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Abbreviated terms

ADCS	Attitude Determination and Control System
COMM	Communication subsystem
DT	Deployment Team
EM	Engineering Model
EPS	Electrical Power System
ESA	European Space Agency
FM	Flight Model
GS	Ground Station
LEO	Low Earth Orbit
MA	Mission Analysis
MCU	Mission Controller Unit
MDR	Mission Definition Review
PDR	Preliminary Design Review
PV	Photovoltaic cell
RTD	Resistance Thermal Detector
SC	Spacecraft
SKA	Studenckie Koło Astronautyczne (Students' Space Association)
Sps	Samples per second
SSO	Sun-Synchronous Orbit
SW	Software
TBC	To Be Continued
TBD	To Be Defined
TCS	Thermal Control System
WUT	Warsaw University of Technology

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

Two cameras will be used on board of the PW-Sat2 satellite. The aim of the cameras is to take photos, observe the Sail deployment and Sail structure behavior during satellite's deorbit phase. The cameras are an experimental payload. They will be operated mainly from the ground station.

1.2 DOCUMENT STRUCTURE

Chapter 1 introduces the document and its structure.

Chapter 2 summarizes the Cameras system.

Chapter 3 provides cameras' specification.

Chapter 4 presents mechanical design of the system.

Chapter 5 describes briefly operation of the Cameras.

Chapter 6 provides the testing plan and philosophy for Cameras.

1.3 PROJECT DOCUMENTATION STRUCTURE

See section 1.3 in [PW-Sat2-C-00.00-Overview-CDR].

1.4 REFERENCE DOCUMENTS

The documents referenced in the Cameras CDR are:

[1] 4dsystems, "Serial Camera Module uCAM-II Document Revision: 1," 29 01 2015. [Online]. Available: http://www.4dsystems.com.au/productpages/uCAM-II/downloads/uCAM-II_datasheet_R_1_4.pdf. [Accessed 20 11 2016].

[2] "ECSS-E-ST-10-03C Space engineering - testing," ESA Requirements and Standards Division, Noordwijk, 2012.

[3] „ECSS-E-ST-10-06C Space engineering - Technical requirements specification," ESA Requirements and Standards Division, Noordwijk, 2009.

1.5 APPLICABLE PROJECT DOCUMENTS

- [PW-Sat2-C-10.00-CONF-CDR]
- [PW-Sat2-C-11.01-Tests-Plan-Mechanical]
- [PW-Sat2-C-11.02-Tests-Plan-Thermal]

1.6 DOCUMENT CONTRIBUTORS

This document and any results described were prepared solely by PW-Sat2 project team members.

2 SYSTEM DESCRIPTION

There were many changes since phase B in the Cameras subsystem. Because of the cooperating company resignation, the CAM1 was removed from the design. Later to the satellite configuration there was added Secondary Structure, the additional structure between the electronics stack and the Sail's Container, for stiffening and because of thermal transfer issues. Then there was made a decision to have two the same cameras, mounted to the Secondary Structure, both directed towards the Sail, for the Sail structure's performance visual verification. Cameras will use different lenses, with different field of view. New cameras names have been selected: CamNadir (CAM1) and CamWing (CAM2). They will operated by the OBC through the Payload board, were the cameras will be connected.

2.1 SYSTEM REQUIREMENTS

There were made new requirements for the cameras, partially similar to the earlier design.

The cameras operation will be switched by the OBC, on the same interface, so there is possible to get data from one camera at one time. As a mechanical requirements, the maximum dimensions for the lens and board for the cameras are 35mm x 35mm x 35mm. The weight of two cameras should be less than 100g. The limit for power is 0.5mW. This requirements fit to the small board cameras, with the standard C-mount optics.

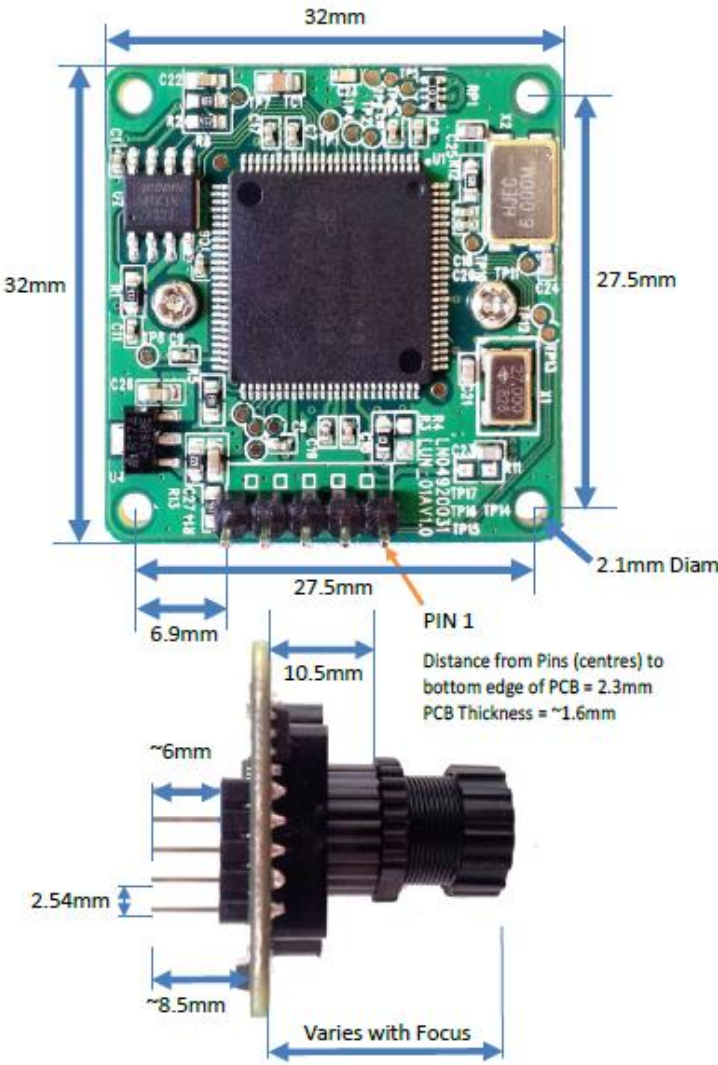
3 CAMERAS SPECIFICATION

Below there are presented the parameters of used cameras. There has been chosen the board camera uCAM-II from the 4D Systems [1], with the standard C-mount lenses from the same company. Precise description of the camera modules is in the camera datasheet [1].

Table 3-1 Camera and sensor parameters [1]

Item	Parameter
Voltage	5V DC
Interface	UART
Resolution	640x480,320x240,160x128 (JPEG) or 160x120,128x128, 128x96,80x60 (RAW)
Data format	16-bit CrYCbY, 8-bit gray, 16-bit RGB, RAW or JPEG
Board weight	6g
Board dimensions	32x32x21mm
Image Sensor	1/4” CMOS, 300K pixels
Pixel Size	5.55um x 5.55um
Effective Pixel Array	656 x 496
SNR	44.2dB @ 60 degree
Dynamic Range	51dB @ 60degree
White Balance	Automatic
Exposure	Automatic, self-regulating, 1/50(1/60) – 1/100,000(sec)
Dark Signal	25.2mV/sec
Sensitivity	2.93V/Lux.sec
Operating Ambient Temp	-30 to +85°C
Storage Temperature	-40 to +105°C

Figure 3-1 Camera dimensions [1]



Two different objective lenses will be used: with 76° and 116° diagonal field of view. This will give respectively 64°x50° and 104°x88° rectangular field of view on the cameras' detectors.

Except the PCB and the electronic components, the camera has a PP lens mounting with CR-39 optics.

This camera model does not have a flight heritage, but other small board cameras with a standard optics as a uCAM-II have been used earlier on the CubeSats missions.

4 MECHANICAL DESIGN

There were prepared the camera mountings, with the camera board mounting and the lens holder. The camera's mounting structure is screwed to the Secondary Structure's frames (Fig. 4-1). This mounting allows for the cameras to observe different parts of the Sail's structure after it's deployment. Cameras are mounted on the X- and Y- sides. CamNadir is mounted with the 44° angle, has 76° diagonal field of view and on the X- wall there is a hole for the observation. CamWing is mounted with the angle 42°, has 116° diagonal field of view and requires the Solar Panel deployment for operation.

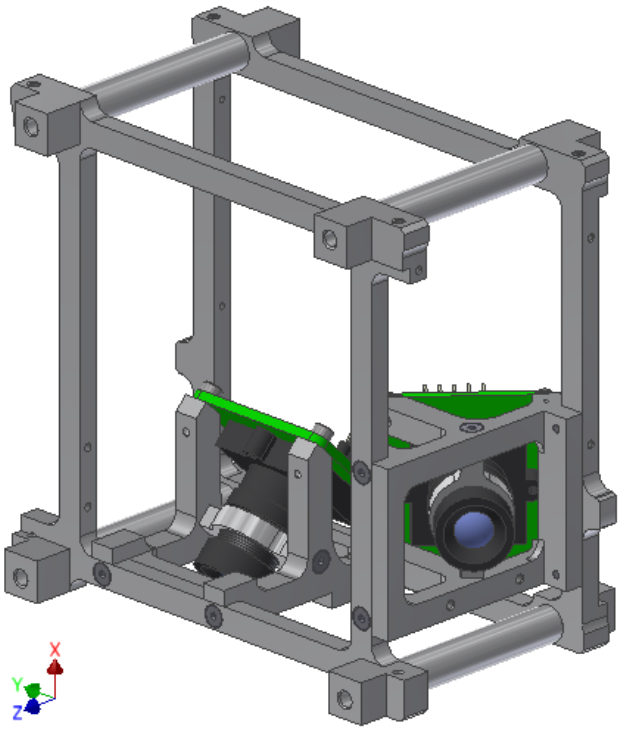


Figure 4-1 Cameras mount to the Secondary Structure

Different fields of view enable to see more details with this two cameras. Their Sail coverage is presented on the picture below. The 116° FOV enables to see the corner of the Sail, what will give better information about Sail's rotation and bending during on orbit operation. Lens holder is for excluding the vibrations for the lens itself, because of the probably weak standard lens mounting. More information about the Secondary Structure is in the [PW-Sat2-C-10.00-CONF-CDR].

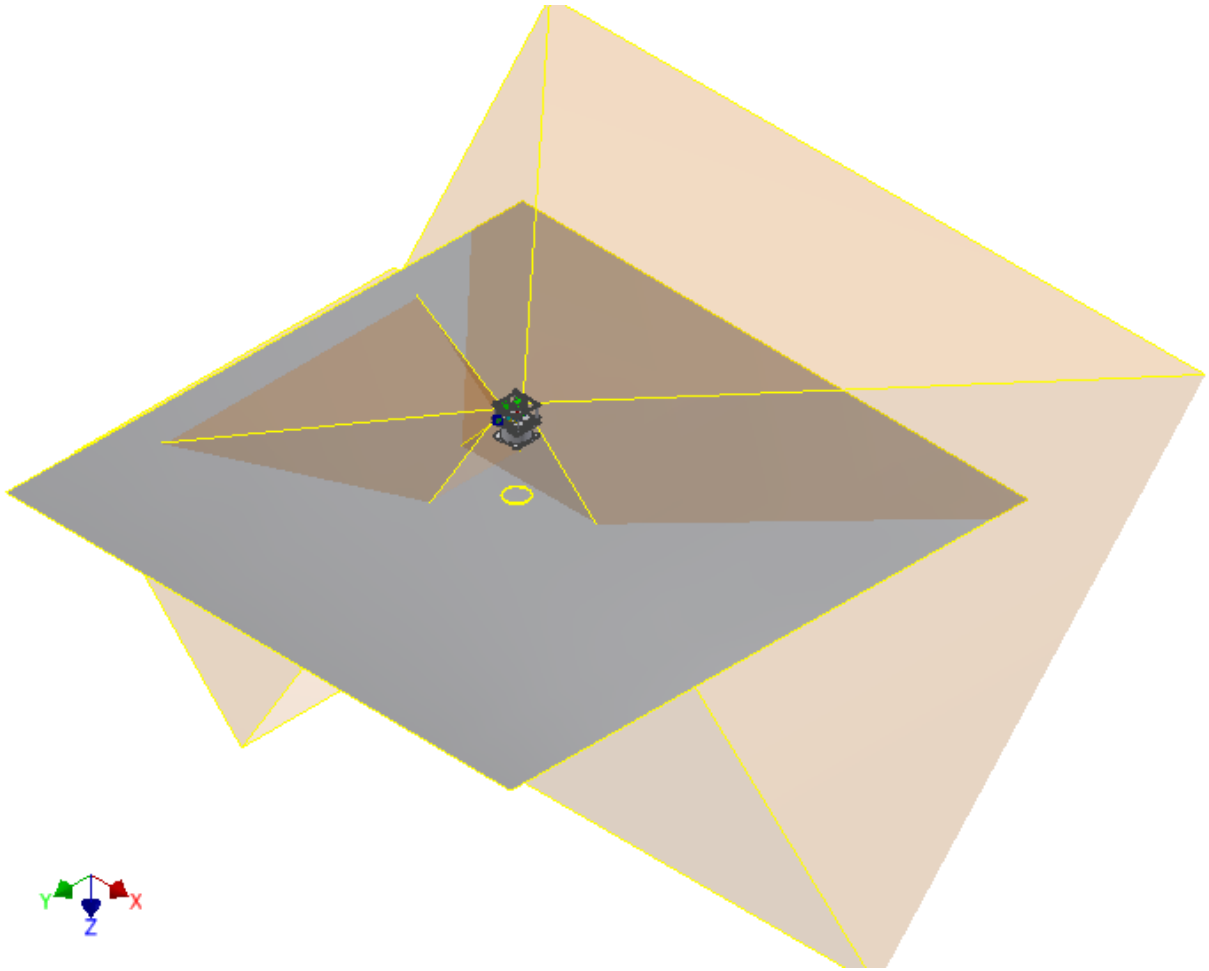


Figure 4-2 Sail visibility by the cameras

The Sail structure orientation with relation to the cameras position is not determined. There is assumed, that Sail will slightly tilt and rotate. This Sail behaviour observation is one of the goals of the cameras.

5 DESCRIPTION OF OPERATION

Cameras are turned on by the OBC and their operation is switched between them on the same interface by the OBC. Cameras operations are to be done by the ground commands. All the photos will be with JPEG compression and size 640x480 (TBC).

Cameras are going to be used during the experiments phase for about 5 days (TBC), during the Sail deployment and after it, if possible.

Telecommand “take a photo” has parameters:

- Which camera;
- Numbers of photos;
- Frame rate;
- Send it now (true/false).

The OBC operations sequence consists of;

- choosing selected camera;
- taking photo(s) and saving in the memory;
- sending to ground station (in case of send_now==true).

Only 10 (TBC) last photos will be stored in the on board memory. Every stored photo can be chosen for sending to GS on demand later.

The Sail deployment sequence contains the cameras operation, with taking 10 photos (TBC) by both cameras during the deployment and saving them to memory.

After the Sail deployment, the communication link may be weakened and it may be harder to send photos to the ground station. This issue is presented in the Communication document.

6 TESTING

The cameras tests assume the cameras overall performance after vibrations, in vacuum and different thermal conditions as the qualification tests. Also the functional tests of the Sail visibility are to be done.

6.1 FUNCTIONAL TESTS

Functional tests are mainly to check the correctness of the camera driver and communication with the OBC. The test is to turn on the cameras and take a few photos with the PC. Such test will be performed before and after the qualification and acceptance tests. Apart from this there will be a test with OBC evaluation module and Payload board to check the power and data flow correctness.

6.2 TEST OF THE SAIL VISIBILITY

The cameras mounted to the Secondary Structure and Sail Container will be used during the Sail deployment tests to check the overall Sail visibility with the Sail movement. Additionally the observations in different light conditions will be performed. The camera control by the PC will be enough.

6.3 VIBRATION TEST

The camera vibration test will be performed with the Secondary Structure mounted on the STM model, and the cameras will be tested with the whole satellite structure. One of the cameras can be substituted by a dummy camera model in the vibration testing.

6.4 VACUUM TEST

In the vacuum tests there will be tested the lenses itself as well as the electronics.

6.5 THERMAL CYCLES TEST

During the thermal cycles there will be checked the cameras thermal resistance. It will be done on the cameras turned off. Additionally in the expected lowest and highest temperatures for the cameras from the thermal simulations, there will be done the operational test of the cameras.