive attitude stabilization systems such as the one developed for this mission achieve the equilibrium state within a few weeks of operation [7].

The GOLDS-UFSC satellite does not feature an orbit control subsystem.

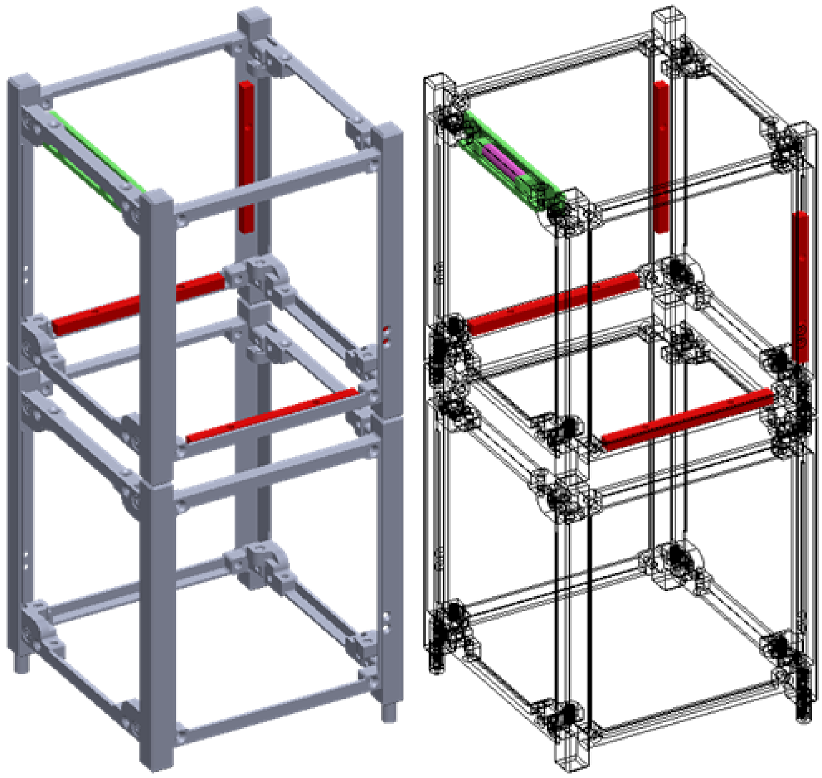

Figure 5.6: ACS subsytem. Rare earth magnet (pink) and hysteresis bars (red) installed in the structure.

5.5 Mechanical Structure

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5.6 Interconnection Modules

5.6.1 PC-104 Interconnection Boards

The PC-104 interconnection boards are intended to be used as an interconnection of the two PC-104 bus segments of the 2U structure (top and bottom units). This interconnection is made with a set of PicoBlade cables between the top and bottom boards. The set of two boards can be seen in Figure 5.7.

More information about these boards can be found in [10].

5.6.2 External Connection Boards

The Interstage Interface Panels (IIP) are three vertical internally mounted PCBs designed to give external access up to four modules inside of a 2U CubeSat during final assembly, integration and testing (AIT) before launch. The complete set of the boards allow the nanosatellite to be charged, programed and debugged. The usage of this hardware platform is taking into account the use of a MSP-FET: MSP430 Flash Emulation Tool from Texas Instruments for JTAG programing and debugging, UART debugging through a mini USB

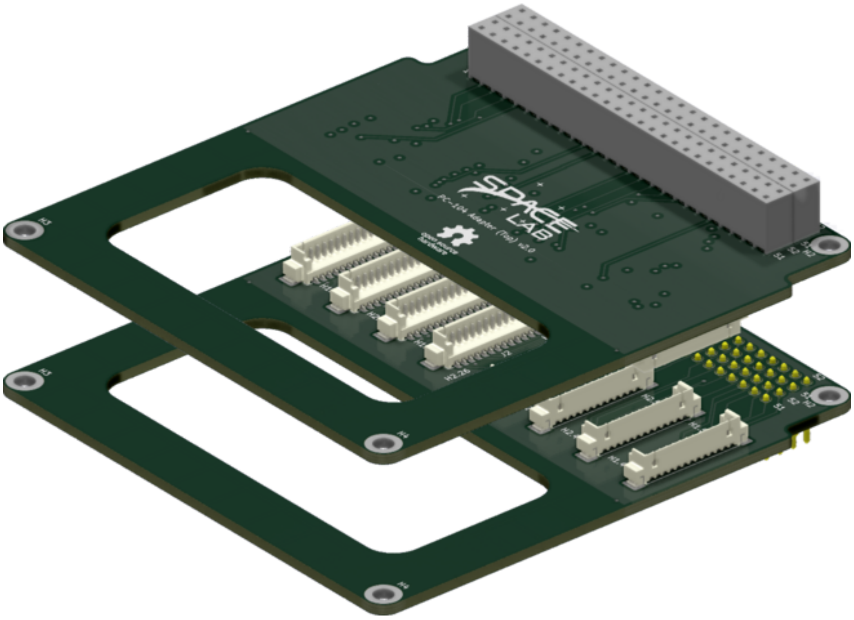

Figure 5.7: PC-104 adapter boards (top and bottom).

type B port interfacing the FT4232H USB bridge IC from FTDI, a JST XH header for charging internal batteries and a Remove Before Flight (RBF) pin header. The boards can seen in Figure 5.8.

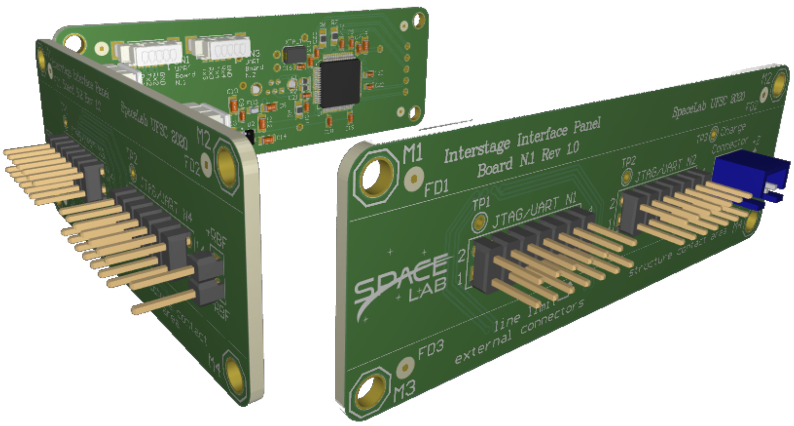

Figure 5.8: Set of external connection boards.

More information about these boards can be found in [11].

5.7 Payloads

5.7.1 Environmental Data Collection

EDC [12]

5.7.2 Redundant OBDH (Payload-X)

Payload-x [?]

5.7.3 Radiation Monitor

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CHAPTER 6

Test Plan and Results

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6.1 Flatsat

[13]

CHAPTER 7

Ground Segment

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CHAPTER 8

Operation Planning

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