STUDENTS' SPACE ASSOCIATION
THE FACULTY OF POWER AND AERONAUTICAL ENGINEERING
WARSAW UNIVERSITY OF TECHNOLOGY

PRELIMINARY DESIGN REVIEW

CAMERAS

Phase B of PW-Sat2 student satellite project

June 2015

Issue 2 (November 2016 update)

Changes

Date	Changes	Responsible
2015-02-23	Initial issue	Mateusz Sobiecki
2015-05-29	Editorial changes	Dominik Roszkowski
2015-08-11	Small editorial changes	Dominik Roszkowski
2016-11-29	New template, disclaimer	Dominik Roszkowski

Attention Phase B documentation may be outdated in many points. Please be aware of that and do not depend on Phase B or Phase A documents only. More recent documentation is available on project website.

Published by

Students' Space Association

Warsaw University of Technology, 2015

Project logo by Krzysztof Karaś

Artist's impressions by Marcin Świetlik

Quote as: PW-Sat2 Team, *Phase B Documentation – Preliminary Design Review – Cameras (Issue 2)*, Students' Space Association, Warsaw University of Technology, pw-sat.pl 2015

Table of contents

List of figures

List of tables

Abbreviated terms

ADCS – Attitude Determination and Control System

COMM – Communication subsystem

DT – Deployment Team (mechanical team, responsible for sail system and solar arrays opening mechanism)

EPS – Electrical Power System

ESA – European Space Agency

ESEO – European Students Earth Orbiter

FRR – Flight Readiness Review (as defined in [RD. 1])

PDR – Preliminary Design Review (as defined in [RD. 1])

RAAN – Right Ascension of the Ascending Node

SC – Spacecraft

SKA – Studenckie Koło Astronautyczne (Students' Space Association)

SSO – Sun-Synchronous Orbit

TBC – To Be Confirmed

TBD – To Be Defined

WUT – Warsaw University of Technology

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

During phase B of the PW-Sat2 project, we have changed a bit in satellite's payload. We came back to the idea of two cameras. At the end of phase A the team has abandoned the use of the camera CAM1, working as Earth-pointing camera, because of the lack of strong arguments and financial issues. Later on we started a cooperation with Creotech Instruments company, that proposed their own design of the On-Board Computer and camera working as a star tracker. We were also looking for appropriate camera for CAM2 (a camera for sail observation) but selection of camera that meets all of the preliminary requirements was very difficult. The team was obliged to check all of the possible solutions to find the most advantageous one.

2 REFERENCES

2.1 PROJECT DOCUMENTS

Table 2-1 List of applicable project documents

Ref.	Title	Code	Version	Date
[PD. 1]	PW-Sat2 – Preliminary Requirements Review – Cameras	PW-Sat2-A-07.00-CAM-PRR-EN	1.0.1 EN	2014-07-02
[PD. 2]	PW-Sat2 – Preliminary Design Review - Overview	~~PW-Sat2_00_PDR_Overview~~ PW-Sat2-B-00.00-Overview-PDR	1.0	~~2015-05-18~~ 2016-11-28
[PD. 3]				

2.2 REFERENCE DOCUMENTS

Table 2-2 List of applicable reference documents

Ref.	Title	Version	Date
[RD. 1]	ECSS-M-ST10C – “Space project management.”	Rev.1	2009.03.06
[RD. 2]			

3 CAMERAS OBJECTIVES

3.1 TEAM OBJECTIVES

The mission assumes preparing two cameras. CAM1 – camera working as a star tracker, additionally as an Earth camera. CAM2 – camera for sail observation. The cameras are not the main payload, therefore the main requirement is not to hinder other payload and subsystems, especially in mechanical configuration, and they do not have the priority in operation and power consumption. We mainly care about appropriate operation of basic subsystems, and later we will use the cameras as far as possible, to check the computer processing and communication capabilities while using the camera's data.

3.2 GENERAL REQUIREMENTS

The design requirements has changed a bit due to the cooperation with Creotech Instruments. The On-Board-Computer design assumes the same electronic interface for both cameras. The OBC will switch the operation between the cameras, disabling the cameras operating in the same time, and simplifying the OBC electronic board.

As a mechanical requirements, we still do not have too much space between the PC-104 electronic stack and the Sail's container. The maximum dimensions for the lens and board of CAM1 are 35mm x 45mm x 35mm; for CAM2: 20mm x 20mm x 25mm. The weight of tow cameras should be less than 100g. The limit for power is 0.5mW.

4 CAM1 DESIGN

CAM1 Star Tracker design and cameras signal interface are the part of the Creotech Instruments involvement in the project, so here we mention only general information about parameters and mechanical aspects connected with satellite's mechanical configuration.

CAM1 Star Tracker main mission is to test the operation as a star sensor, it's algorithms and precision.

4.1 CAM1 PROPERTIES

As it was analysed during earlier phases, the CAM1 will be small board camera, with CMOS sensor and fixed lens on the CS mount. The selected sensor and lens are described below.

Table 4-1 CMOS sensor parameters

Sensor	MT9T031
Optical format	1/2-inch
Active imager size	6.55mm x 4.92mm 8.19mm (Diagonal)
Active pixels	2048 x 1536
Pixel size	3.2µm x 3.2µm
Color filter array	RGB Bayer pattern
Shutter type	Global reset release (GRR); electronic rolling shutter (ERS)
Maximum data rate/master clock	48 MPS/48 MHz
ADC resolution	10-bit, on-chip
Supply voltage	3.0V−3.6V (3.3V nominal)
Power consumption	244mW (nominal); 1.65µW (standby)
Operating temperature	0°C to 60°C
Packaging	48-pin CLCC

Table 4-2 Selected lens parameters

Lens	MPL4.0
Focal length	4mm
Format	1/2-inch
Mount	CS mount
F number	F1.8
Iris	fixed
Dimensions	Ø30mm x 17.5mm
Weight	40.2g
FOV	55.5°

4.2 MECHANICAL DESIGN

The mounting of the CAM1 is going to be realized with four threaded rods or screws. They will be mounted on the one side to the sensor's PCB, on the other to the satellites X-minus wall. If this will not be enough to pass the shock tests, there is a possibility to prepare an additional mounting to the main electronics' stack or to the Sail's container.

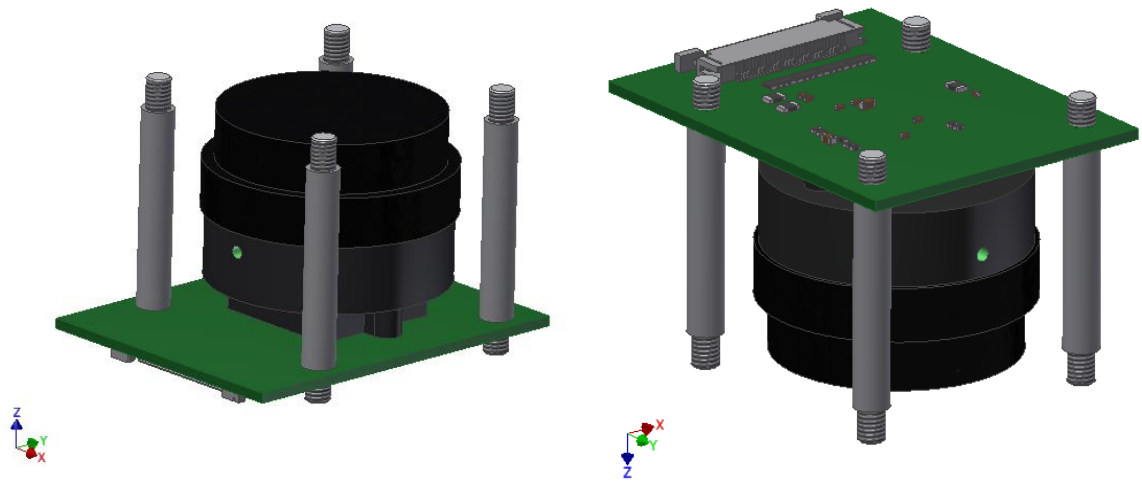

Figure 4-1 CAM1 and mounting elements

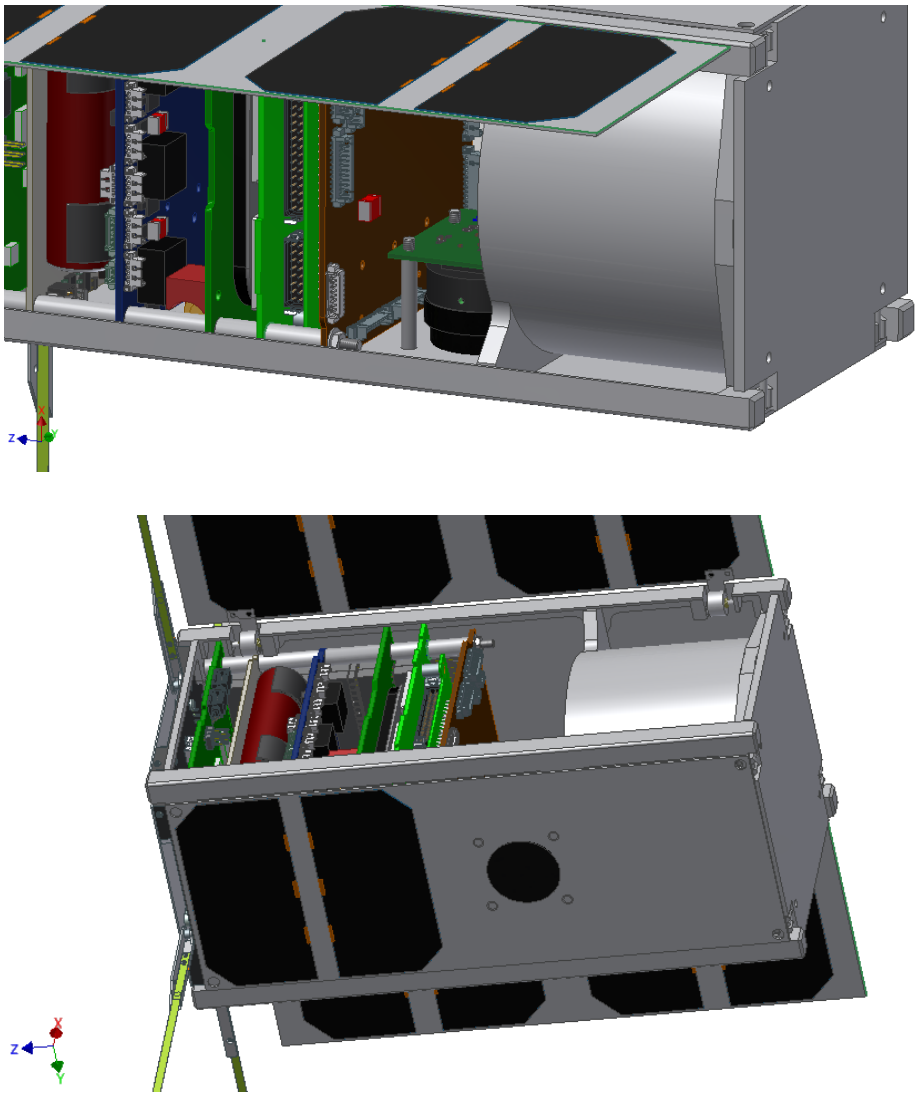

Figure 4-2 CAM1 position on the satelllite

4.3 CAM1 ON-ORBIT OPERATION

CAM1 will operate on the command from the Ground Station. The On-Board Computer will check what is on the taken photo, and process the image to calculate the satellite's position in reference to the stars in the case of the deep space photo, or threat the image as the Earth photo and prepare the image to be send to the Ground Station during the closest communication session.

5 CAM2 DESIGN

In the phase A there was selected the camera, but because of the cooperation with Creotech Instruments, we decided to choose another one. The main priority was to fit the CAM2 interface to the CAM1 camera. Our requirement of wide field of view, ~90°-100°, was really hard to achieve. The CMOS module cameras are produced with a typical diagonal FOV 45° or 65°. Therefore without the additional optics it is impossible to have a wider field of view.

The mission of the CAM2 is to record a video with the moment of deploying the Sail. This will give us the useful information to verify the Sail design and Sail's deployment mechanism. Additionally CAM2 will take some photos during the deorbit phase to see the Sail during operation.

5.1 CAM2 PROPERTIES

There have been made a decision to select the Leopard Imaging LI-OV9712-FF-65 camera, with parameters as below:

Table 5-1 CMOS module parameters

Sensor	OmniVision OV9712
Optical format	1/4-inch
Active pixels	1280 x 800
Pixel size	3µm x 3µm
Output format	10-bit RAW RGB
Focal length	3.5mm
Focusing range	60cm to infinity
F number	F2.8
FOV	65°(Diagonal)
Supply voltage	3.0V−3.6V (3.3V nominal)
Power consumption	110mW (nominal); 50µA (standby)
Operating temperature	-30°C to 70°C
Module size	6.5mm x 6.5mm

There are two problems with the selected camera:

- The FOV is relatively small;
- The focusing range is out of the smallest distance from Sail to the camera.

The focusing is not the big problem since we will not use the full resolution of the sensor. Due to minimizing the size of the images, normally we are going to use the VGA resolution (640x480) for the video, higher resolution may be used in the photos.

The small field of view of 65° gives the possibility to see the very small part of the Sail (about 1/7). This may be enough, but we want to have better view. Therefore we are analysing the use of the additional lens to have wider field of view, about 90-100°. This will let us to see the 1/4 of the Sail, In the picture below there is showed a comparison between the nominal field of view of the camera, and the widened field of view.

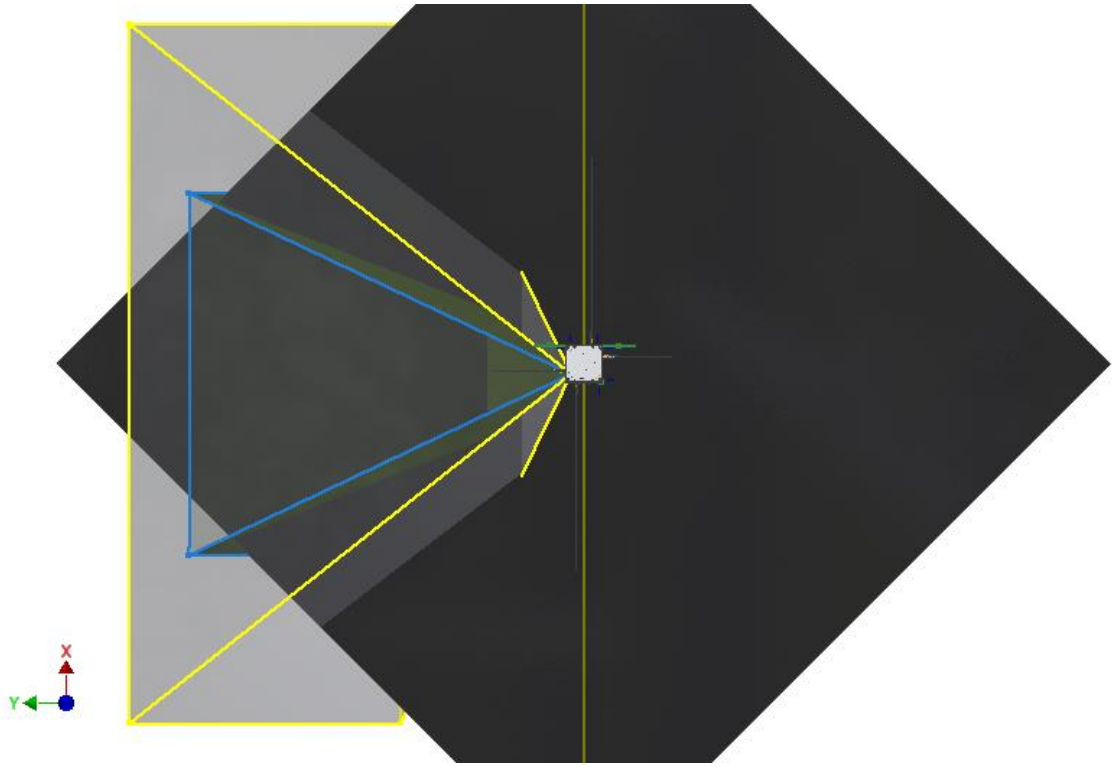

Figure 5-1 CAM2 field of view: 65° (blue), 95° (yellow)

The additional lens is during the first design. It may require a two or three lens system, with maximum aperture of 20mm diameter. The lens will be much bigger than the camera module, but it will be still smaller than using bigger camera with wider field of view.

5.2 CAM2 MECHANICAL DESIGN

The CMOS module will be built into the mounting. The picture below shows the CAM2with the additional lens mounted to the electronics' stack with a small metal element.

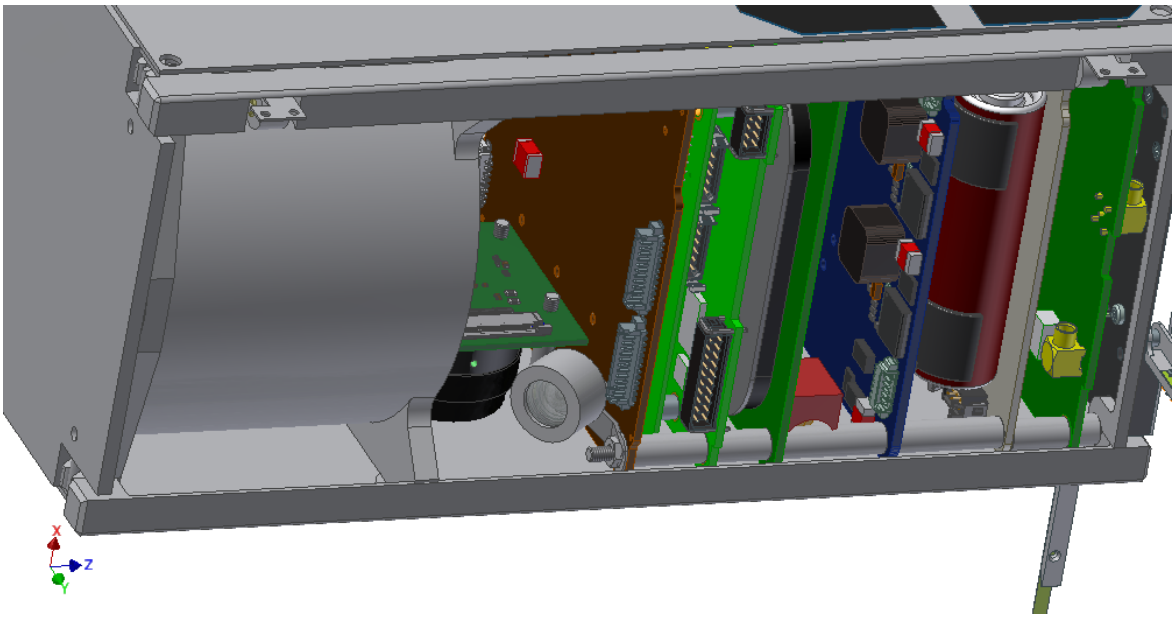

Figure 5-2 CAM2 mounting

The CAM2 may be also mounted to the CAM1 PCB board, if the first proposed mounting will be not enough.

5.3 CAM2 ON-ORBIT OPERATION

As it was mentioned earlier, the CAM2 will record the video of the Sail deployment. Before this moment, there may be a command from the ground to take a test photo to check the camera's operation or check if the Solar Array has deployed properly. Sail deployment will be recorded in the VGA resolution, with a 4-10 frames per second, in the time of 1-2 minutes. Later there will be photos taken periodically to check the Sail behaviour during deorbit phase.

6 CONCLUSIONS AND FUTURE WORK

During the phase B we have returned to the CAM1 idea because of the cooperation with the Creotech Instruments company. The design of the CAM1 is in the final phase, and in the close future there will be build the first prototype. Also we are going to buy and test the module chosen for the CAM2. The design of the CAM2 additional lens will be prepared and checked in action with the camera. Finally there will be simulated the CAM2 operation with the Sail