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INTERFACE CONTROL DOCUMENT

Attitude Determination And Control System

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Abbreviated terms

ADCS	Attitude Determination and Control System
COMM	Communication subsystem
DT	Deployment Team
EKF	Extended Kalman Filter
EM	Engineering Model
EPS	Electrical Power System
ESA	European Space Agency
FM	Flight Model
GS	Ground Station
ISIS	Innovative Solutions In Space
LEO	Low Earth Orbit
MA	Mission Analysis
MDR	Mission Definition Review
PDR	Preliminary Design Review
PLD	Payload
SC	Spacecraft
SKA	Studenckie Koło Astronautyczne (Students' Space Association)
SSO	Sun-Synchronous Orbit
SW	Software
TBC	To Be Continued
TC	Tele command
TBD	To Be Defined
WUT	Warsaw University of Technology

1 INTRODUCTION

1.1 FUNCTIONAL DESCRIPTION

According to [PW-Sat2-C-01.00-ADCS-CDR] and [PW-Sat2-C-00.00-Overview-CDR] the PW-Sat2 ADCS will provide attitude sensing and control capabilities to 2U CubeSat in order to meet the system requirements. Attitude control required for:

- Stabilize
- Gain power
- Payload direction
- Test of algorithm

In terms of meet these requirements the sensors shall have an attitude control with pointing accuracy of ±10° and pointing knowledge of ±10° from its initial launch altitude down to at least 200km. In addition, CubeSats shall be able to recover from tip-off rates of up to 60 degrees/second within 4 days.

Due to the mission profile the sun pointing mode will be used only before the deorbit sail deployment.

1.2 REFERENCE DOCUMENTS

Below a list of documents, datasheets or manuals that are referenced in this document is presented

[1] ISIS, „ISIS.IMTQ.UM.001 Magnetotorquer Board User Manual,” 2011.
[2] InvenSense Inc., "PS-ITG-3200A-00-01.4 ITG-3200 Product Specification," 2010.
[3] Sensixs Design B.V., „XEN1210 Magnetic Sensor,” 2013.
[4] SSBV, „Cubesat Sun Sensor ICD SCSS-SA05-D1-ICD02,” 2013.
[5] Analog Devices, „ADXRS453 High Performance Digital Output Gyroscope Datasheet,” 2011.

2 FUNCTIONAL DESCRIPTION

The PW-Sat2 ADCS will make use of a combination of magnetometer, sun sensor and gyroscopes measurements to estimate the current attitude. It will use magnetorquers board to stabilize and control the attitude of the satellite.

The integrated ADCS functionality is provided by two PC104 sized boards:

Table 2-1 ADCS boards in PW-Sat2

Board	Status	Reference document
iMTQ	Procured from ISIS	[1]
PLD	Developed by the team	[PW-Sat2-C-08.01-PLD-ICD]

2.1 BODY AXES DEFINITION AND SENSOR/ACTUATOR MOUNTING

2.1.1 BODY AXES DEFINITION

The satellite body axes definition is presented on the following pictures.

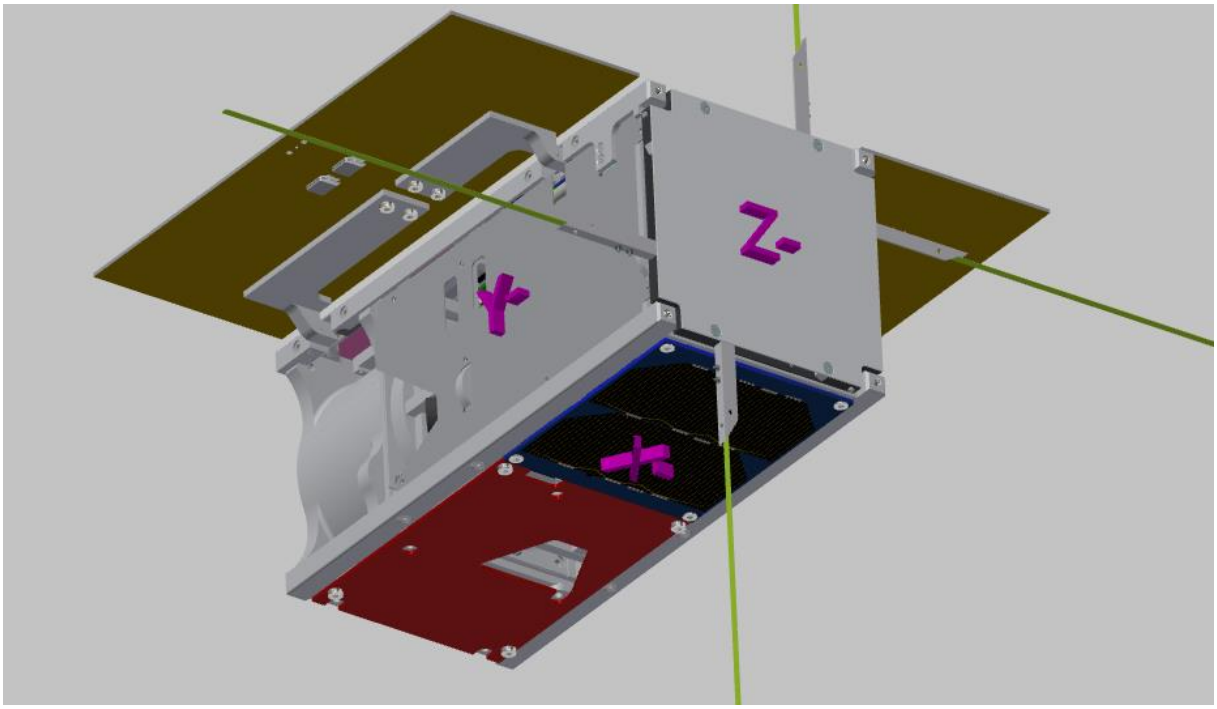

Figure 2-1 Body axes definition [X-;Y-;Z-].

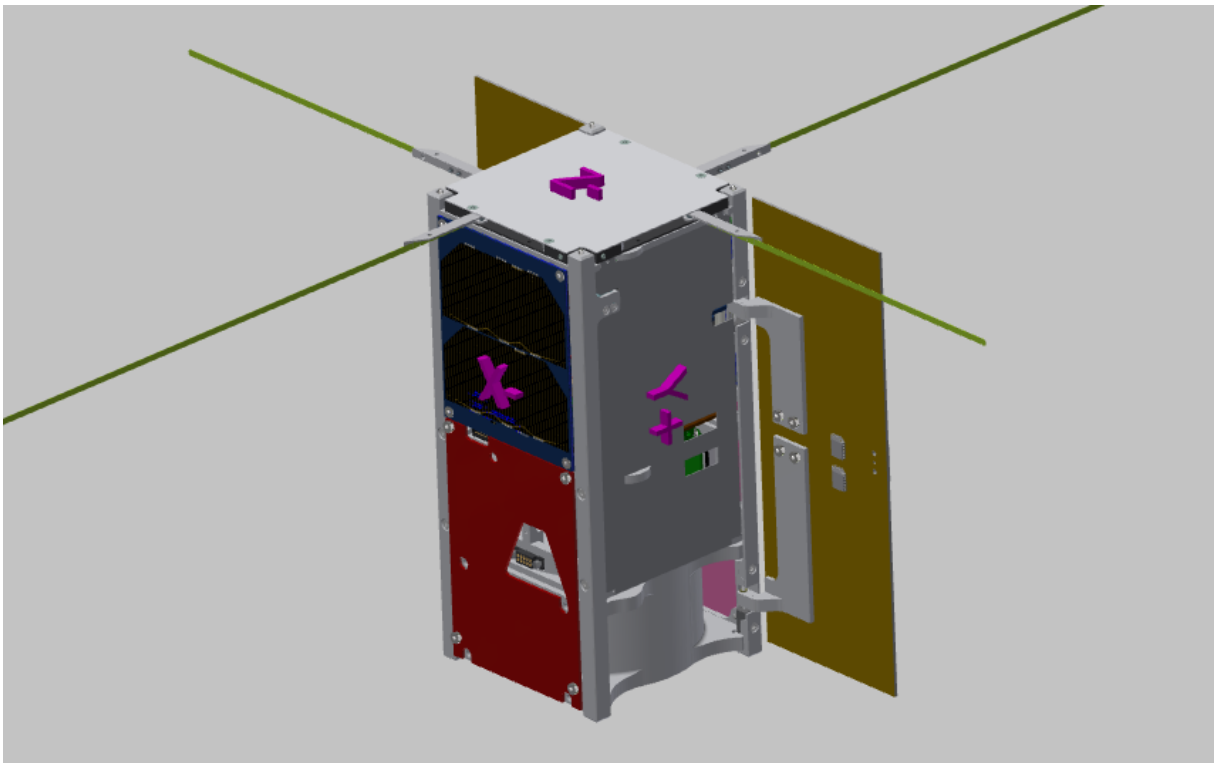

Figure 2-2 Body axes definition [X-;Y+;Z-].

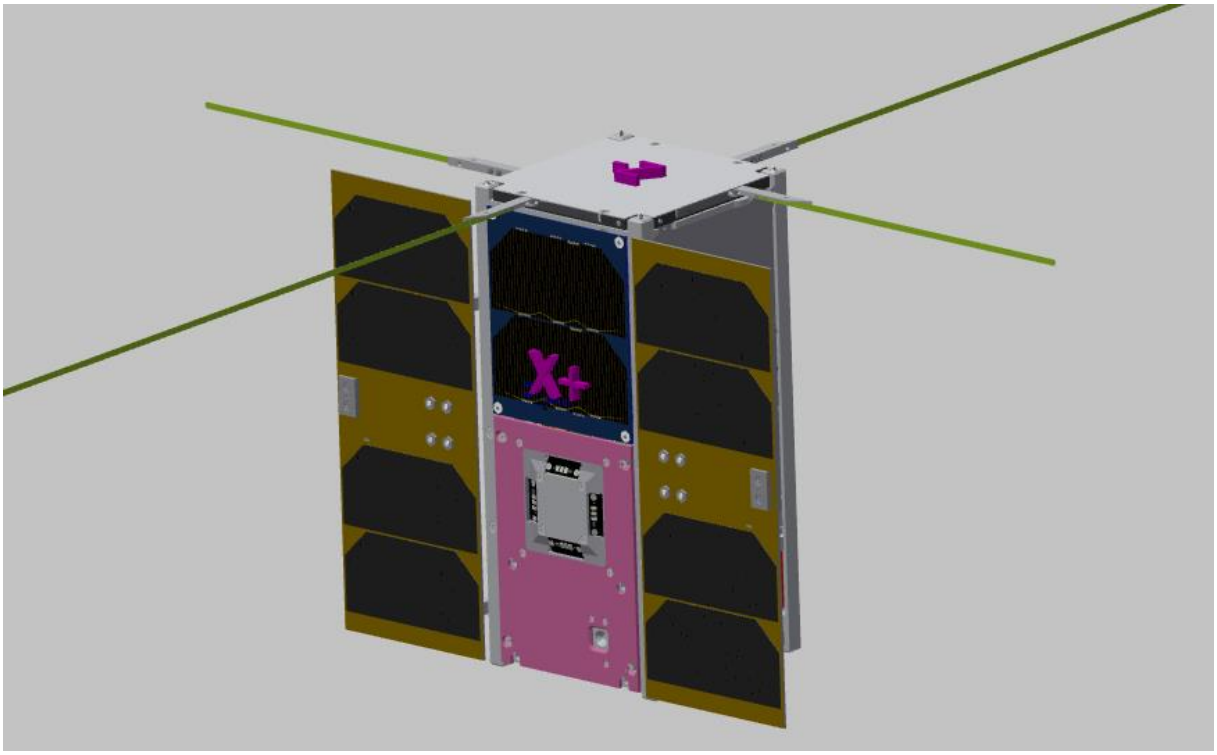

Figure 2-3 Body axes definition [X+].

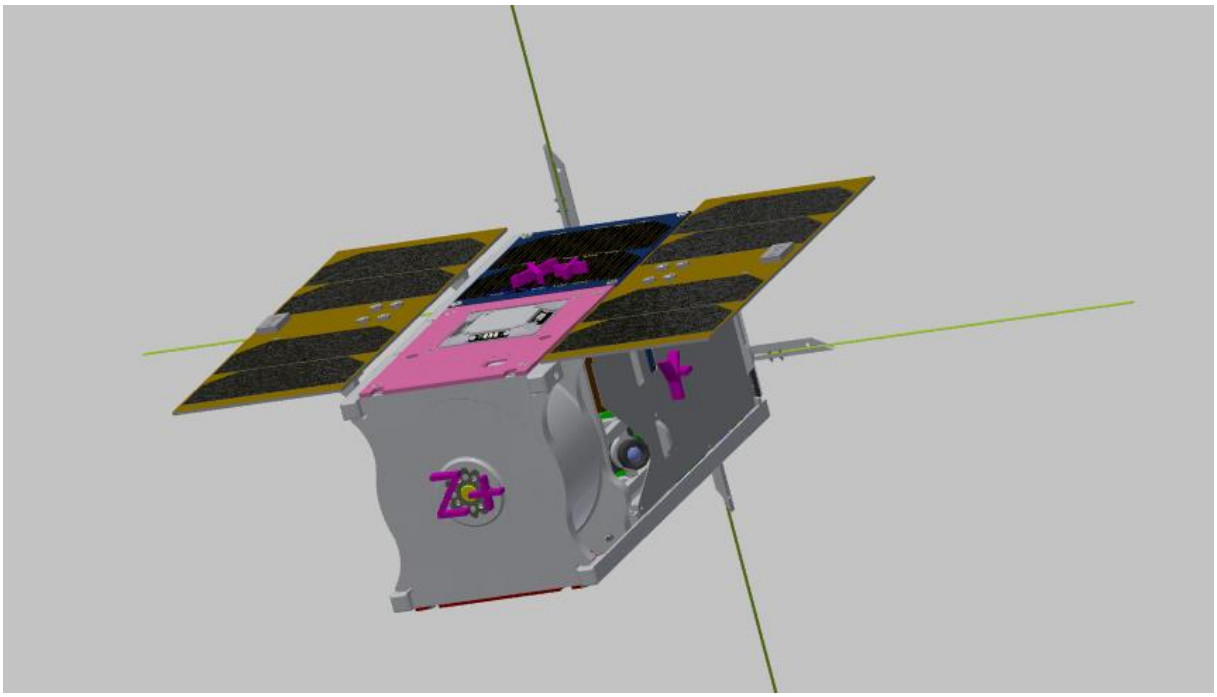

Figure 2-4 Body axes definition [Z+].

2.1.2 SENSOR/ACTUATOR MOUNTING

ADCS contains four types of sensors. Their number and placement is explained in the Table 2-2 below. The general view of the electronic boards placement is shown on the Figure 2-5.

Table 2-2 ADCS sensors/actuators number and placement

ADCS component	Board	Reference document	Number of sensors
Sensors			
Gyroscopes	PLD	[2]	1 (3-axis)
Magnetometer	iMTQ	[3]	3
Sun Sensor (Reference)	1 on X+	[4]	1
Actuators			
iMTQ	iMTQ	[1]	1

Detailed description of the components placement and mounting is available in the section 4 Mechanical interface.

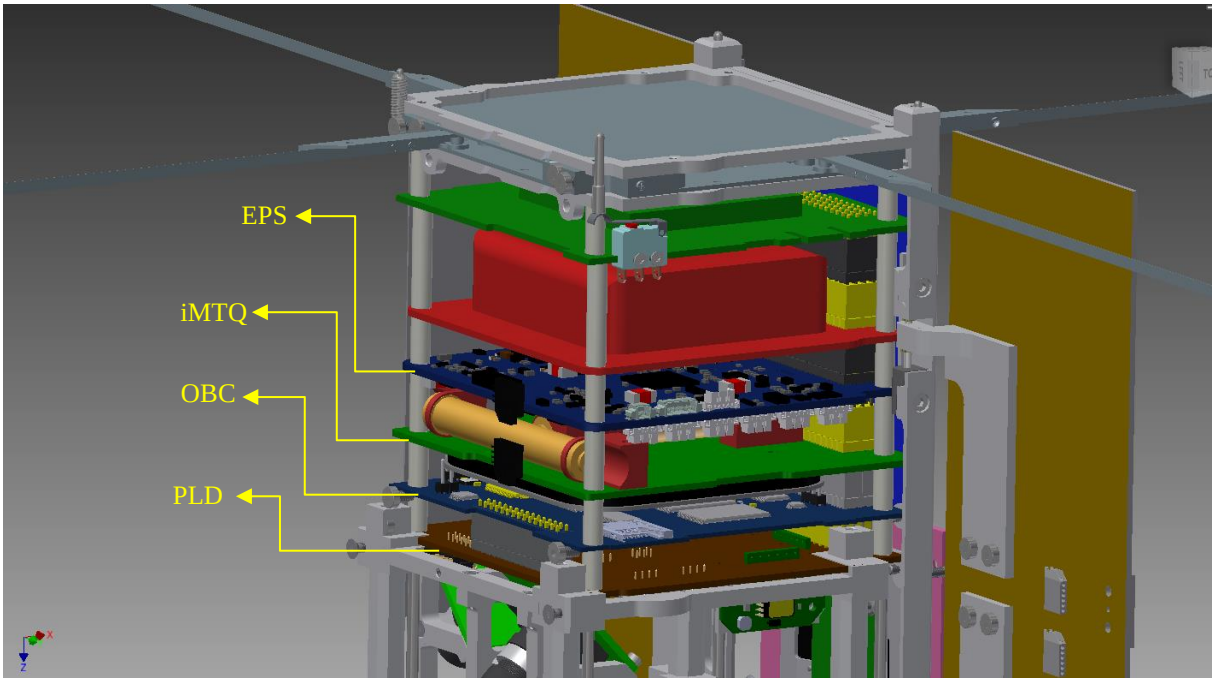

Figure 2-5 ADCS boards placement.

2.2 CONTROL MODES

There are 3 main control modes of the ADCS system. The Table 2-3 shows attitude determination and control modes for each of ADCS modes.

Table 2-3 ADCS control modes

ADCS mode	Attitude estimation mode	Control mode
Idle	None	None
Detumbling	None	Detumbling
Sun pointing	Full-state EKF	Sun pointing

2.3 ADCS CONTROL LOOP

The ADCS control loop executes on the CubeComputer at a rate of 1Hz for detumbling mode and 5Hz for Sun Pointing mode. Sensors are thus also sampled at this frequency.

The ADCS will always start up in the idle condition – that is with no estimation or control active. The orbit and attitude estimation and control modes can be changed via telecommands or by OBC, except sun pointing mode which is only available by TC. The state diagram below shows the various states and transitions that should occur to transition from idle to stabilized state.

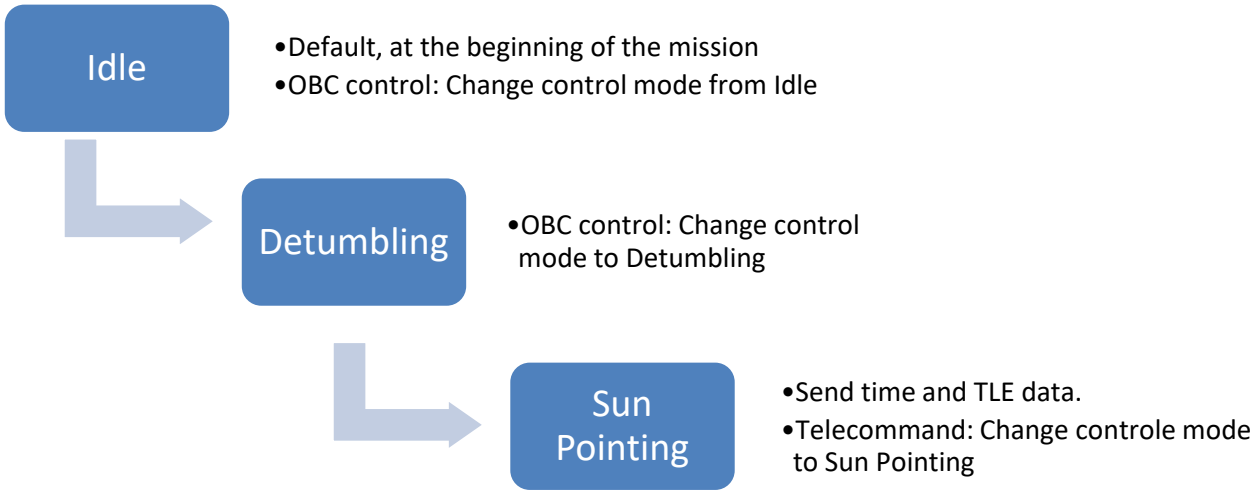

Diagram 2-1 ADCS state diagram.

3 ELECTRICAL INTERFACE

The ADCS consists of one actuator board and three types of sensors. All of the ADCS components had been procured from various suppliers. Magnetorquers board had been procured as the whole subsystem PC104 board. Whether sensors had been procured separately and assembled to various parts of the satellite. Gyroscopes and Sun sensor had been integrated on the PLD board.

Table 3-1 Electrical interface description

ADCS component	Board	Reference document	Electrical interface
		Sensors	
Gyroscopes	PLD	[5]	Compliant with reference document
Magnetometer	iMTQ	[3]	Compliant with reference document
Sun Sensor (Reference)	PLD	[4]	TBD
		Actuators	
iMTQ	iMTQ	[1]	Compliant with reference document

3.1 POWER

Each of the subsystem has its own power requirements, which can be found in the relevant documents. The below shows the list of ADCS hardware components with the associated document and page numbers with required information.

Table 3-2 Power interface references for ADCS components

ADCS component	Reference document	Page
	Sensors	
Gyroscopes	[2]	8
Magnetometer	[3]	2
Sun Sensor (Reference)	[4]	11
	Actuators	
iMTQ	[1]	2

Current and voltages are measured at various points in the ADCS and can be requested using TLM requests. The ADCS will also use this to switch off components in case of latch-up.

3.2 COMMUNICATION

The ADCS iMTQ board will communicate using the system I2C interface on the standard PC104 header. The sensors will be communicate various interfaces listed below:

Table 3-3 Communication protocols list

ADCS component	Reference document	Communication protocol
Gyroscopes	[2]	Compliant with reference document
Magnetometer	[3]	Compliant with reference document
Sun Sensor (Reference)	[4]	TBD

The OBC will act as a master on the system I2C bus, sending the commands and receiving the telemetry.

3.2.1 I2C PULL-UP RESISTORS

The ADCS will have no pull-up resistors on the system I2C bus.

3.3 LOGGING

The ADCS has to ability to automatically log data and save it to flash memory located on OBC.

4 MECHANICAL INTERFACE

4.1 iMTQ BOARD

The magnetorquers board use in PW-Sat2 had been procured from ISIS Innovative Solutions in Space. The board had been developed and manufactured in ISIS.

The ISIS MagneTorQuer board (iMTQ) is a PCB based 3-axis magnetic system. It is designed to provide maximum flexibility in placing actuators and magnetometer in a CubeSat structure. Providing actuation of 0.2Am2, the system is placed between EPS and OBC. The system can be controlled over digital or analogue interface, and provides telemetry over I2C.

Detailed description of all interfaces can be found in Reference Documents in position [1].

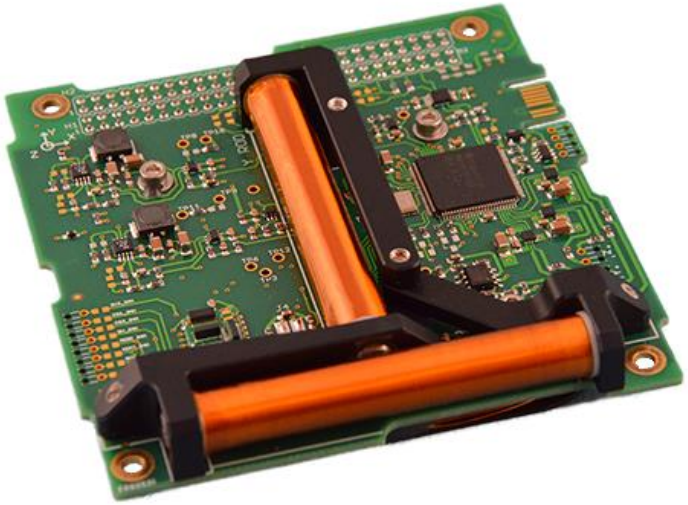

Figure 4-1 iMTQ Board top view. Credits: ISIS.

Figure 4-2 iMTQ Board bottom view. Credits: ISIS.

Figure 4-3 iMTQ Board side view. Credits: ISIS.

4.2 MAGNETOMETERS

The default magnetometer mounted on iMTQ board will be used for ADCS modes as a sensor. Therefore all the relevant information can be found in the iMTQ datasheet [1] and XEN1210 magnetometer datasheet [3].

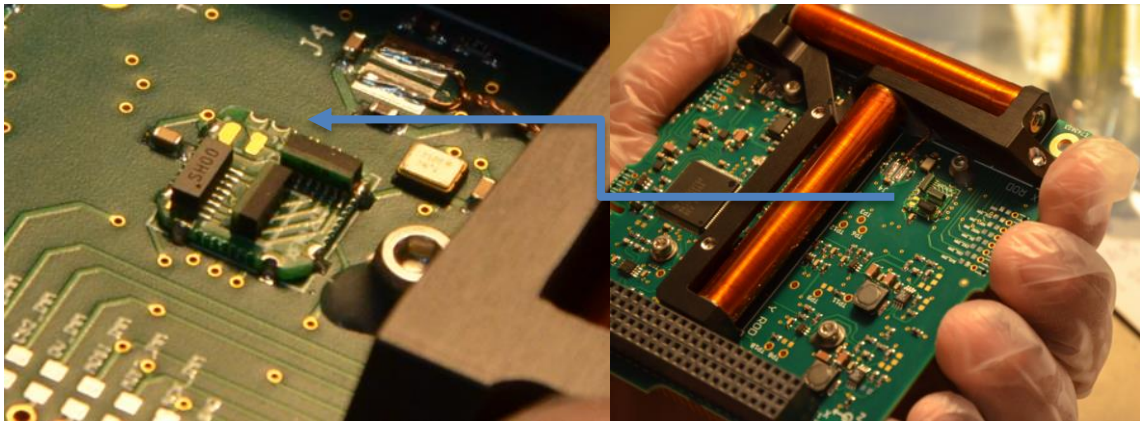

Figure 4-4 Magnetometers placement on iMTQ board

4.3 GYROSCOPES

There will be one 3-axis gyroscope mounted on the PLD board (Figure 4-5). The detailed description of the procured devices can be found in [5].

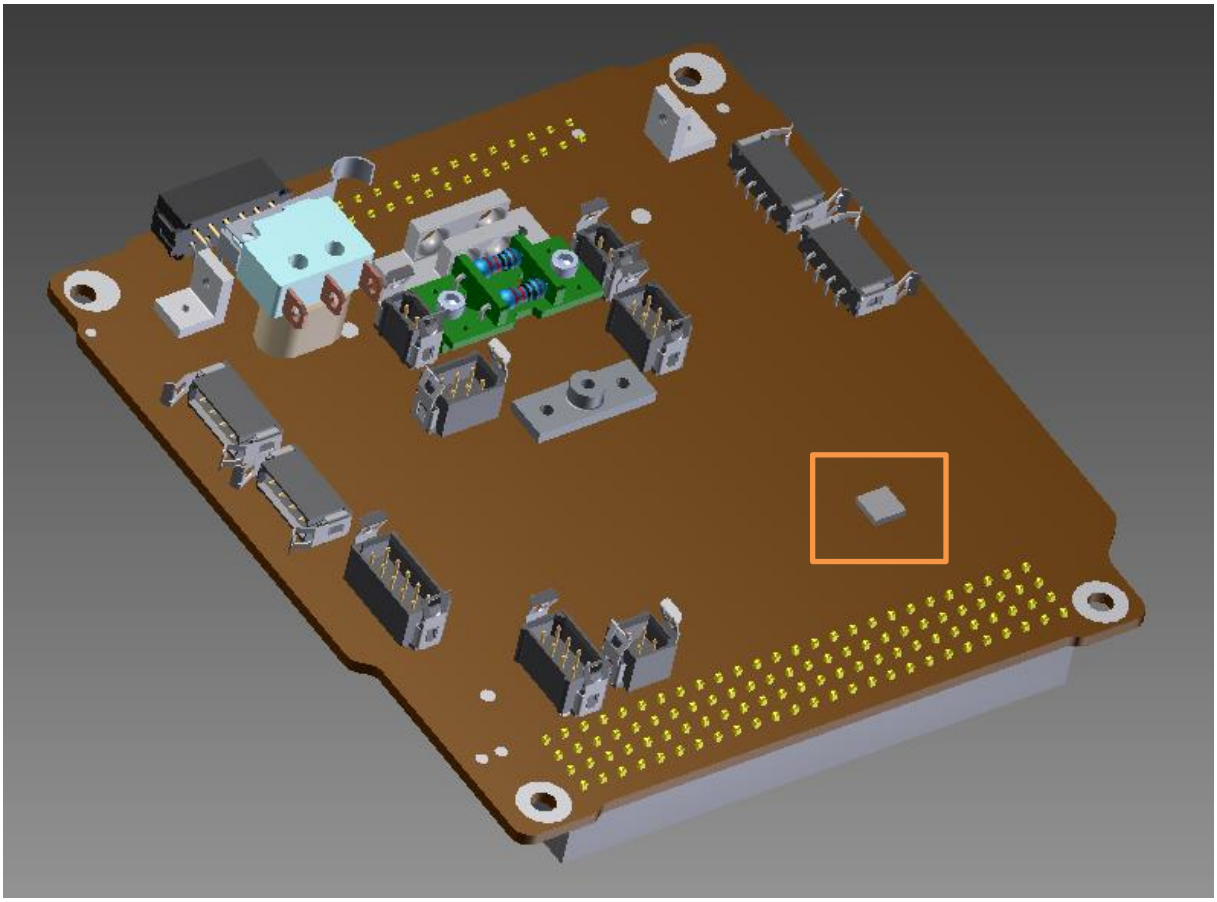

Figure 4-5 Gyroscope mounting on PLD board

4.4 REFERENCE SUN SENSOR

The reference sun sensor (Figure 4-6) had been procured to perform the test of the sun sensor designed by the team – SunS. It will be mounted on the wall X+ close to SunS. It will be also used as a part on ADCS component. Its mechanical properties can be found in the reference document [4].

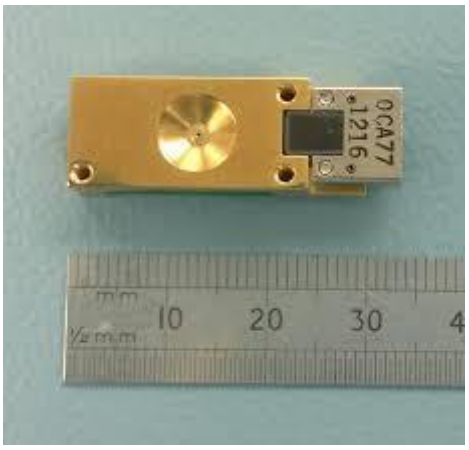

Figure 4-6 SSBV Sun Sensor. Credits: SSBV.

The sensor placement shown on Figure 4-7 and Figure 4-8. The sensor will be mounted on the wall using screws (Figure 4-9, Figure 4-10). The mechanical ICD is describe in the document [4].

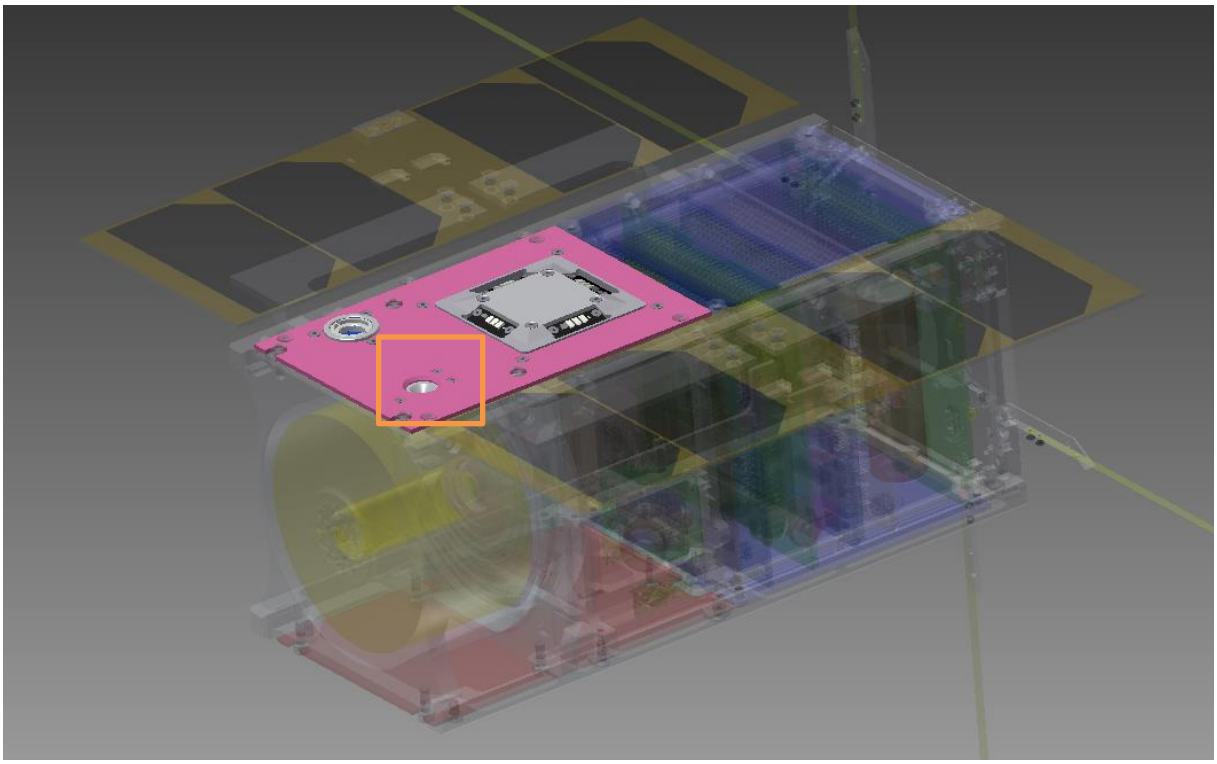

Figure 4-7 Sun sensor placement X+ view

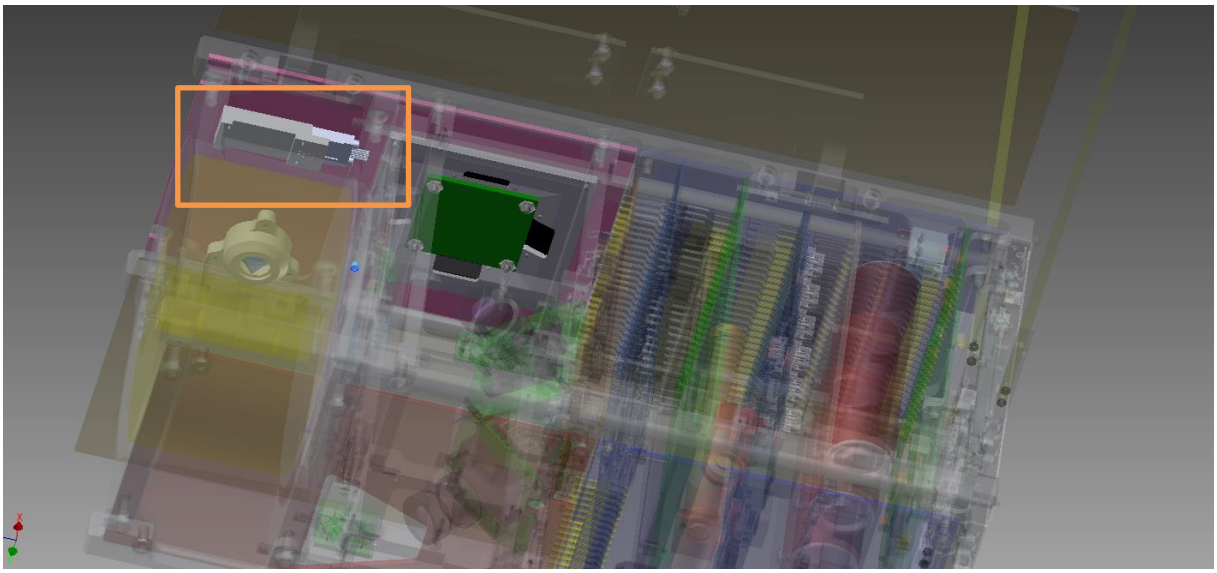

Figure 4-8 Sun sensor placement X- view

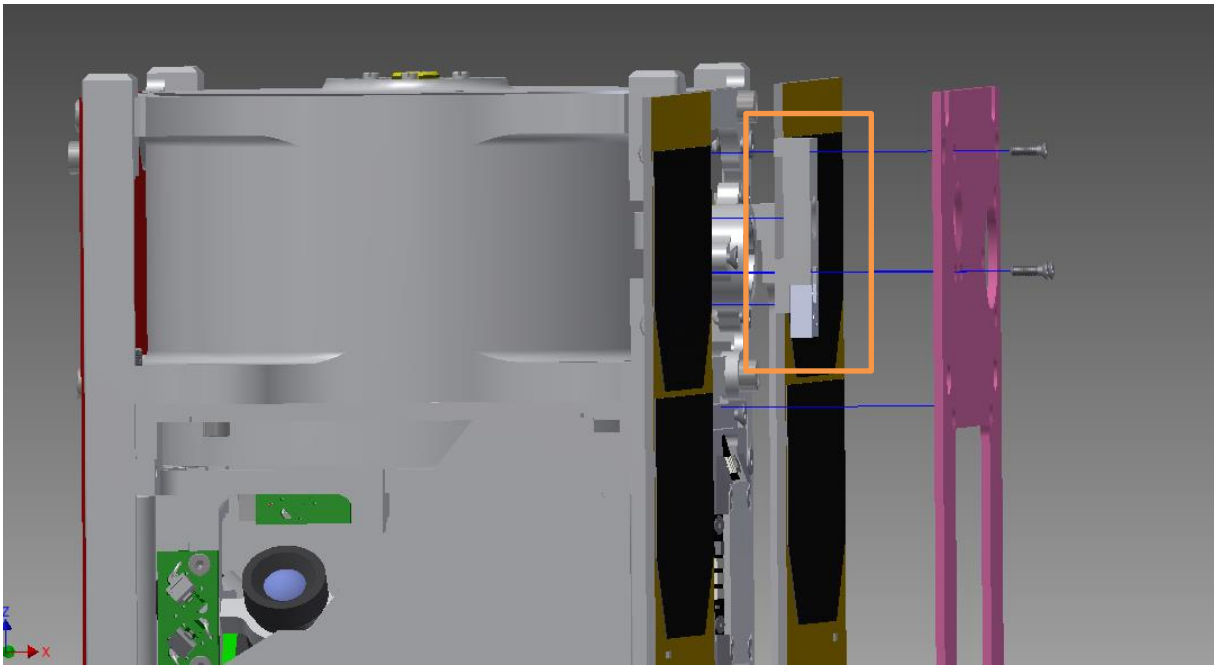

Figure 4-9 Sun sensor mounting Y- view

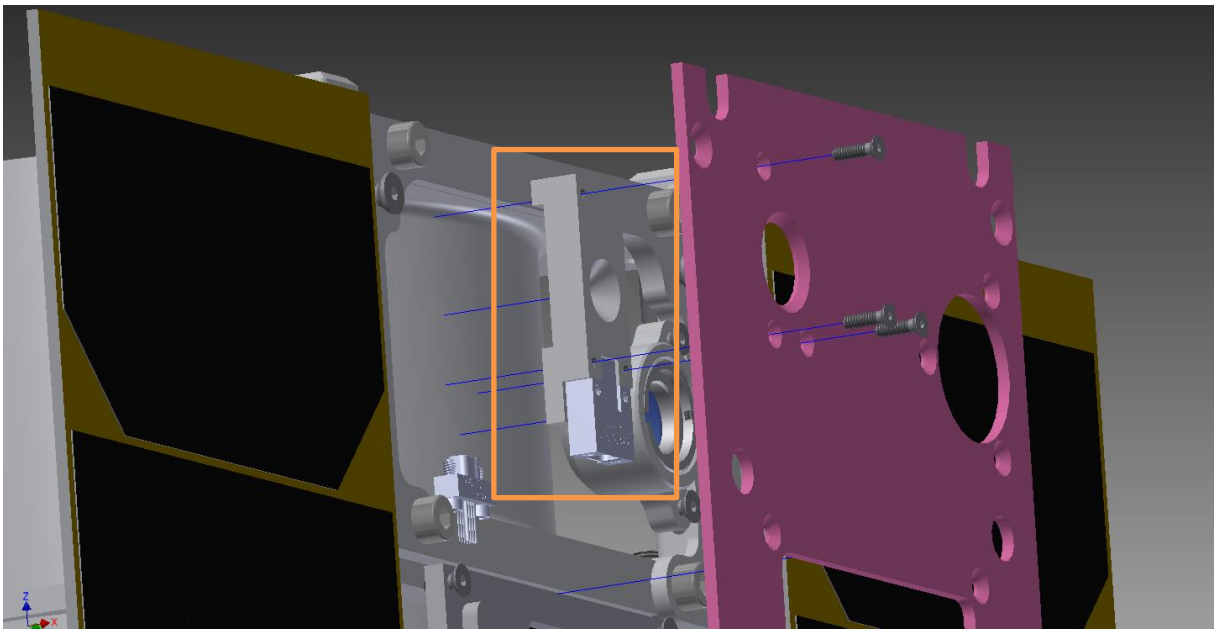

Figure 4-10 Sun sensor mounting X+ view