Phase C

Mechanical & Thermal ICD

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12/03/2008
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RECORD OF REVISIONS

ISS/REV	Date	Modifications	Created/modified by
1/0	09/07/07	Initial Issue	Guillaume Roethlisberger
1/1	23/07/07	M.N. and R.K. comments	Guillaume Roethlisberger
1/2	07/08/07	Contact areas between components	Guillaume Roethlisberger
1/3	17/01/08	Phase C update	Guillaume Roethlisberger
1/4	13/02/08	External panels and kill-switch updates	Guillaume Roethlisberger
1/5	12/03/08	ADCS sensors	Guillaume Roethlisberger

1 REFERENCES

1.1 Normative references

CubeSat Design Specification. Revision 10, Cal Poly, August 2006

2 TERMS, DEFINITIONS AND ABBREVIATED TERMS

2.1 Abbreviated terms

ADCS	Attitude Determination and Control System
ADS	Antenna Deployment System
CDMS	Command and Data Monitoring System
CDS	CubeSat Design Specifications document
C.o.M.	Center of Mass
COTS	Commercial off The Shelf
CTE	Coefficient of thermal Expansion
EPS	Electrical Power System
EQM	Engineering Qualification Model
FEA	Finite Element Analysis
FM	Flight Model
ICD	Interface Control Document
LV	Launch Vehicle
NA	Not applicable
P-POD	Poly Picosatellite Orbital Deployer
PCB	Printed Circuit Board
RF	Radio Frequency
STM	Structural and Thermal Model
TBC	To be confirmed
TBD	To be defined

2.2 Language

The word *shall* is used to indicate mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).

The word *should* is used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

The word *will* indicates a statement of fact or intention.

2.3 Definitions

3 INTRODUCTION

This document describes the mechanical interfaces of the Swisscube subsystems with the Swisscube main frame. It is intended to document the interfaces so that subsystem components can be designed and fabricated based on clear, understood values for their interfaces to the rest of the SwissCube satellite.

Figure 1 shows the configuration of the different subsystems and parts composing the SwissCube satellite.

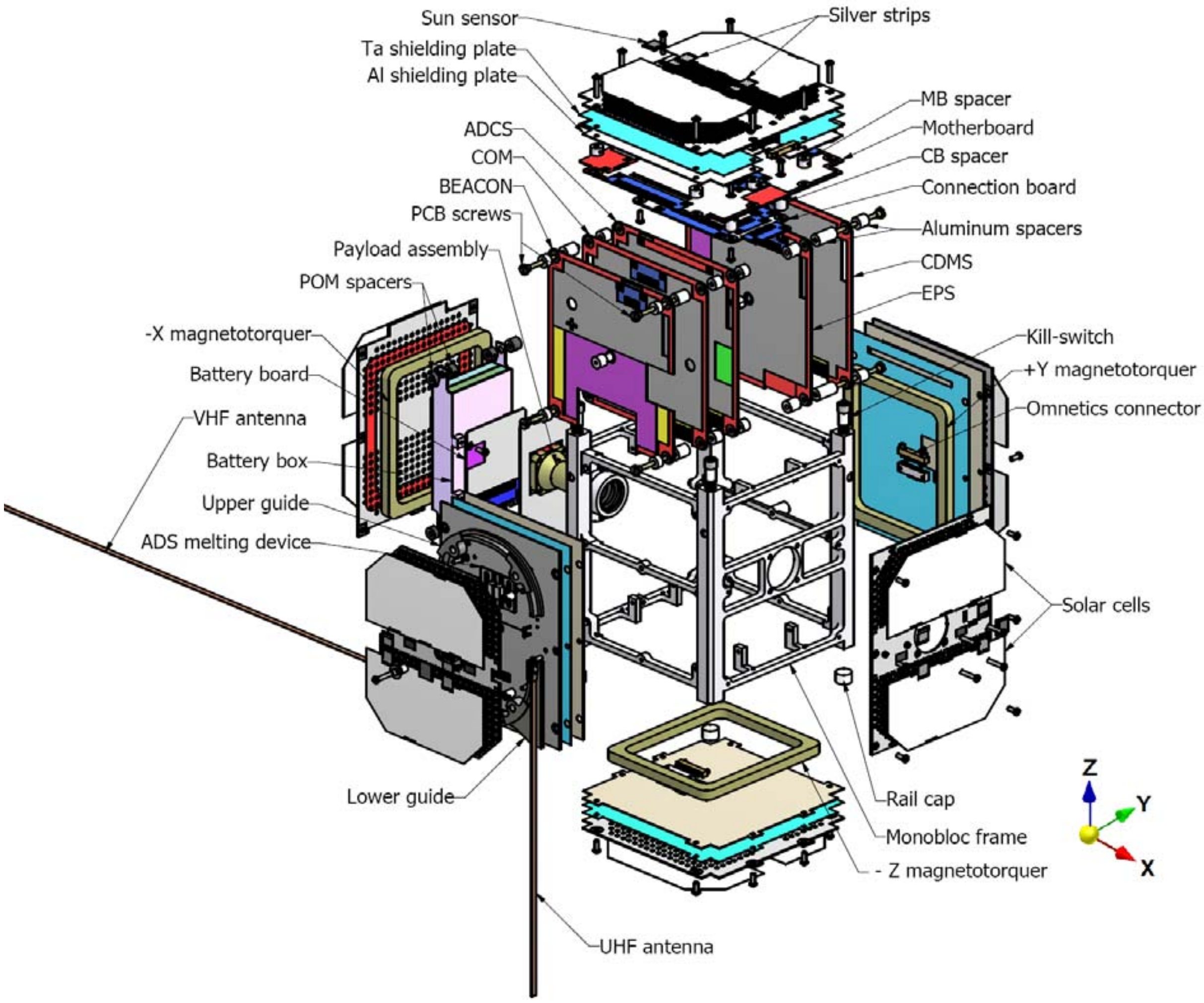


Figure 1 Exploded view of the SwissCube satellite.

The mechanical interfaces comprise:

- SwissCube to P-POD
- Structural components to main structure

- PCBs to main structure
- External panels to main structure
- Antenna deployment system to main structure
- Payload to main structure
- Batteries to main structure
- Solar cells to external panels
- MT to external panels

4 UNITS

Units and dimensions shall be quoted in metric units. All values will be quoted to the following number of decimal places:

- Mass (g): .x
- Dimension (mm): .x

The accuracy shall be (unless otherwise noted):

- ± 0.5 gram for the mass
- ±0.1mm for dimensions

In case of English units, the following conversion factors shall be used:

- 1 lb = 453.59g
- 1 in = 25.4 mm

5 COORDINATE SYSTEM

The satellite reference frame (SRF) is provided in Figure 2. In this right handed frame the payload aperture shall be oriented towards +X. The Z axis shall be parallel to the structure rails with the motherboard perpendicular to +Z, and the antenna deployment system shall be located in -Y. The satellite reference point (SRP) shall be in the geometrical center of the "cube".

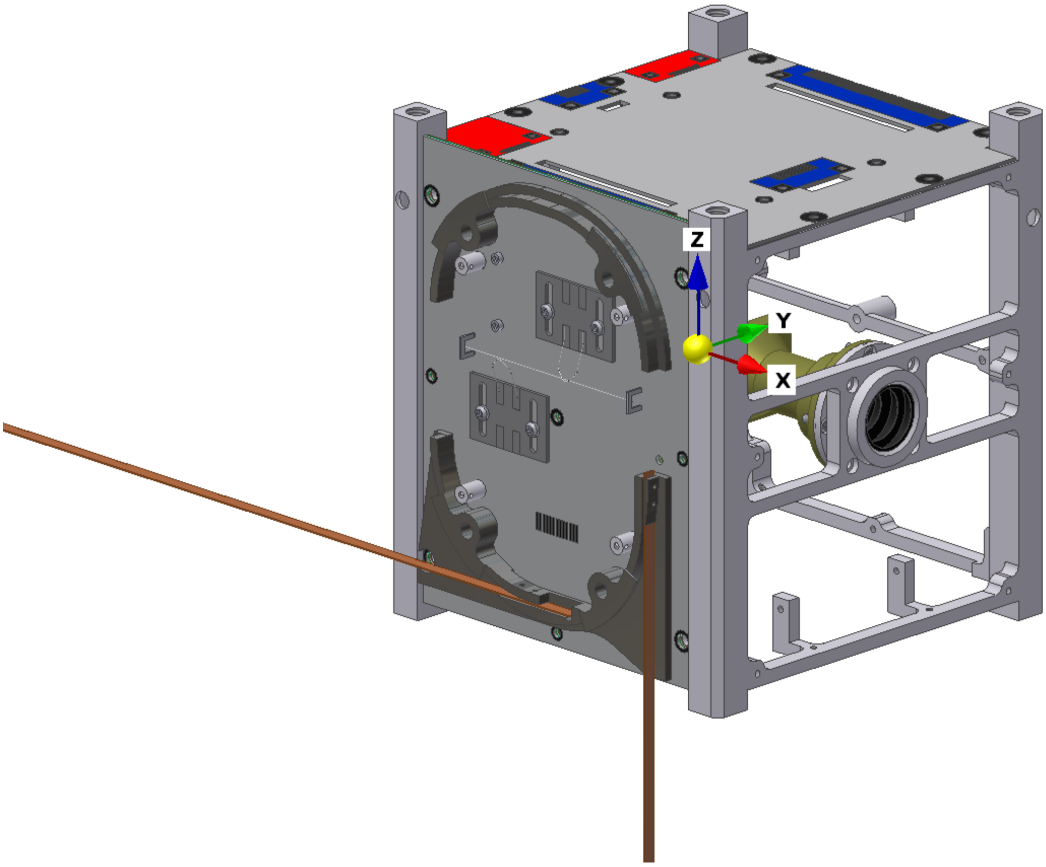


Figure 2 : Satellite reference frame (SRF).

6 SWISSCUBE TO P-POD INTERFACES

The Poly Picosatellite Orbital Deployer (P-POD) is Cal Poly's standardized CubeSat deployment system. It is capable of carrying three standard CubeSats and serves as the interface between the CubeSats and launch vehicule. The P-POD is an aluminum, rectangular box with a door and a spring mechanism, see Figure 3. CubeSats slide along a series of rails during ejection into orbit. CubeSats must be compatible with the P-POD to ensure safety and success of the mission, by meeting the requirements outlined in the CubeSat Design Specification (CDS) document.

Figure 3 : Cross section of the P-POD.

6.1 Physical properties

CubeSats are cube shaped picosatellites with a nominal length of 100 mm per side. Dimensions and features are outlined in the CubeSat Specification Drawing, see Figure 4. Most important features of all CubeSats are that a single CubeSat shall not exceed 1 kg mass, that the center of mass shall be within 2 cm of its geometric center and that components on the side panels shall not extend more than 6.5 mm normal to the surface of the rails.

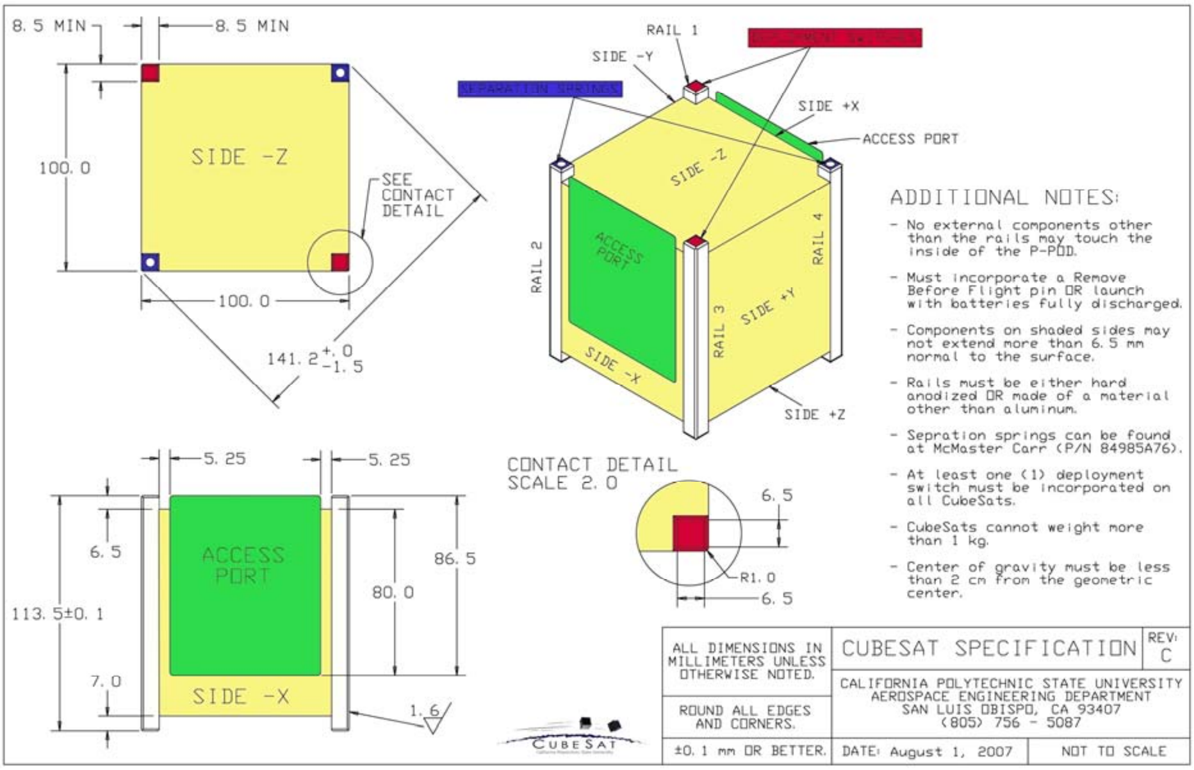


Figure 4 : CubeSat Specification Drawing.

6.2 Material

The structure of the SwissCube shall be strong enough to survive maximum loading defined in the launch environment document. The SwissCube structure shall be compatible with the P-POD. For this reason, the use of Aluminum 7075 or 6061-T6 is suggested for the main structure. If other materials are used, the thermal expansion must be similar to that of Aluminum 7075-T73 (P-POD material). The selected aluminum alloy is the so-called Certal®. The characteristics of this material are described in Appendix B.

6.3 Surface characteristics

At least 75% of the rail must be in contact with the P-POD rails. All rails shall be hard anodized to prevent cold-welding, reduce wear, and provide electrical isolation between the SwissCube and the P-POD.

After the Titanox (Ematal 78) treatment, the surface characteristics of the both external sides and extremities of the rails are:

- thickness of the layer 10-12 µm
- Roughness TBD Ra

- Vickers hardness 500 Vickers
- Heat capacity TBD $J \cdot mol^{-1} \cdot K^{-1}$
- Emissivity ε = TBD
- Absorptivity coefficient α = TBD
- Thermal conductivity TBD $W \cdot m^{-1} \cdot K^{-1}$
- Breakdown voltage 35-50 V/m

The contact area between the P-POD and the SwissCube consists of the four rails (sides and extremities). The total area is 6000mm^2.

The rest of the monobloc frame will undergo a chromating treatment named Alodine 1200 S, the surface characteristics are:

- thickness of the layer 2-3 µm
- Roughness TBD Ra
- Vickers hardness TBD Vickers
- Heat capacity TBD $J \cdot mol^{-1} \cdot K^{-1}$
- Emissivity ε = TBD
- Absorptivity coefficient α = TBD
- Thermal conductivity TBD $W \cdot m^{-1} \cdot K^{-1}$
- Breakdown voltage TBD V/m

6.4 Connectors location

The access port allows communicating with the SwissCube when inserted inside the P-POD. It may be located at the designated area in Figure 4.

7 INTERNAL ELECTRONIC BOARDS

This section describes the mechanical interfaces between the internal PCB and the monobloc frame of the SwissCube. The internal electronics boards shall be composed of five standard PCBs, a payload headboard, a motherboard a connection board and a battery board.

The five standard PCBs, named ADCS, BEACON, CDMS, COM and EPS, are separated in two PCB stacks, one of three PCBs, the other of two PCBs. The payload headboard is located at the end of the payload assembly. The battery board is fastened onto the +X side of the battery box. The connection board is attached to the motherboard and both are located on the top (+Z) of the SwissCube. For more details, see Figure 1.

7.1 Physical properties

The dimensions of the standard PCB shall be 89.0 x 85.0 x 0.8 mm (height x width x thickness).

The dimensions of the motherboard shall be 99.0 x 97.3 x 0.8 mm (height x width x thickness).

The dimensions of the connection board shall be 86.0 x 40.0 x 0.8 mm (height x width x thickness).

The dimensions of the payload headboard shall be 80.0 x 35.0 x 0.8 mm (height x width x thickness).

The dimensions of the battery board shall be 46.0 x 40.5 x 0.8 mm (height x width x thickness).

The standard PCB will have a mass of no more than 13 grams without electronics. The mass of the copper layers will be no more than 7 grams.

The motherboard will have a mass of no more than 15 grams without electronics. The mass of the copper layers will be no more than 9 grams.

The connection board will have a mass of no more than 6 grams without electronics. The mass of the copper layers will be no more than 3.5 grams.

The payload headboard will have a mass of no more than 4.5 grams without electronics. The mass of the copper layers will be no more than 2.5 grams.

The battery board will have a mass of no more than 3.5 grams without electronics. The mass of the copper layers will be no more than 2 grams.

7.2 Material

The datasheet of the PCB substrate is in Appendix A. All internal PCBs shall be six layers printed circuit boards. For more info about that stacking sequence, see the electrical Fabrication Plan.

The main physical properties of the PCB substrate are:

- Density $2.0\ g\cdot cm^{-3}$
- CTE (in plane/out-of-plane) $14\ /\ 40\ ppm\ K^{-1}$
- Thermal conductivity $0.62\ W\cdot m^{-1}\cdot K^{-1}$
- Specific heat $950\ J\ kg^{-1}\cdot K^{-1}$

7.3 Surface characteristics

Some area of the PCBs will be covered with conformal coating. For more info see the *Fabrication Plan – Electrical parts* document.

The contact area between the standard PCB and the spacers is 222 mm^2.

The contact area between the motherboard and the monobloc frame is 1320 mm^2.

The contact area between the connection board and the connection board spacers is 100 mm^2.

The contact area between the payload headboard and the payload frame is 165 mm^2.

The contact area between the battery board and the battery box is 92 mm^2.

7.4 Overall layout

This section and the following figures describe the layout of each internal board, the position of the various connection zone and the restrictions concerning some areas.

For each side of an electronic board the maximal height of components is cited. The denomination of the side corresponds to the SRF. The gray colored surfaces may be used for electronic components. Red areas shall be served as margins in case of slight design changes or are restricted areas. I/O pins shall be situated in the blue zones, stress relief shall also included in these areas. Yellow areas concern the programming connector (not applicable for every board). Finally the black areas symbolize the mechanical ground or pins of each board. For the function of each pin, please refer to the last version of the electrical block diagram document.

Figure 5 shows the footprint of the programming connector, the ribbon cable and Omnetics connector.

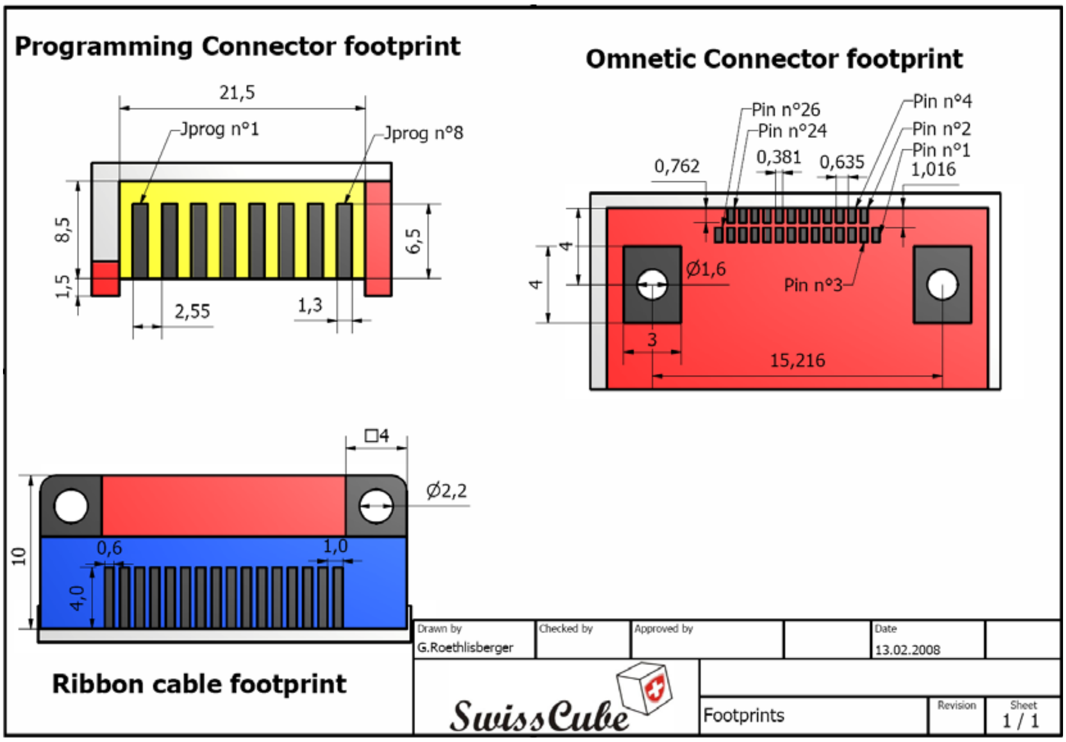


Figure 5 : Footprints of the programming connector, ribbon cable and Omnetics connector.

7.4.1 Standard PCBs

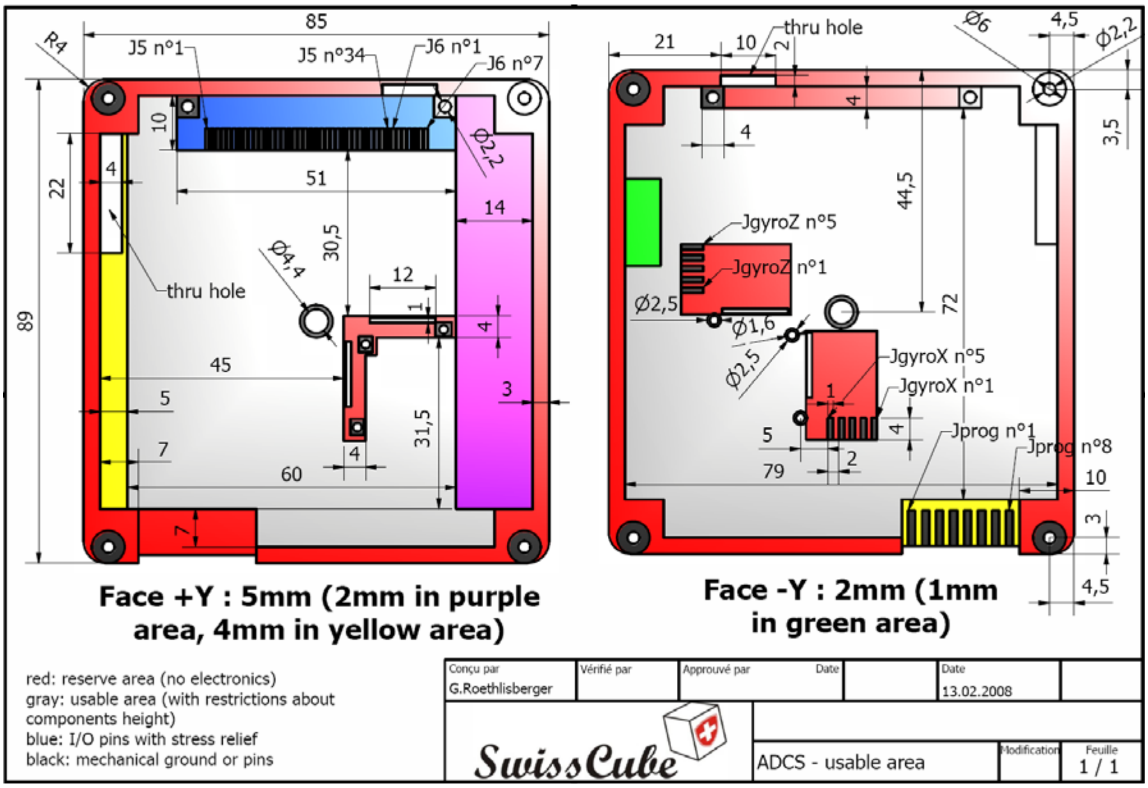


Figure 6 : ADCS layout.

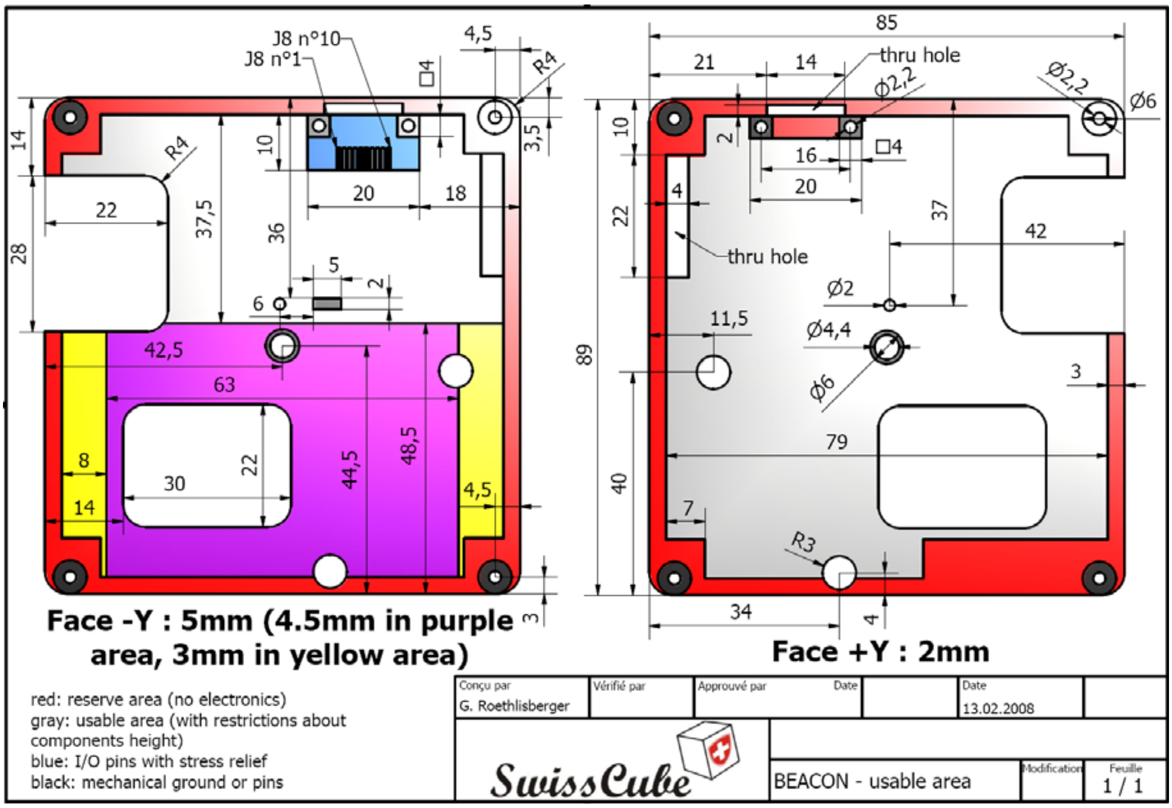


Figure 7 : BEACON layout.

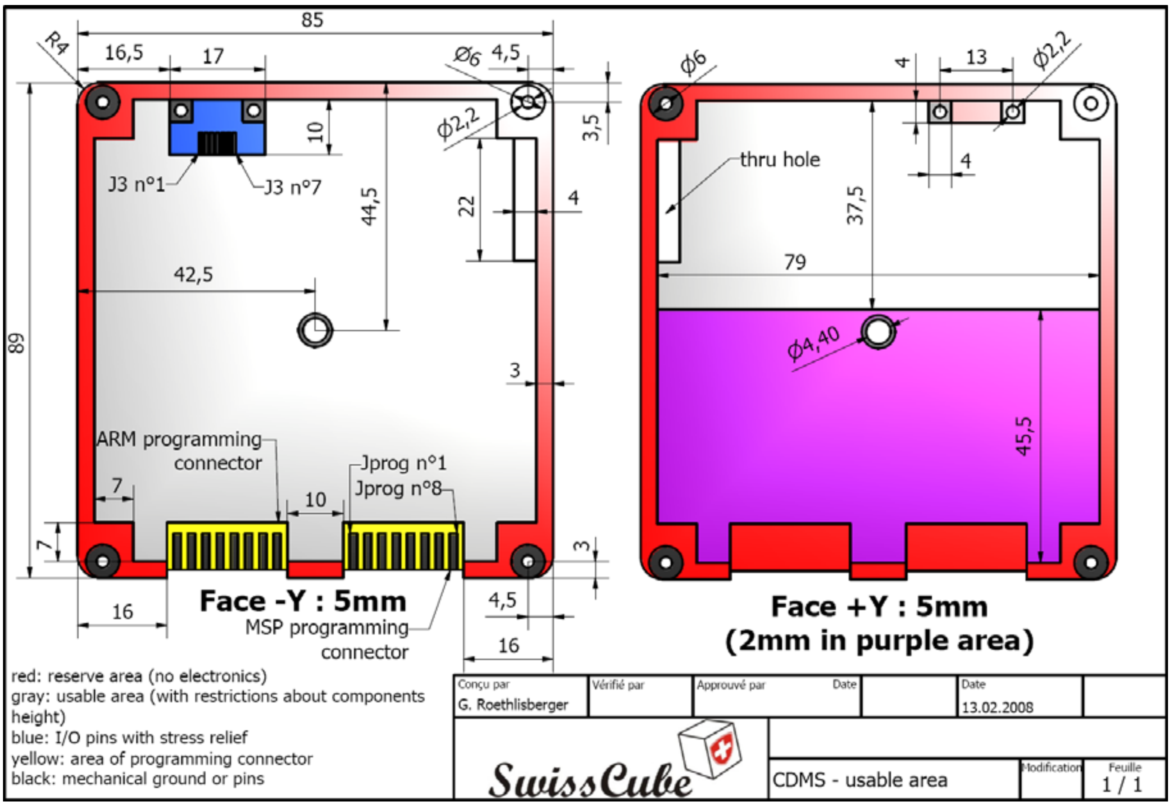


Figure 8 : CDMS layout.

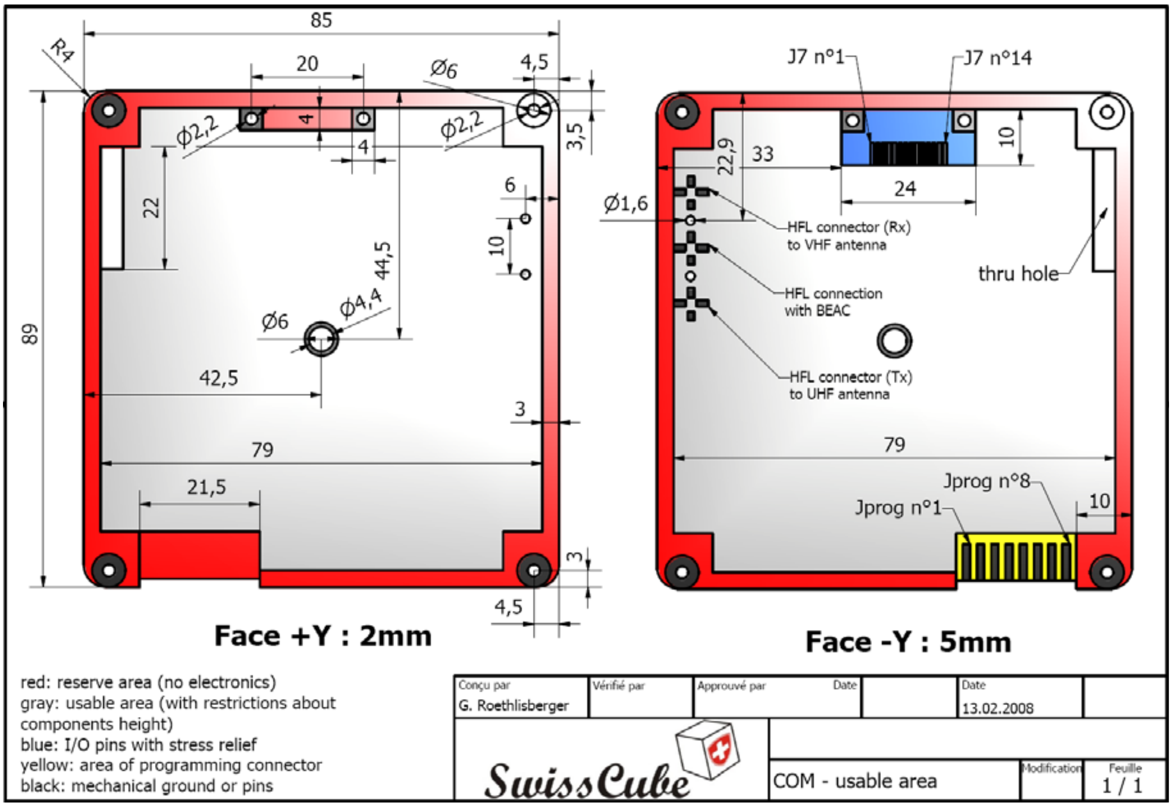


Figure 9 : COM layout.

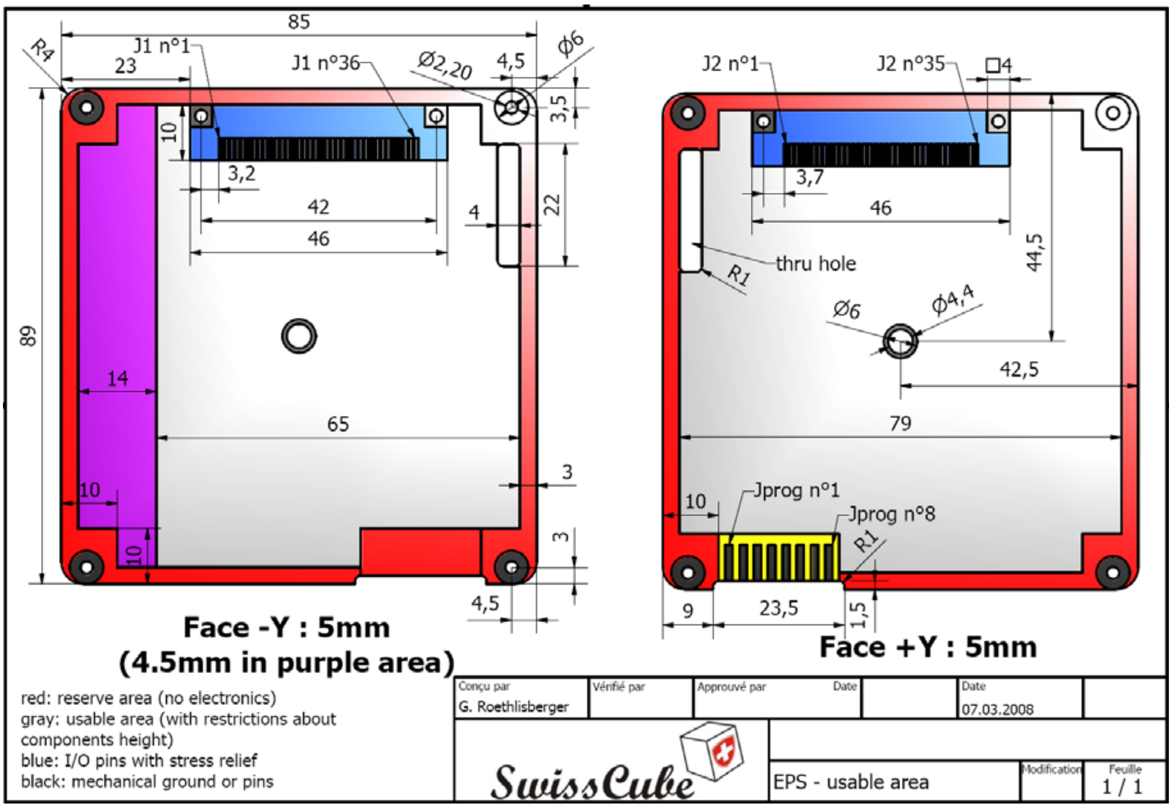


Figure 10 : EPS layout.

7.4.2 Motherboard

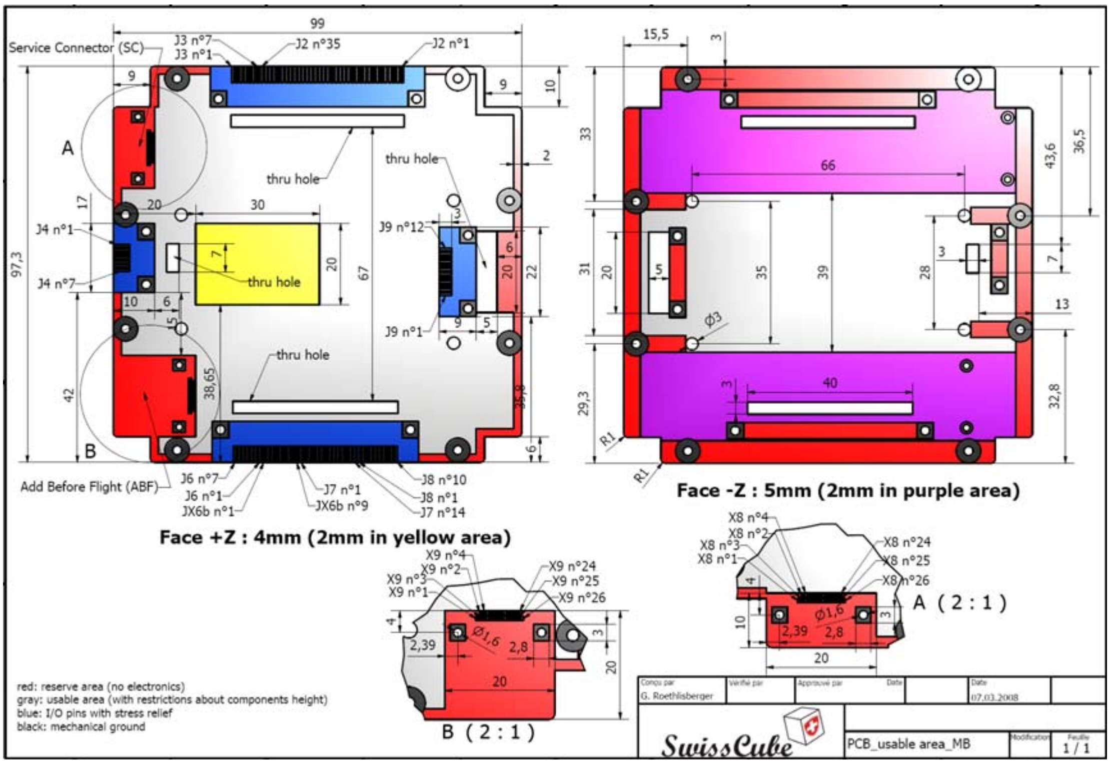


Figure 11 : Motherboard layout.

7.4.3 Connection board

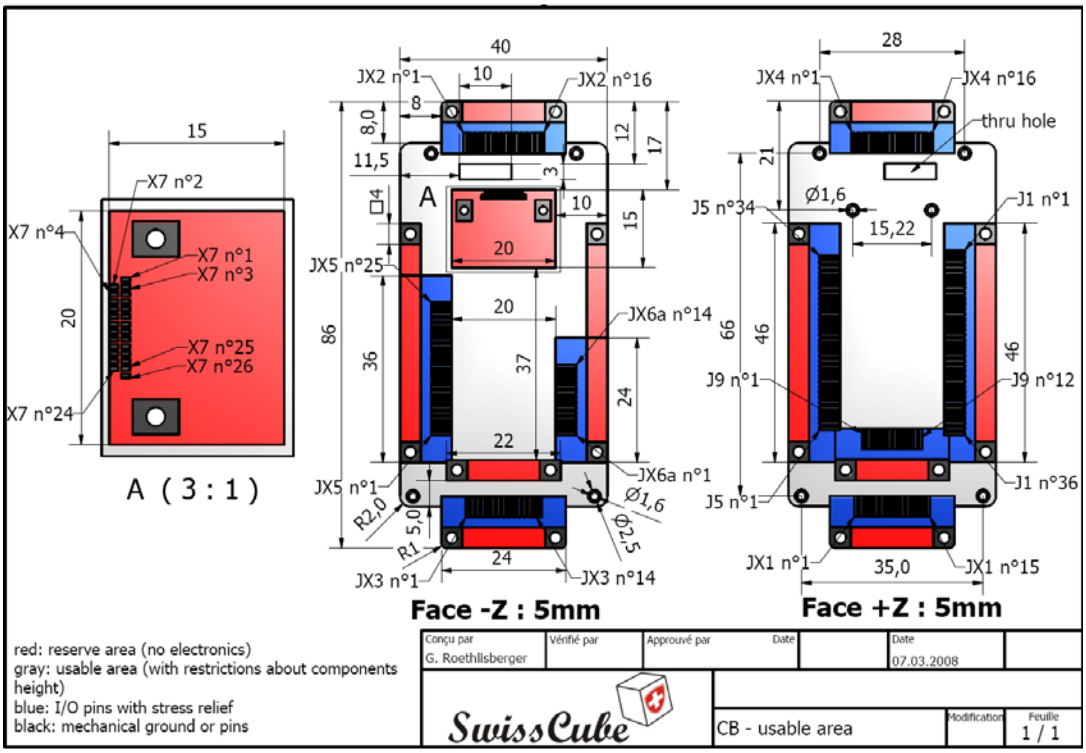


Figure 12 : Connection board layout.

7.4.4 Payload headboard

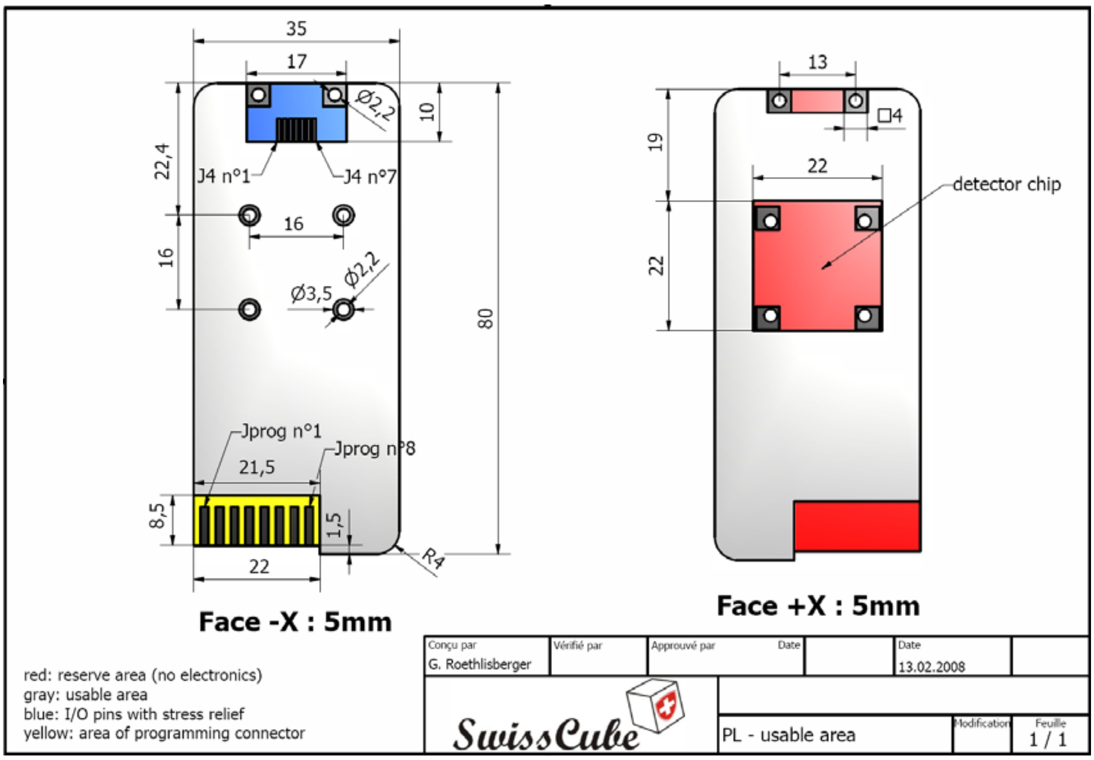


Figure 13 : Payload headboard layout.

7.4.1 Battery board

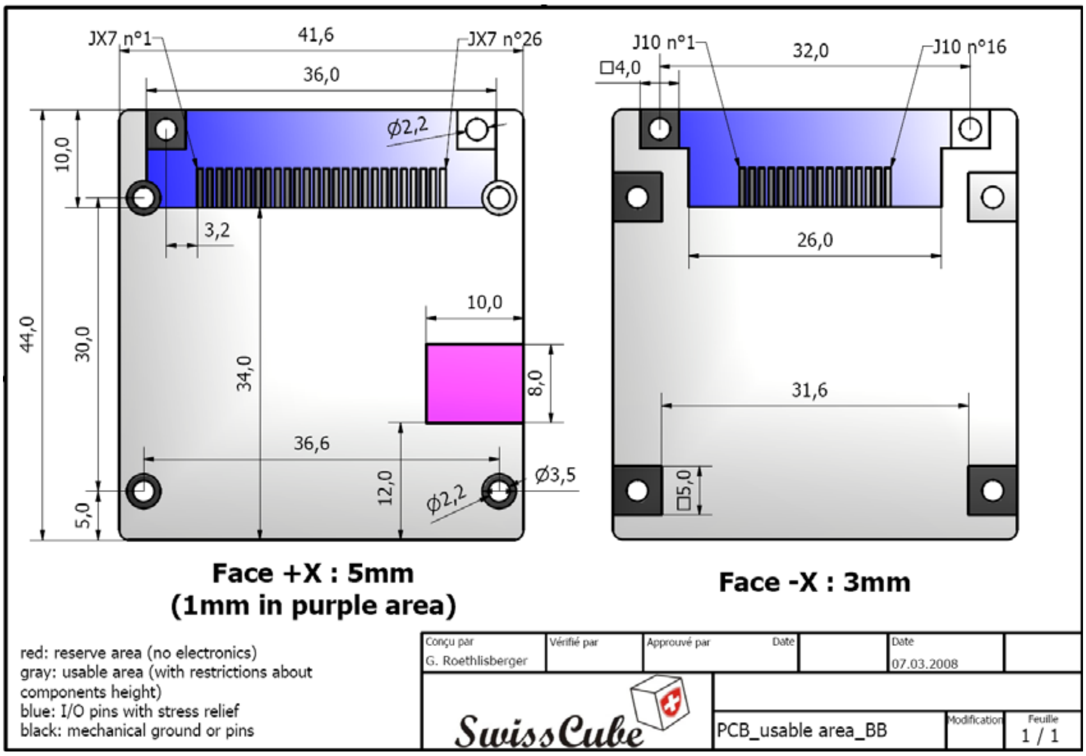


Figure 14 : Battery board (BB) layout.

7.5 Fixation and mounting techniques

This section describes the techniques of attachment for the various electronic boards of the SwissCube.

7.5.1 Standard PCBs

The five standard PCBs form two stacks of two and three boards. These boards are separated using aluminum spacers. The diameter of the spacers is 6 mm, the length depends of the case. The role of the spacers is to connect the different PCBs between each other and at the same time to fix the PCB's stack and battery subassembly to the main frame. Additionally, the spacers serve as a thermal path between the PCBs and the aluminum frame. For this reason, those that are in contact with the battery box are in POM in order to isolate the battery subassembly. The others are in aluminum in order to guarantee a good thermal path.

The PCB stacks and the battery box shall be fixed with special screws made of titanium, for more details, see §16.2.

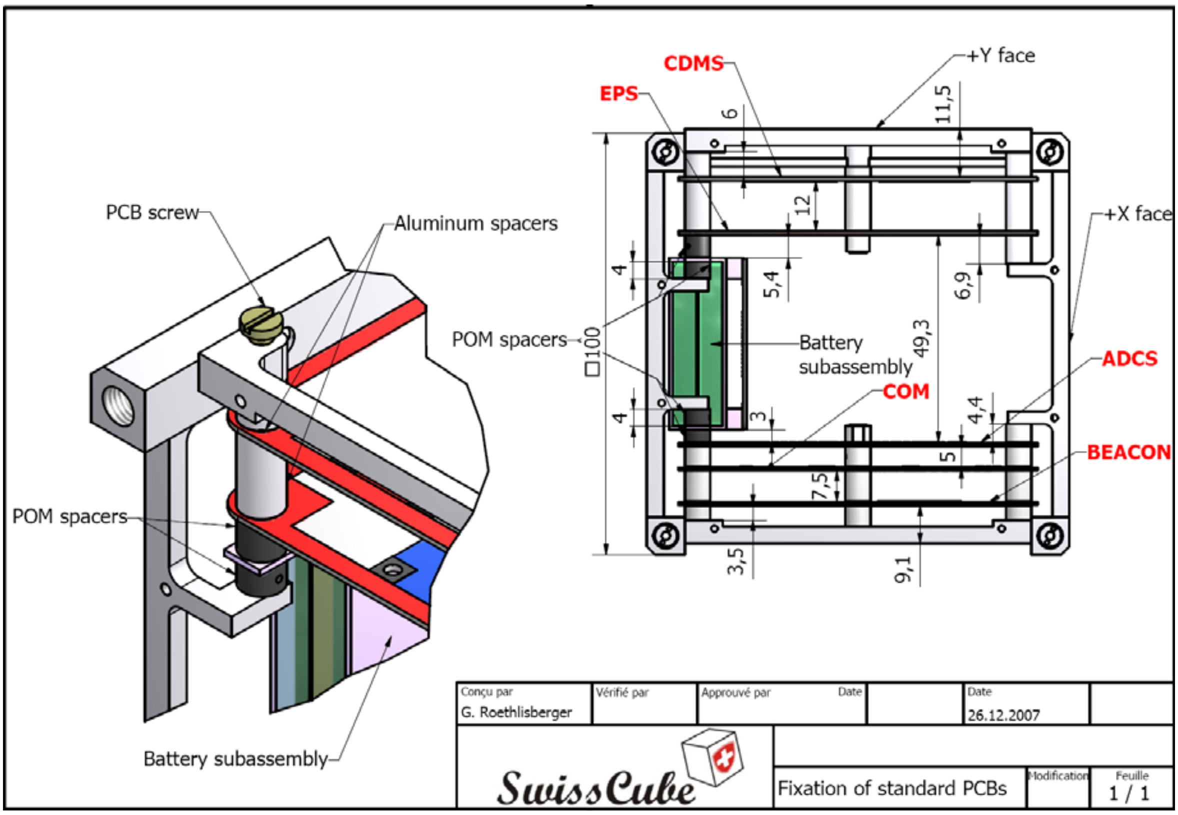


Figure 15 : Fixation of standard PCBs.

7.5.2 Motherboard

The motherboard shall be fixed with eight M2 screws to the crossbars on top of the satellite (+Z side), parallel to the XY-Plane. These eight M2 screws serve also to attach the +Z panel subassembly. MB spacers are required to separate this subassembly and the motherboard, see Figure 16.

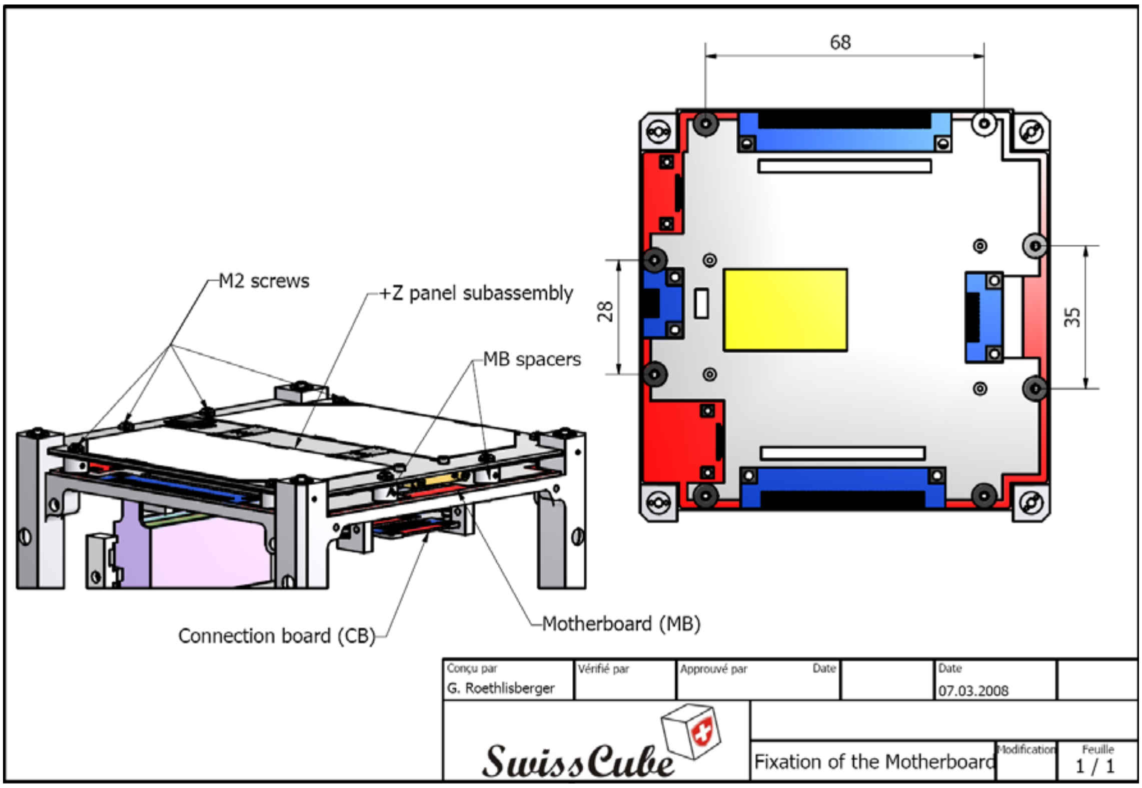


Figure 16 : Fixation of the Motherboard.

7.5.1 Connection board

The connection board shall be directly attach with four M1.4 screws to the monobloc frame, see Figure 17.

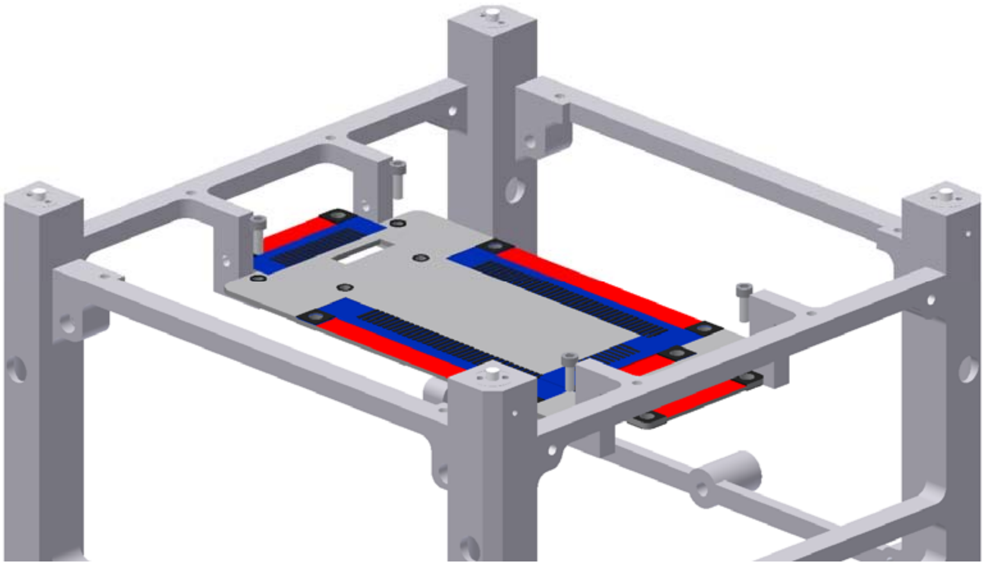


Figure 17 : Fixation of the Connection board.

7.5.2 Payload headboard

The payload headboard shall be attached at the bottom of the payload frame using four M2 screws.

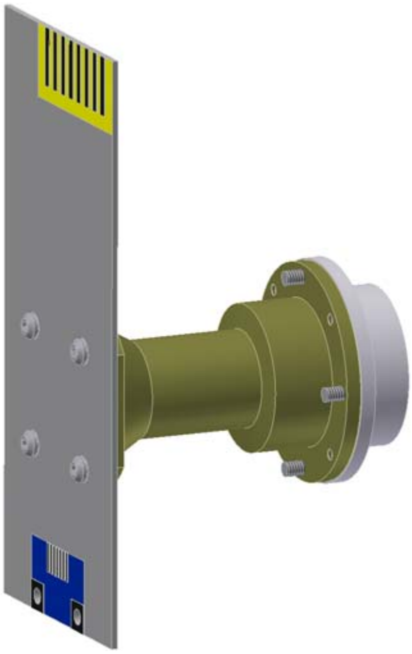


Figure 18 : Fixation of the payload headboard.

7.5.3 Battery board

The battery board shall be attached at the +X side of the battery box using four M2 screws, see Figure 19.

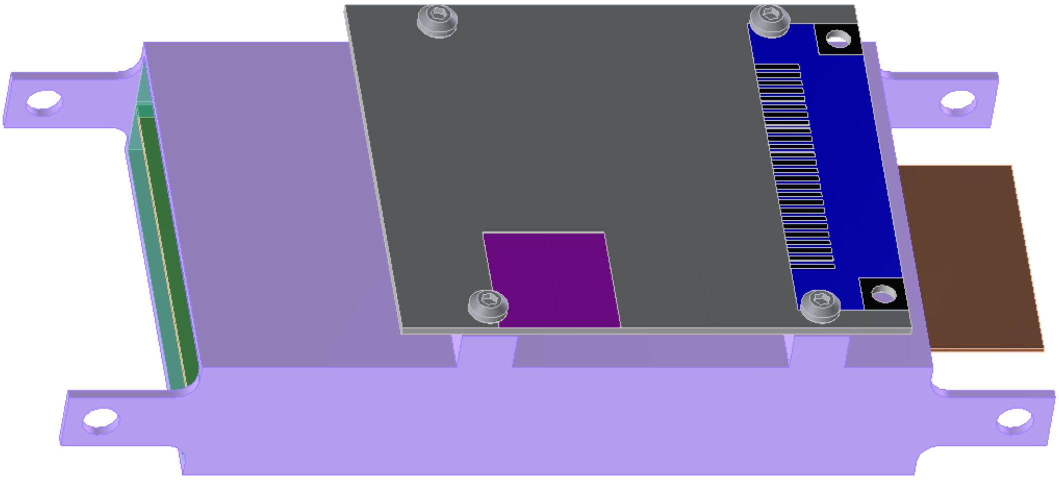


Figure 19 : Fixation of the battery board.

7.6 Miscellaneous

7.6.1 Electrical grounding

Each internal electronic board has some electrical grounding areas. Every interface between electronic board and spacers, screws or stress reliefs is connected to the ground. In Figure 6 to Figure 14 every black area that is not a programming connector, ribbon cable or Omnetics connector footprints is an electrical grounding area.

8 EXTERNAL PANELS

There are five standard external panels. The sixth face of the satellite is closed by the Antenna deployment system. This interface is discussed in §14.

These five panels shall be separated in two categories : top panels (+Z and –Z) and side panels (+X, -X and +Y).

8.1 Physical properties

The dimensions of the top panels (+Z and –Z) shall be 99.0x 97.3 x 0.8 mm (height x width x thickness).

The dimensions of the –X and +Y panels shall be 106.0 x 81.0 x 0.8 mm (height x width x thickness).

The dimensions of the +X panel shall be 107.0 x 81.0 x 0.8 mm (height x width x thickness).

The top panels shall have a mass of no more than 15 grams without components (solar cell, sun sensor, connector). The mass of the copper layers shall be no more than 12.5 grams.

The –X and +Y panels shall have a mass of no more than 13.5 grams without components (solar cell, sun sensor, connector). The mass of the copper layers shall be no more than 11 grams.

The +X panel shall have a mass of no more than 13.5 grams without components (solar cell, sun sensor, connector). The mass of the copper layers shall be no more than 11 grams.

8.2 Material

The external panels shall be made of the same material as the internal electronic boards. The datasheet of the PCB substrate is in Appendix A. All PCBs shall be six layers PCBs. For more info about that stacking sequence, see the *electrical Fabrication Plan* document.

The main physical properties of the PCB substrate are:

- Density 2.0 $g \cdot cm^{-3}$
- CTE (in plane/out-of-plane) 14 / 40 ppm K^{-1}
- Thermal conductivity 0.62 $W \cdot m^{-1} \cdot K^{-1}$
- Specific heat 950 J $kg^{-1} \cdot K^{-1}$

8.3 Surface characteristics

The PCBs will be covered with conformal coating. For more info see the *Fabrication Plan – Electrical parts* document.

The contact area between the top panel +Z and the motherboard spacers is 198 mm^2.

The contact area between the top panel -Z and the monobloc frame is 960 mm^2.

The contact area between the side panel +X and the monobloc frame is 1180 mm^2.

The contact area between the side panel -X and the monobloc frame is 386 mm^2.

The contact area between the side panel +Y and the monobloc frame is 510 mm^2.

8.4 Fixation and mounting techniques

This section and the following figures describe the layout of each external panel, the position of the various components and the dimensions.

The external panels shall be screwed to the satellite. Depending on the face, six to eight screws (see §16.1) are used for this matter.

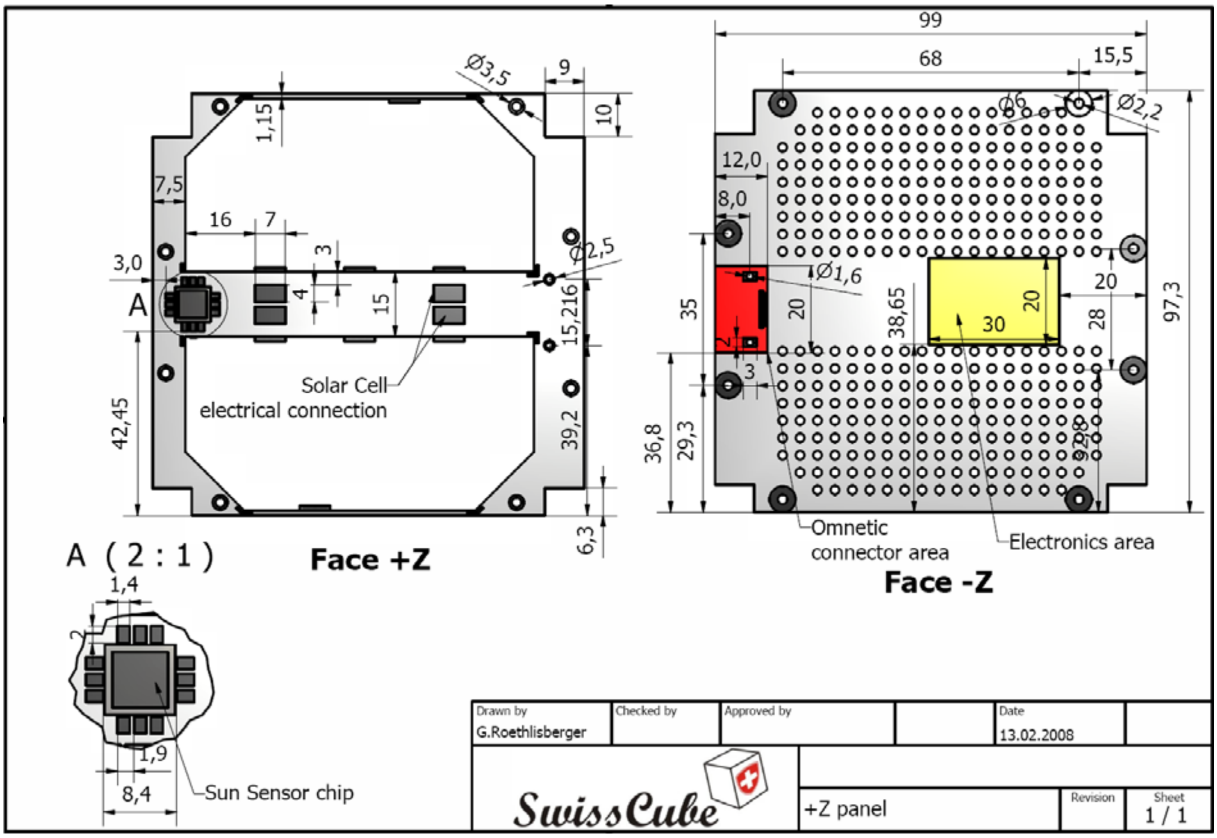


Figure 20 : +Z : Panel dimensions, fixation and layout.

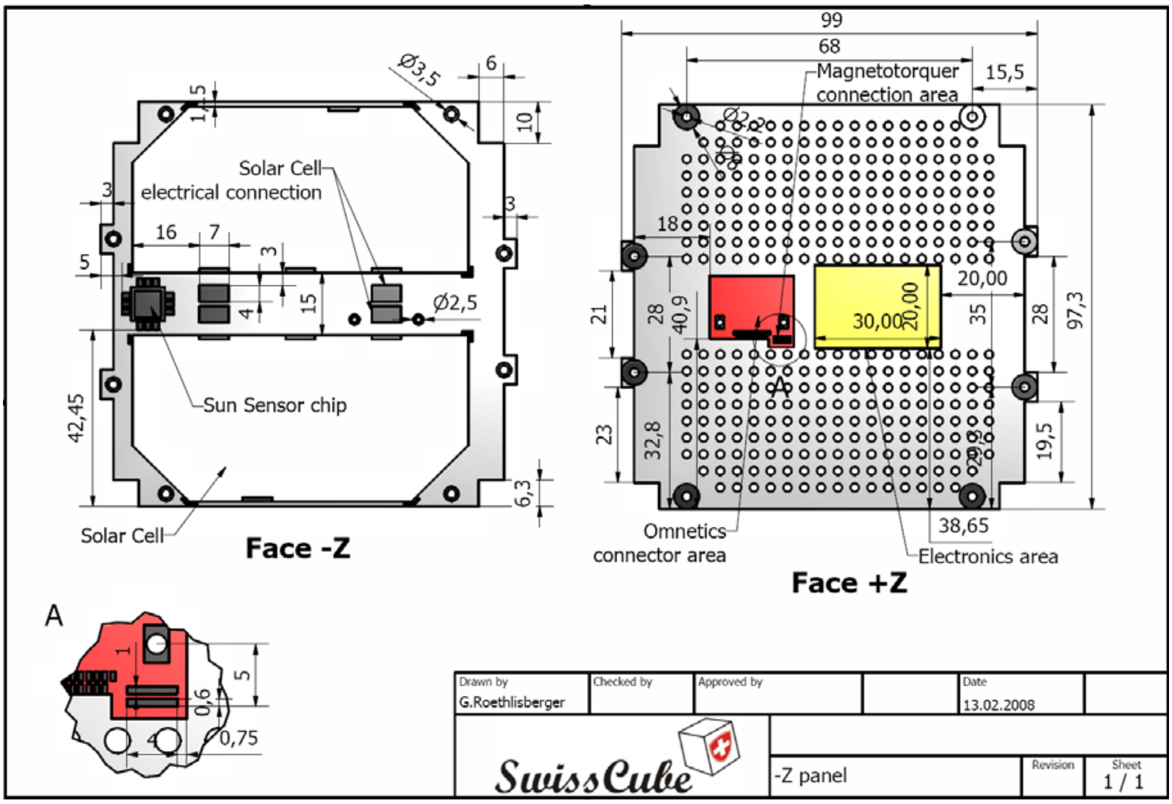


Figure 21 : -Z : Panel dimensions, fixation and layout.

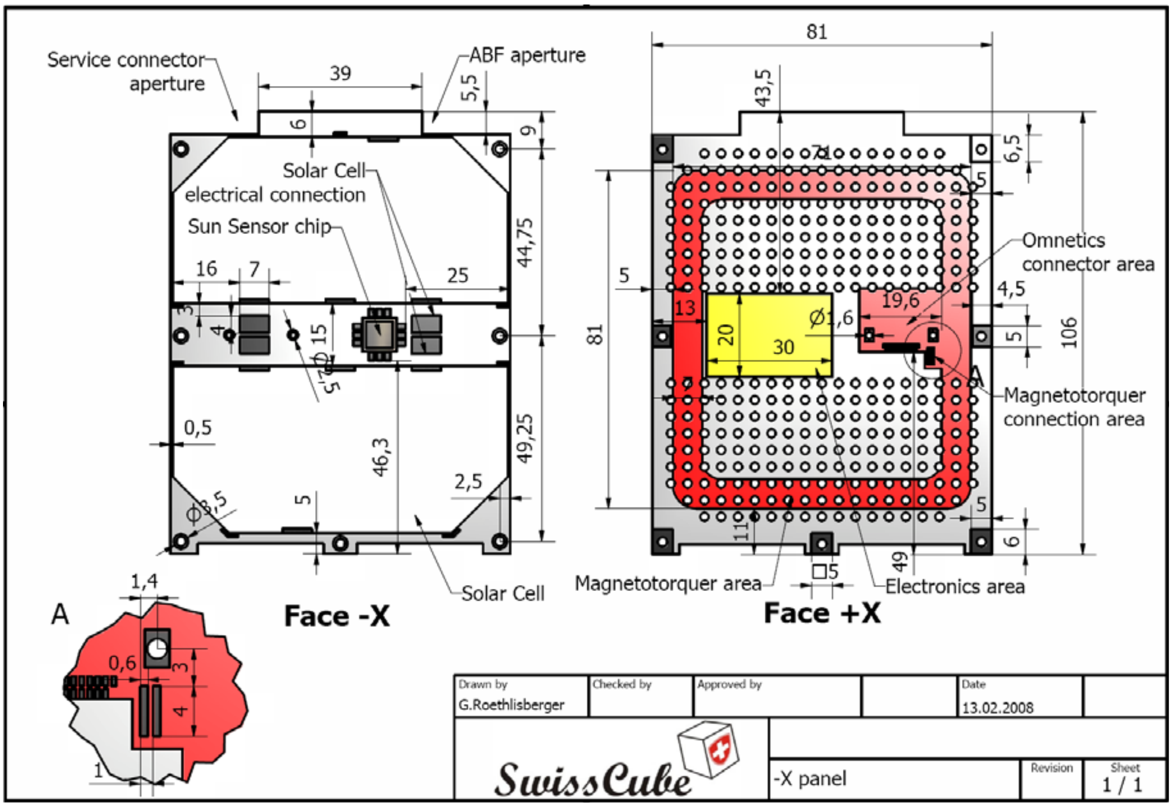


Figure 22 : Side Panel -X dimensions, fixation and layout.

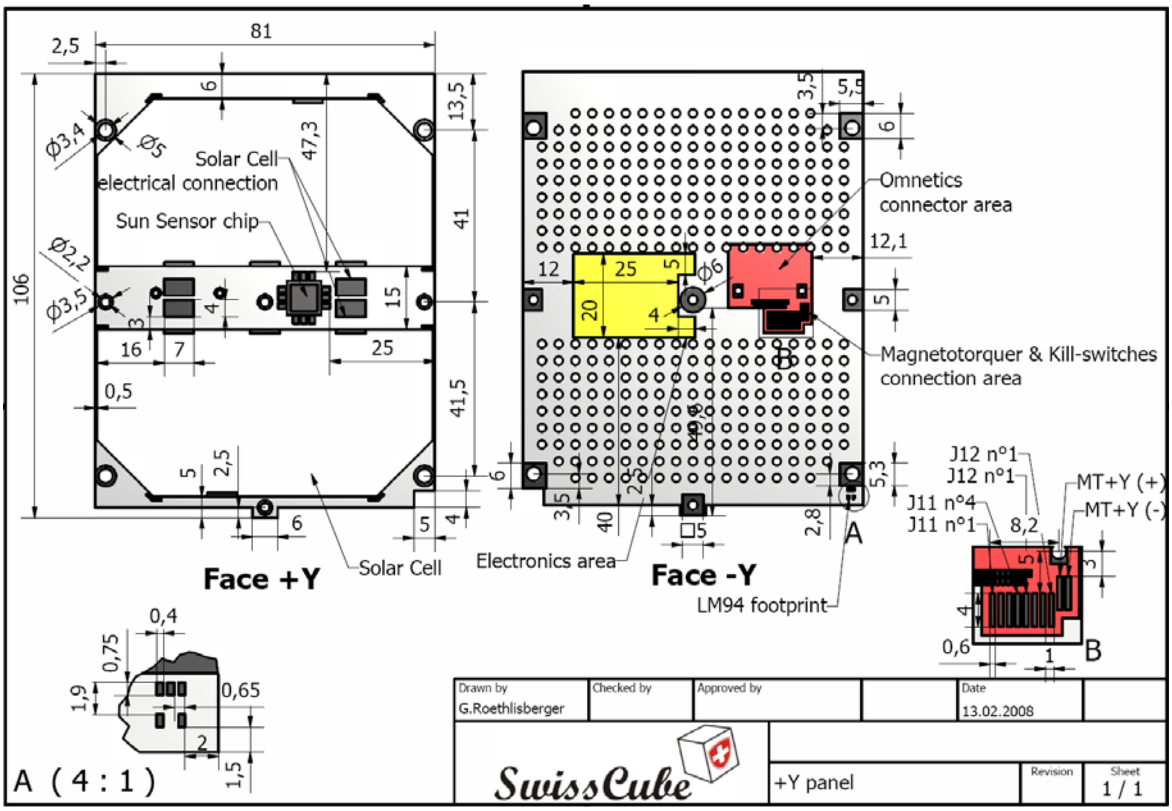


Figure 23 : Side Panel +Y dimensions and fixation.

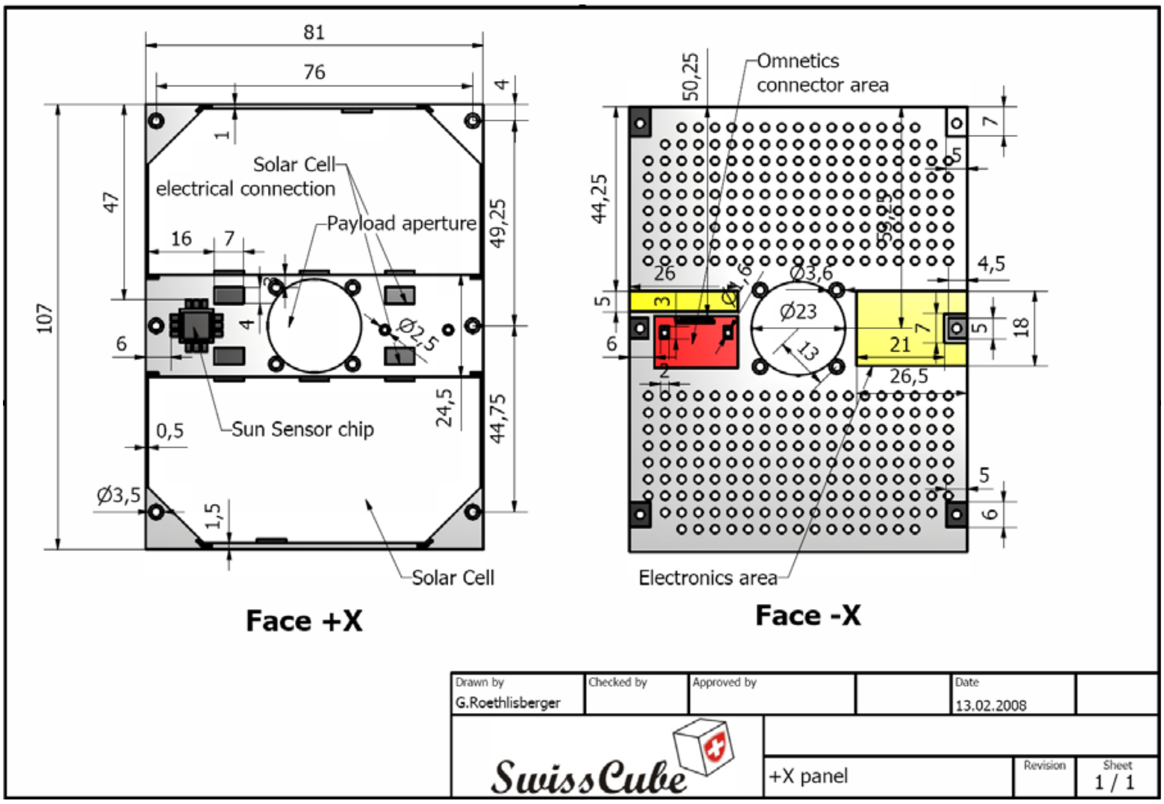


Figure 24 : Payload Panel (+X) dimensions, fixation and layout.

8.5 Connectors location

For solar cells, sun sensors and thermal sensors, an electrical connector is used to link the external panel with internal electronic boards. This Omnectics connector is attached on the inner side of the panel and its reserved area is in red in the previous figures (see §8.4). For more info about its footprint, see Figure 5.

Access port and add before flight pin are located on the motherboard (see Figure 11). Therefore a cut out shall be foreseen at top of the –X plate (see Figure 22).

8.6 Miscellaneous

8.6.1 Venting holes

Venting holes should be added to the external panels, in order to depressurize the inner of the SwissCube during the launch. The precise location of these venting holes will be established when the electrical layout will be made.

8.6.2 Electrical grounding

Each external panel has some electrical grounding areas. Every interface between external electronic board and SwissCube frame, screws or Omnetics connector is connected to the ground. In Figure 20 to Figure 24 every black area that is not an Omnetics connector footprint is an electrical grounding area.

9 SHIELDING PLATES

In order to protect the internal PCBs from space radiation, shielding plates will be located just behind external panels, more precisely + Z, -Z, +Y and –Y panels.

According to a publication1, an optimal shield consists of multiple layers of different shield materials, a high-Z layer sandwiched between the two low-Z layers.

9.1 Physical properties

The dimensions of the top shielding plates (+Z and –Z) shall be 99.0x 97.3 x (0.1 or 0.5) mm (height x width x thickness).

The dimensions of the side shielding plates (+Y and -Y) shall be 106.0 x 81.0 x (0.1 or 0.5) mm (height x width x thickness).

The top shielding plates shall have a mass of no more than 12 grams and 15 grams for Aluminum and Tantalum plates respectively.

The side shielding plates shall have a mass of no more than 10.5 grams and 13 grams for Aluminum and Tantalum plates respectively.

9.2 Material

Two various materials are used; a 0.1 mm Tantalum foil for high-Z layer material and a 0.5 mm Aluminum foil for low-Z layer material. The datasheet of these materials are provided in Appendix C and Appendix B respectively.

9.3 Surface characteristics

The contact area between the top shielding plates and the monobloc frame is 340 mm^2.

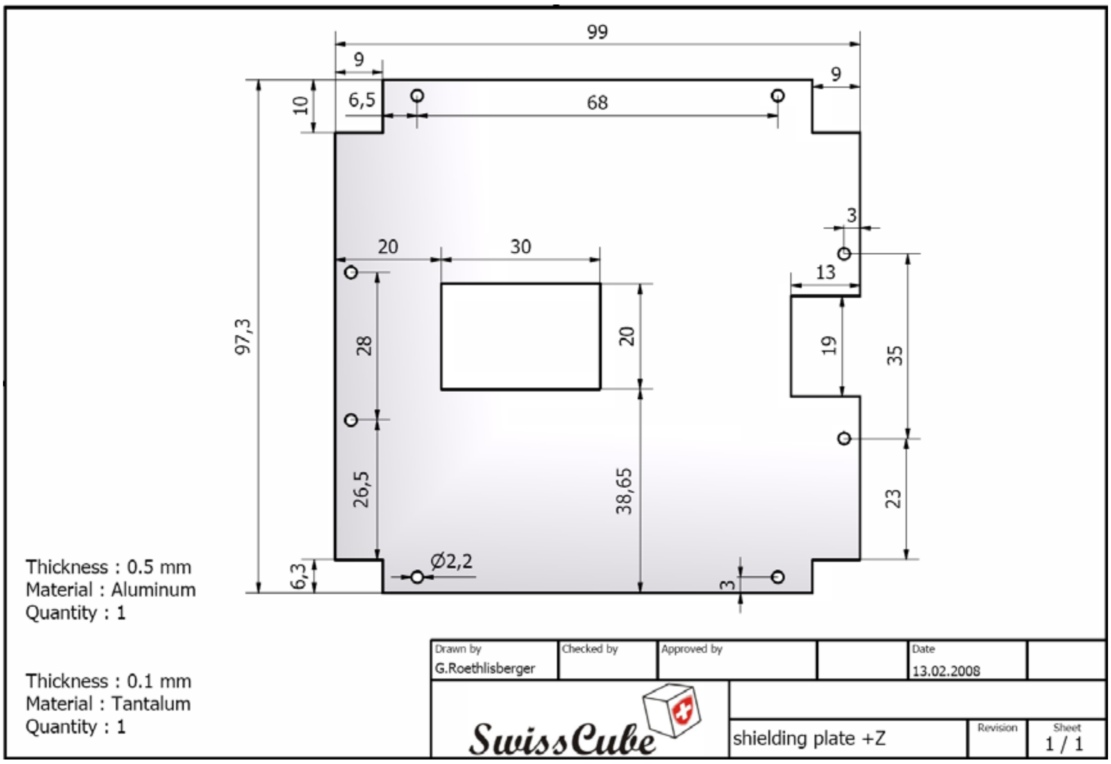
The contact area between the side shielding plates and the monobloc frame is 270 mm^2.

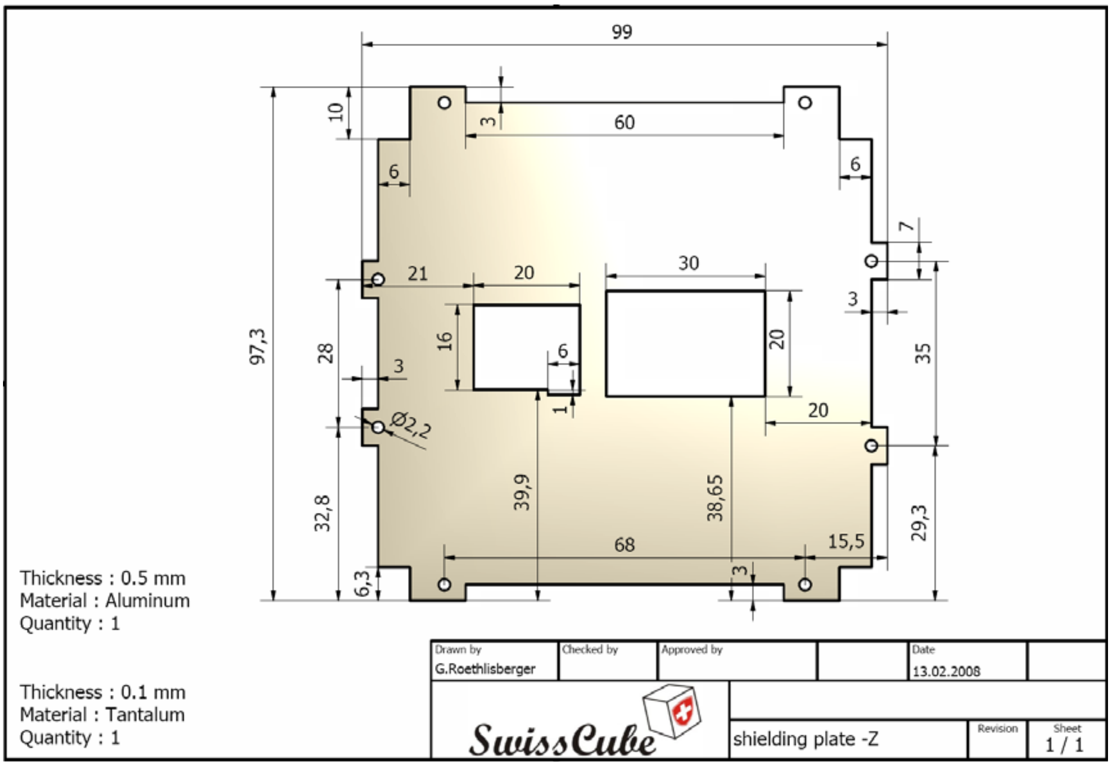
[1] Wesley C. Fan, Clifton R. Drumm, Stanley B. Roeske and Gary J. Scrivner, *Shielding Considerations for Satellite Microelectronics*, IEEE Transactions on nuclear science, vol 43, n°6, December 1996.

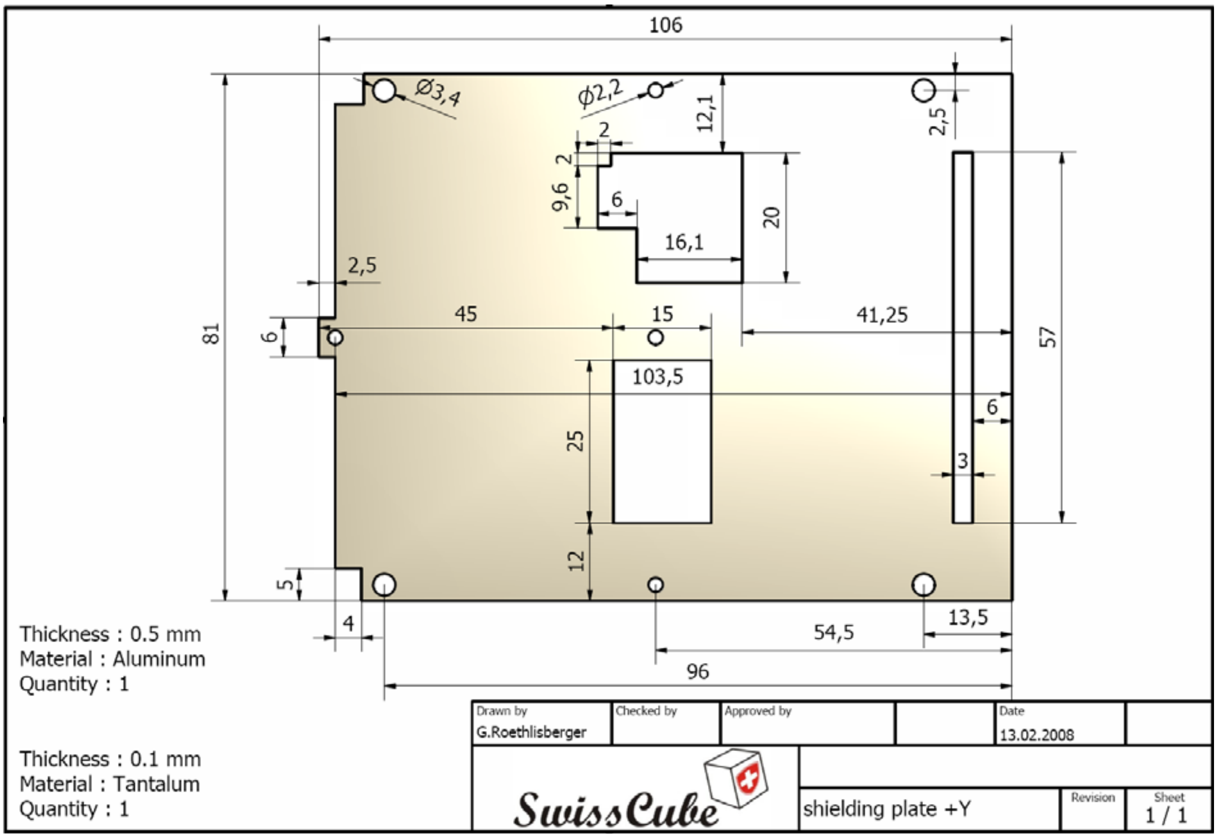
9.4 Fixation and mounting techniques

This section and the following figures describe the layout of each shielding plate, the position of the various holes and the dimensions.

The shielding plates shall be located just between external panels and the satellite structure. . Depending on the face, six to eight screws (see §16.1) are used to attached the external panel-shielding plate sandwich.



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Checked by
Approved by
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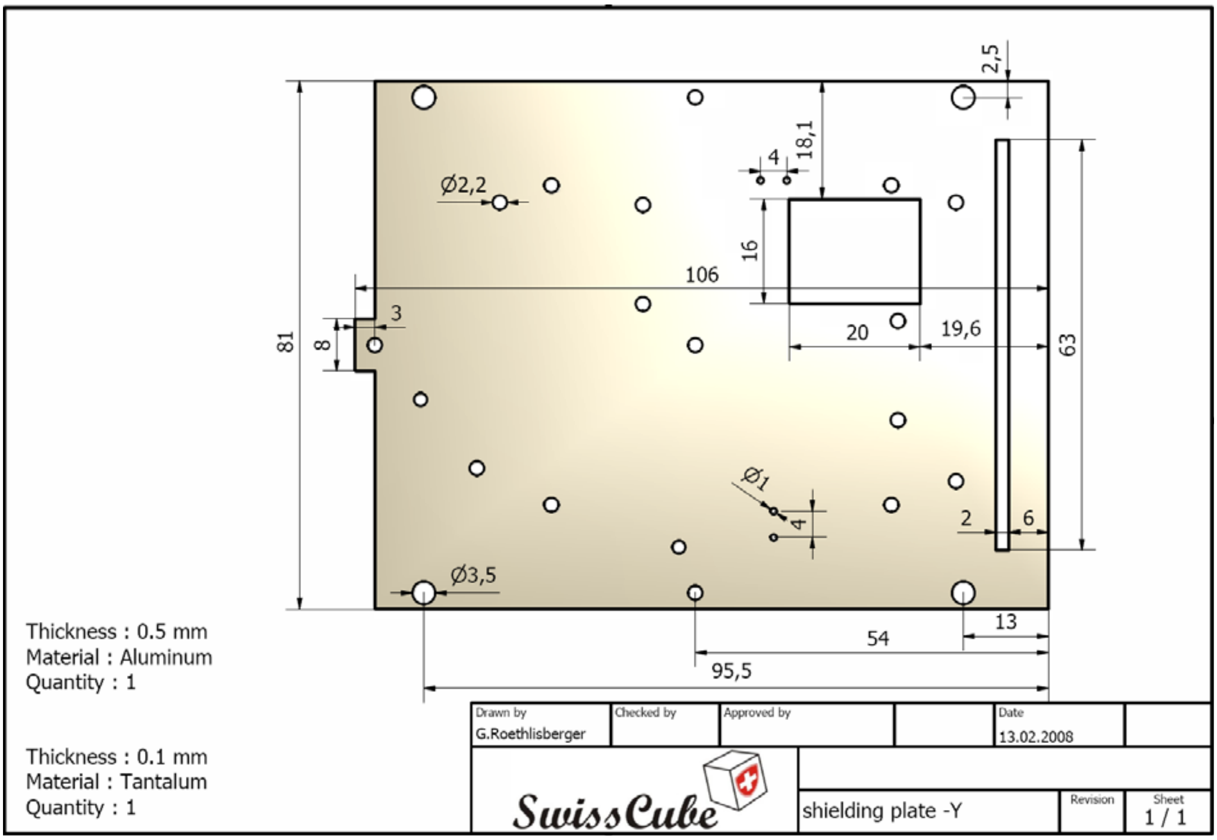
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6
Ø3,5
54
13
95,5
Thickness : 0.5 mm
Material : Aluminum
Quantity : 1
Thickness : 0.1 mm
Material : Tantalum
Quantity : 1
Drawn by
G.Roethlisberger
Checked by
Approved by
Date
13.02.2008
SwissCube
shielding plate -Y
Revision
Sheet
1 / 1

9.5 Connectors location

For solar cells, sun sensors and thermal sensors, an electrical connector is used to link the external panel with internal electronic boards. This Omnectics connector is attached on the inner side of the panel and thus an hole shall be made in the shielding plates.

9.6 Miscellaneous

9.6.1 Venting holes

Venting holes should be added to the shielding plates, in order to depressurize the inner of the SwissCube during the launch.

9.6.2 Electrical grounding

Every shielding plate shall be thermally and electrically conductive since they will be located just between external panels and the satellite structure.

10 Payload Subsystem

The payload consists of two main elements:

- An opto-mechanical system which projects the image of the airglow on a detector
- An electronic circuit (including a detector) to detect incoming photons and to interface with the other SwissCube subsystems. This part is detailed in §7.

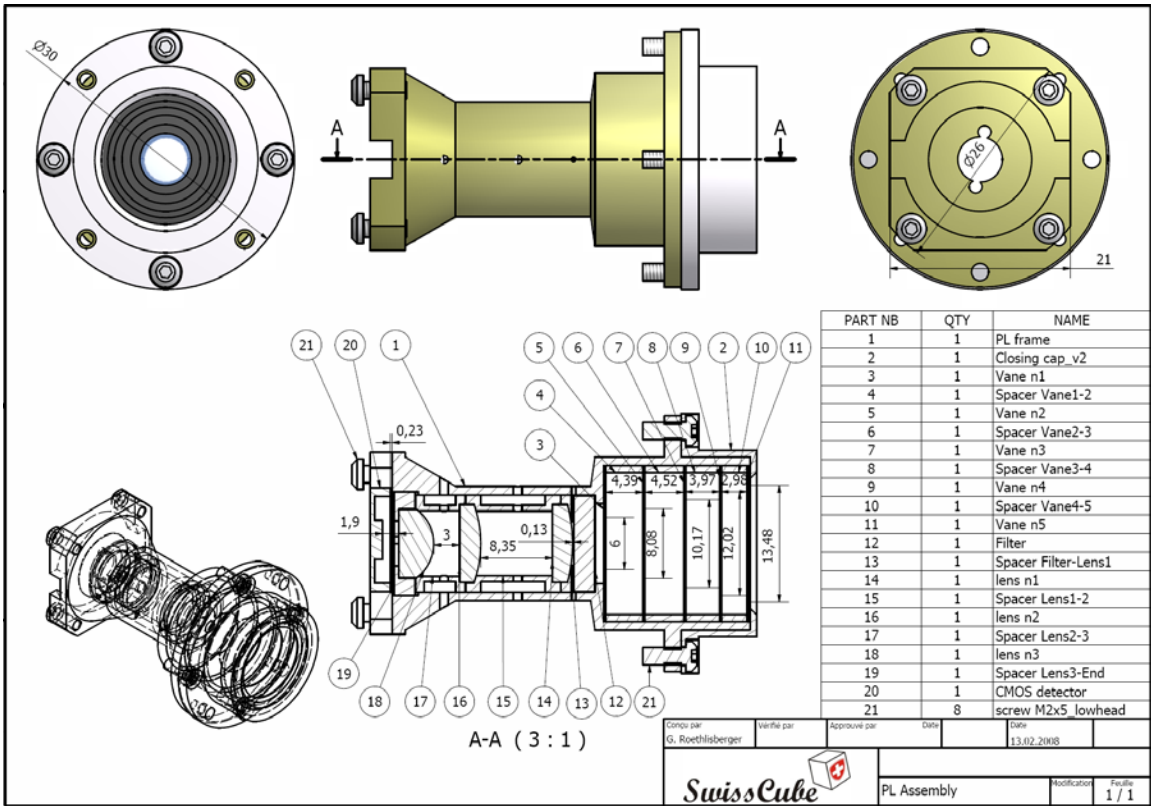
The opto-mechanical system is divided in two parts:

- The lens assembly which is used to focus the image on the detector
- The baffle tube used to attenuate the stray light

10.1 Physical properties

The dimensions of the payload assembly (without headboard) shall be 30.0x 30.0 x 45.3 mm (height x width x depth).

Payload assembly shall have a mass of 31.5 grams without the headboard (electronic board).



PART NB	QTY	NAME
1	1	PL frame
2	1	Closing cap_v2
3	1	Vane n1
4	1	Spacer Vane1-2
5	1	Vane n2
6	1	Spacer Vane2-3
7	1	Vane n3
8	1	Spacer Vane3-4
9	1	Vane n4
10	1	Spacer Vane4-5
11	1	Vane n5
12	1	Filter
13	1	Spacer Filter-Lens1
14	1	lens n1
15	1	Spacer Lens1-2
16	1	lens n2
17	1	Spacer Lens2-3
18	1	lens n3
19	1	Spacer Lens3-End
20	1	CMOS detector
21	8	screw M2x5_lowhead

Figure 25 : Payload assembly.

10.2 Material

The Payload frame, Spacer Filter-Lens1, Spacer Lens1-2, Spacer Lens2-3 and Spacer Lens3-End (see Figure 25) shall be made of Titanium Grade 5. The datasheet of this material is in Appendix D.

The five vanes shall be made of stainless steel 1.4310. The characteristics of this kind of steel can be found in Appendix E.

The closing cap and the four spacers between the vanes shall be made of aluminum Certal©. Its datasheet is in Appendix B.

10.3 Surface characteristics

The inner parts of the payload assembly (vanes, spacers between vanes and spacers between lens) should undergo a treatment in order to reduce the reflecting factor. This treatment will consist of a sanding and blackening of these parts. The suppliers of these treatments are stated in the *Fabrication plan*.

The contact area between the closing cap and the monobloc frame is 570 mm^2.

10.4 Fixation and mounting techniques

The interface between payload and monobloc frame is a planar surface as showed in Figure 26. The payload is attached with four M2 screws on the middle of the +X face of the SwissCube. For more info about the screws, see §16.1.

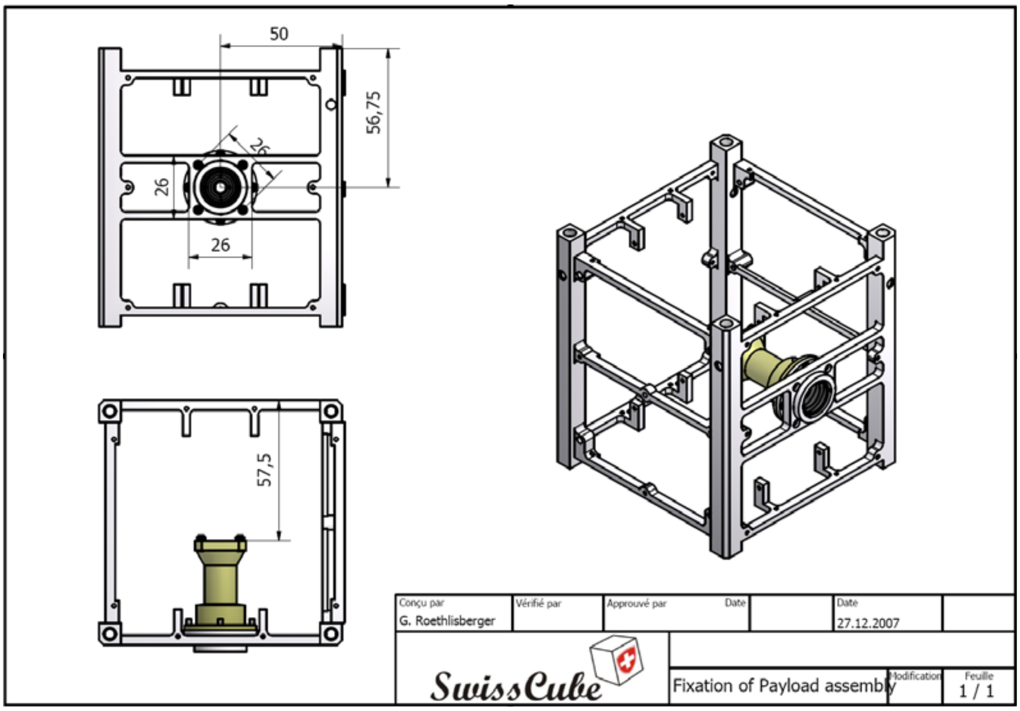


Figure 26 : Fixation of the payload assembly.

10.5 Connectors location

The electrical connection of the payload assembly is defined in §7.4.4.

10.6 Miscellaneous

The space system shall have a payload with a FOV as specified in requirement 2_PR_24_10.

alignment? TBD

11 RAIL ELEMENTS

Some components shall be located in the rails of the monobloc frame. These parts are four kill switches and four caps for the rails.

These four kill-switches are used to turn off all power of the SwissCube when compressed, so when stacked in the P-POD. The kill switches act also as separation springs which allow giving a relative velocity after deployment from P-POD to separate from the other CubeSats.

The passing holes of the four rails shall be closed by a cap to give a support to the springs of the other CubeSats.

11.1 Physical properties

The dimensions of a kill-switch shall be 6.0 x 17.1 mm (diameter x height).

The dimensions of a cap shall be 7.9 x 5.0 mm (diameter x height).

The kill-switch shall have a mass of no more than 0.65 grams.

The cap shall have a mass of no more than 0.67 grams.

11.2 Material

The nut of the kill-switch shall be made of aluminum Certal©. Its datasheet is in Appendix B. The spring is made of stainless steel. The contact parts are made of copper-beryllium, its datasheet is provided in Appendix H. The other parts are made of POM, its datasheet is in Appendix I.

The caps of the rails shall be made of aluminum Certal©. Its datasheet is in Appendix B.

11.3 Surface characteristics

The caps and threaded parts of the kill-switch shall be hard anodized to prevent cold-welding, reduce wear, and provide electrical isolation between the SwissCube and the P-POD.

After the Titanox (Ematal 78) treatment, the surface characteristics of the both external sides and extremities of the rails are:

- thickness of the layer 10-12 μm
- Roughness TBD Ra
- Vickers hardness 500 Vickers

- Heat capacity TBD $J \cdot mol^{-1} \cdot K^{-1}$
- Emissivity ε = TBD
- Absorptivity coefficient α = TBD
- Thermal conductivity TBD $W \cdot m^{-1} \cdot K^{-1}$
- Breakdown voltage 35-50 V/m

The contact area between the kill-switch nut and the monobloc frame is 75 mm^2.

The contact area between a cap and the monobloc frame is 124 mm^2.

11.4 Fixation and mounting techniques

This section describes the techniques of attachment on the monobloc frame for kill-switches and caps.

11.4.1 Kill-switch

The kill-switches should be located at the four +Z extremities of the rails (see Figure 2). The kill-switch subassembly should be inserted in the monobloc frame as specified in Figure 27. Afterwards, the threaded aluminum part (on the top of the kill switch in the following Figure) shall be used in order to loch the kill switch inside the satellite frame.

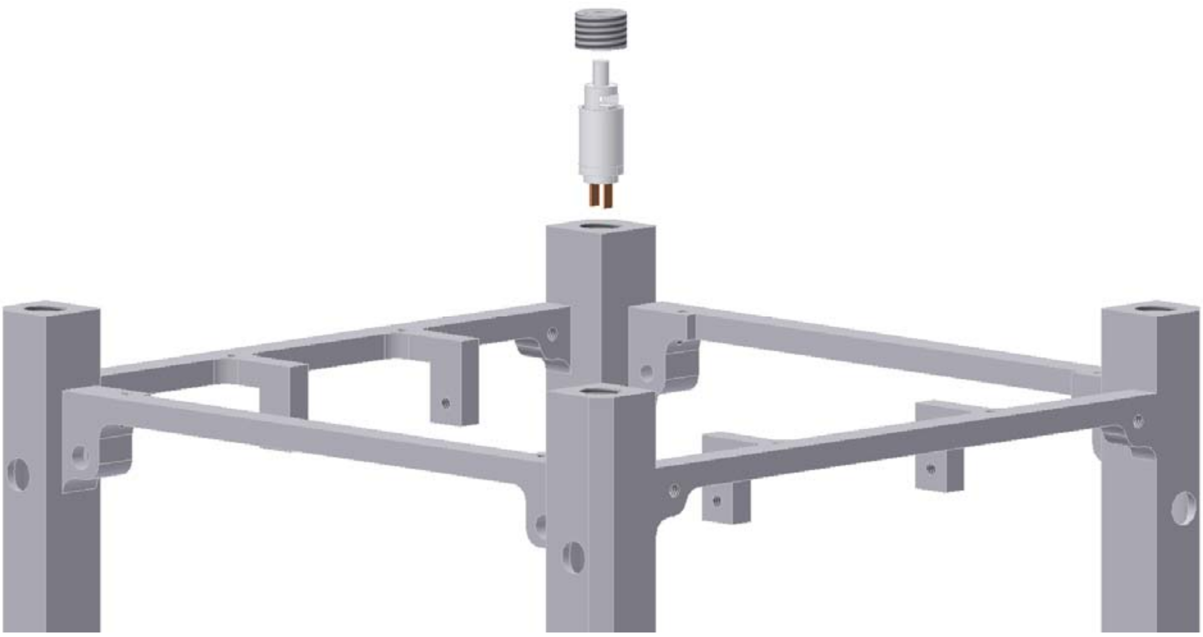


Figure 27 : Interface of the kill-switch.

11.4.2 Cap

Four cap should be used to close the -Z side of the rails. The dimensions of this part are shown in Figure 28. Epoxy should be used to bond these parts on the monobloc frame. The kind of epoxy will be EPO-TEK 920 or 3M EC2216.

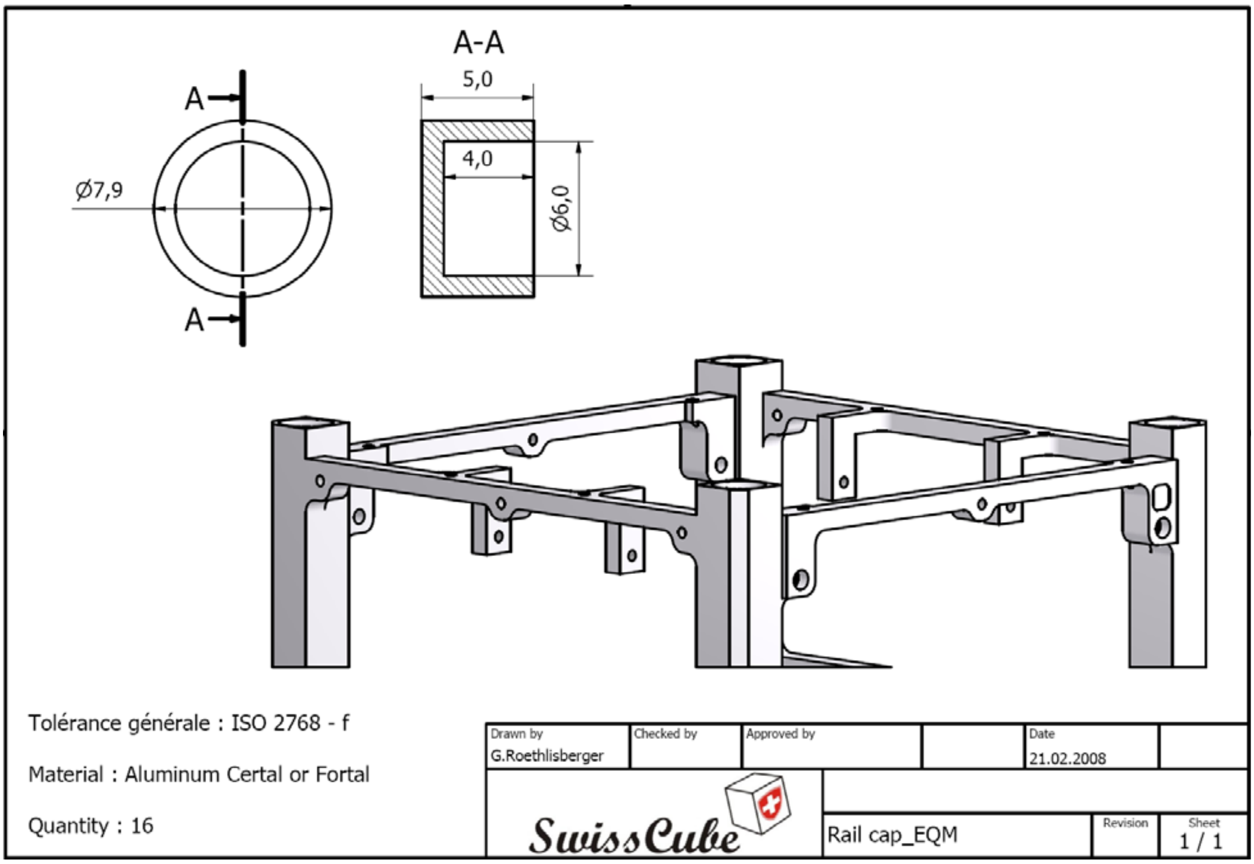


Figure 28 : Interface of the cap.

11.5 Miscellaneous

12 ADCS ACTUATORS

Three magnetotorquers are the main actuators and the only active actuators of the SwissCube. The mounting technique is the following: coils of around 250 spires should be glued to the interior face of the side plate or on the shielding plate.

12.1 Physical properties

The outer dimensions of a magnetotorquer shall be 80.0x 70.0 x 5.0 mm (height x width x thickness).

The mass of a magnetotorquer shall be no more than 29 grams.

12.2 Material

The magnetotorquer shall be composed of a copper wire a diameter of 150µm. To ensure the mechanical solidity, precise outer dimension, acceptable outgassing properties and to protect the coil, the whole magnetotorquer shall be moulded with a space-qualified epoxy resin named EPO-TEK 920. Its datasheet is provided in Appendix G.

12.3 Surface characteristics

The contact area between a magnetotorquer and the external panel or shielding plate is 1660 mm^2.

12.4 Fixation and mounting techniques

The magnetotorquers shall be placed on the following sides of the cube: -X, +Y and -Z (Figure 29). Magnetotorquers +Y and +Z shall be directly glued to the inner face of the corresponding shielding plates. Magnetotorquer -X shall be directly glued to the inner face of the -X plate. The kind of epoxy will be EPO-TEK 920 or 3M EC2216.

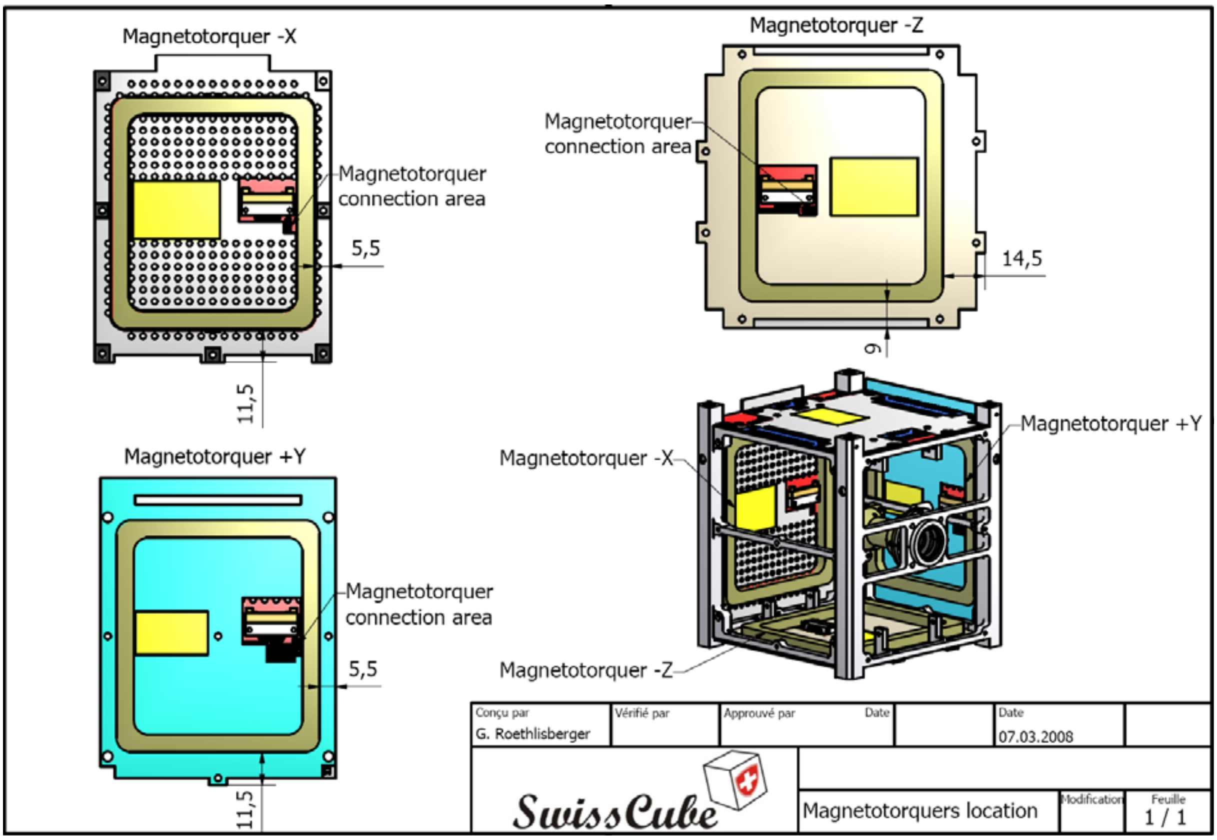


Figure 29 : Locations of the three magnetotorquers.

12.5 Connectors location

The electrical connection of the magnetotorquer to the corresponding external plate is defined in the previous Figure and in more details in Figure 21, Figure 22 and Figure 23.

12.6 Miscellaneous

Alignment? TBD

13 ADCS SENSORS

The sensors used for the ADCS system are:

- A 3-axis magnetometer (MM) AK8970N from Asahi Kasei. to measure the Earth's magnetic field (EMF) intensity and direction. These magnetometers are located on the ADCS board. The precise location will be defined during the routing of this PCB.
- Three 1-axis gyroscopes ADX RS614 from Analog Device measure the spinning rate for each axis. As the gyro electronic chip can measure only on axis, three chips are used by the ADCS. The first one is directly mounted on the ADCS PCB. The two remaining are mounted on a bracket that is screwed on the ADCS PCB.
- 6 Sun sensors (SS) provided by DTU to find the direction of the sun. These sensors are located on each external panels of the SwissCube.

13.1 Physical properties

The dimensions of a sun sensor shall be 8.1 x 8.1 x 1.0 mm (height x width x thickness).

The mass of a sun sensor shall be no more than 1 gram (TBC).

13.2 Material

NA

13.3 Surface characteristics

NA

13.4 Fixation and mounting techniques

13.4.1 Sun sensor

The sun sensor chip shall be glued on the external panel. The kind of glue needs to be defined. One sun sensor stands on each face of the satellite (six at all). The precise location of each sun senor is defined in Figure 20 to Figure 24 and in Figure 33.

13.4.2 Gyroscope

The first one is directly mounted on the ADCS PCB. The two remaining (X and Z) are mounted on a small PCB named gyro PCB, and then fixed on a bracket that is screwed on the ADCS PCB. For more detail see Figure 30.

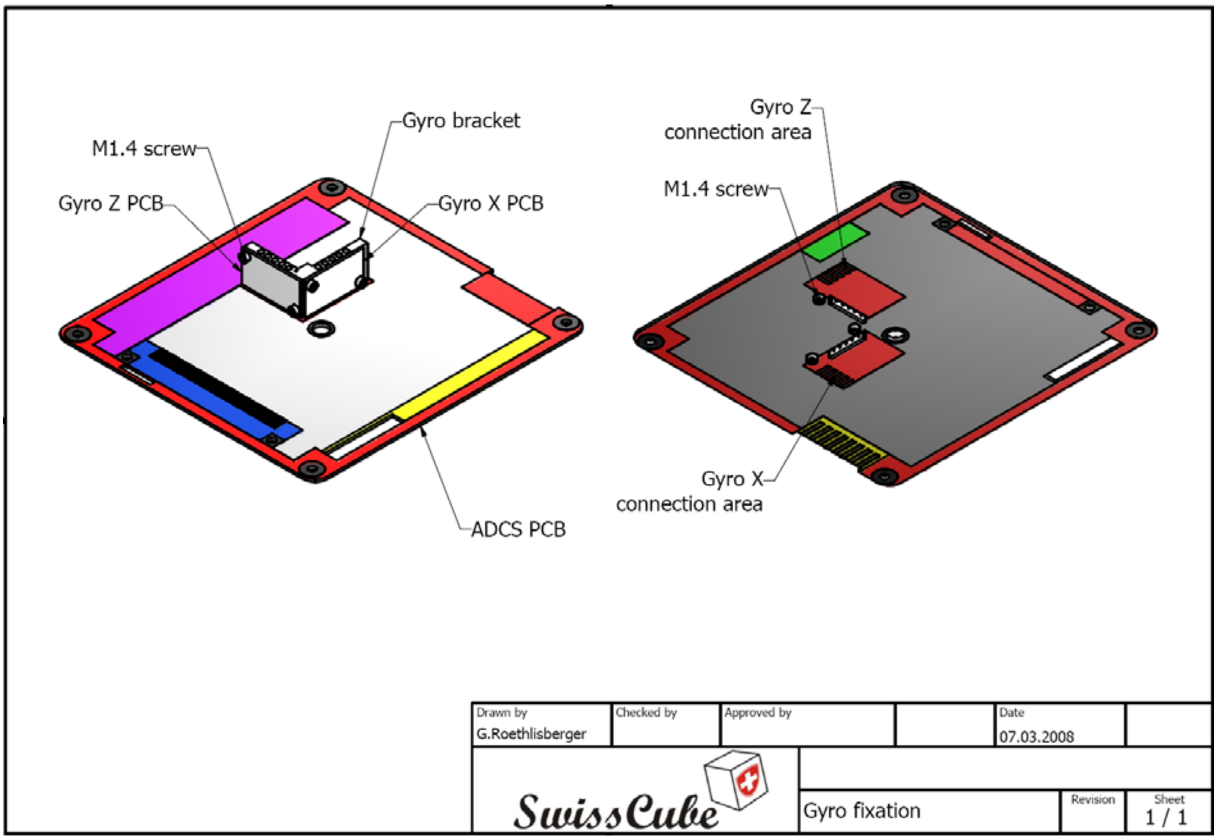


Figure 30 : Fixation and location of the X and Z gyroscopes.

13.5 Connectors location

13.5.1 Sun sensor

The sun sensors shall be glued on the side plate and electrically connected by wire bonding. Some glue will be used to protect these thin wires. The sun sensor footprint is provided in Figure 20.

The electronics for this detector shall be integrated directly on to the side panel which is a PCB. The reserved areas for this electronics are in yellow in Figure 20 to Figure 24.

13.5.1 Gyroscope

The connections between the both Gyro PCB and the ADCS PCB will be made via Kapton wires, directly welded on the both extremities. The connection areas are defined in Figure 30.

13.6 Miscellaneous

Alignment? TBD

Field of view? TBD

14 ANTENNA DEPLOYMENT SYSTEM

There are two antennas on the satellite. The first for downlink data is a 180 mm long UHF monopole antenna of 437.5 MHz frequency. The second one for uplink is a 610 mm long VHF monopole antenna using a frequency of 145.8 MHz.

As the antennas are longer than the satellite, they should be wrapped around an outside face of the satellite. They shall remain winded up during launch by a polymer fibre (dyneema) attached to the structure. After launching, this fiber shall be melted to deploy the antennas. The heat required for melting the fiber should be created by a current passing through a nichrome wire wrapped around the fiber.

14.1 Physical properties

The maximal outer dimensions of the antenna deployment system (ADS) shall be 106.0 x 81.0 x 10.5 mm (height x width x thickness (with the PCB solar cell and Omnetics connector).

The ADS shall have a mass of no more than 76 grams with Omnetics connector and both PCBs.

14.2 Material

The following Table summarizes the various materials and masses used for the ADS. For the denomination, see Figure 31. The various properties of these materials are stated in Appendices.

Table 1 : Components of the ADS and their material.

NAME	QUANTITY	MATERIAL	WEIGHT (GRAMS) PER PIECE	TOTAL WEIGHT
ADS PCB	1	FR4	24	24
Lower guide	1	POM	4.58	4.60
Upper guide	1	POM	2.607	2.60
Tensor	2	FR4	0.82	1.65
Resistor	2	-	0.2 (not confirmed)	0.4
Nichrome wire	2	Nichrome	--------	--------
Dyneema wire	1	Dyneema	--------	--------
Electrical cable	(for heater)	-	--------	0.10
Long antenna (with Kapton)	1	Copper-Brryllium	4.83	4.85
Small antenna (with Kapton)	1	Copper-Brryllium	1.426	1.45
Lock pin	4	Steel	0.05	0.2

Solar cells PCB	1	FR4	20.5	20.5
Solar cell	2	GaAs	2.45	4.90
Sun sensor	1	Si	1 (not confirmed)	1
Coax. Cable with RF connector	2	-	0.462	0.90
Spacer	4	Aluminum	0.1643	0.65
Omnetics connector	1	-	5	5
Screw M2x10 low head	4	Stainless Steel	0.23	0.90
Screw M2x5 low head	8	Stainless Steel	0.15	1.2
Nut M2	8	Stainless Steel	0.114	0.90
TOTAL				75.8

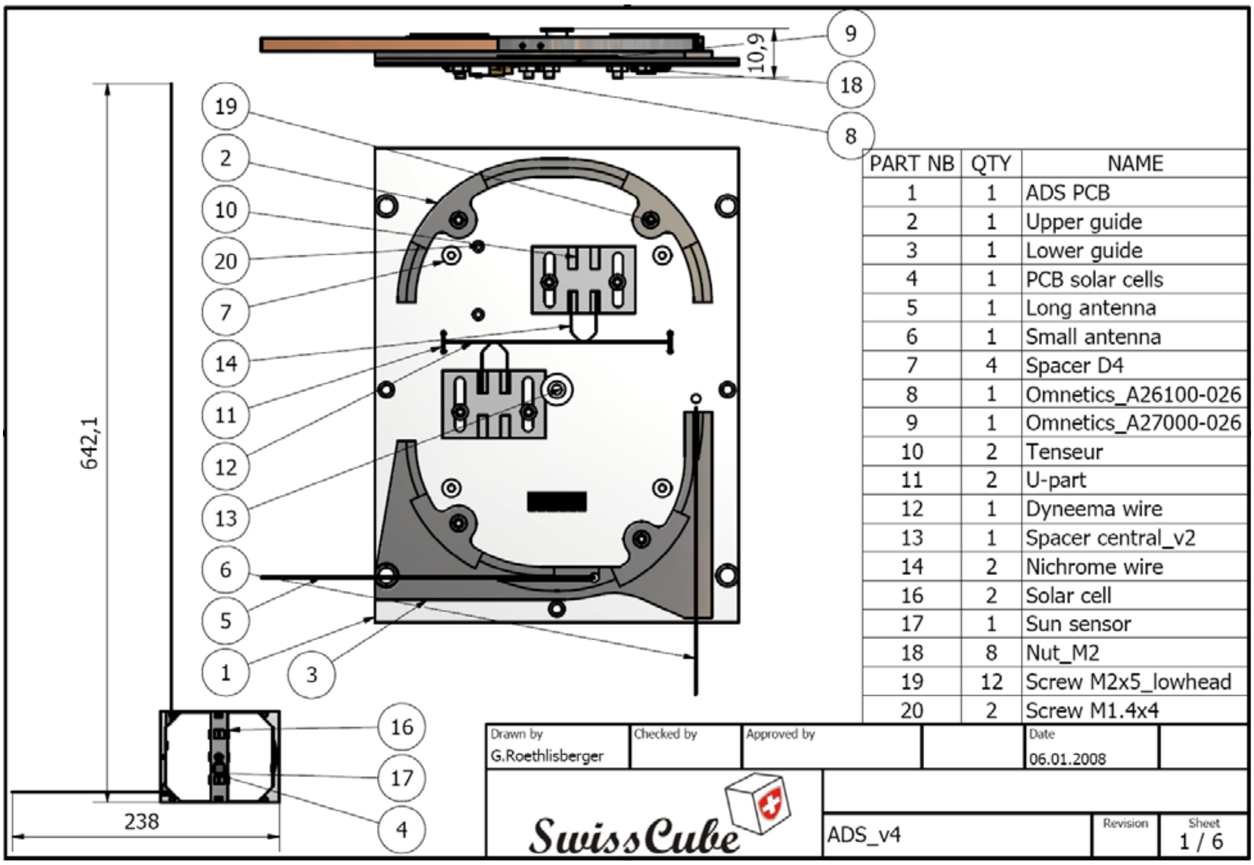


Figure 31 : ADS assembly.

14.3 Surface characteristics

The both PCBs will be covered with conformal coating. For more info see the *Fabrication Plan – Electrical parts* document.

The contact area between the ADS PCB and the monobloc frame is 940 mm^2.

14.4 Fixation and mounting techniques

The antenna deployment system shall be fixed to the -Y face of the SwissCube in the same way as the side plates (with 8 screws). The crossbars on the -Y face present an offset of 2.7 mm in direction of the center of the satellite. Therefore the thickness of the whole ADS shall be equal or lower than 10.5 mm including solar panels.

The both following figures describe the layout of the two PCBs, the position of the various connection zone and the restrictions concerning some areas.

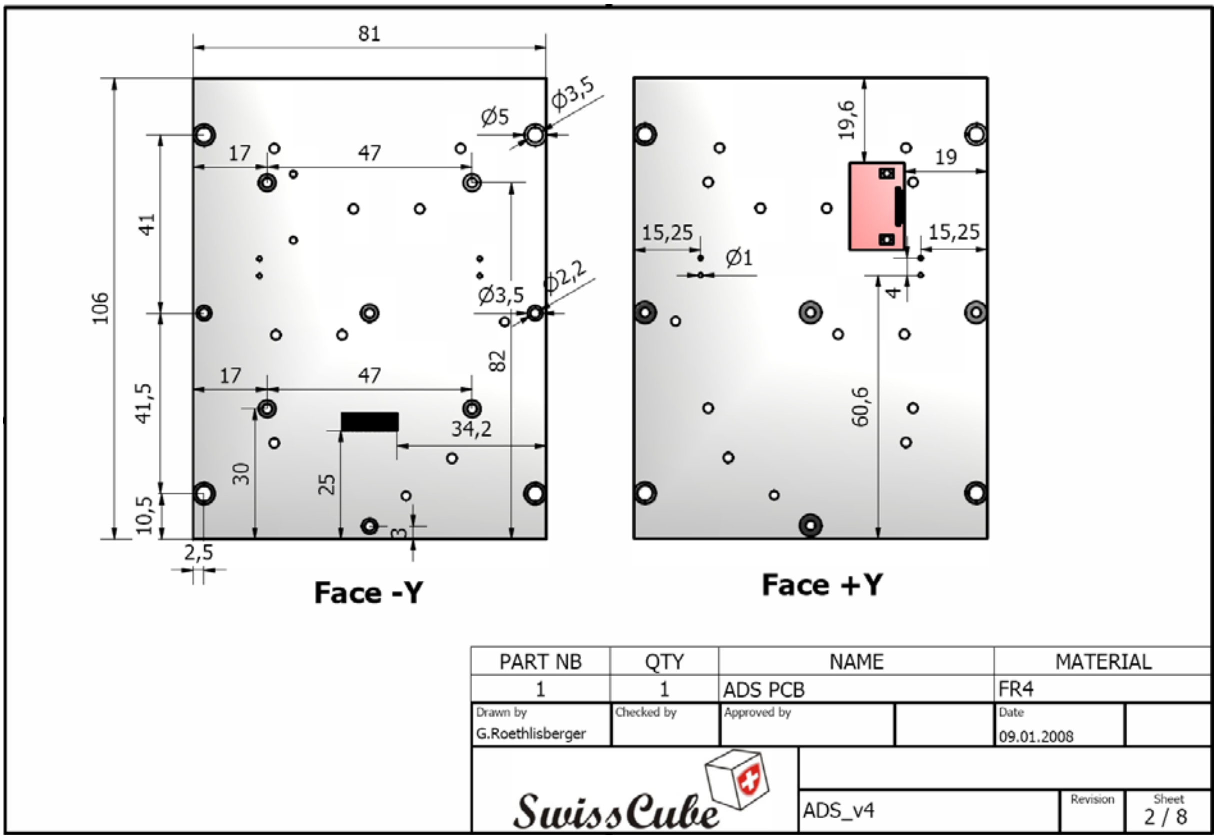


Figure 32 : ADS PCB layout.

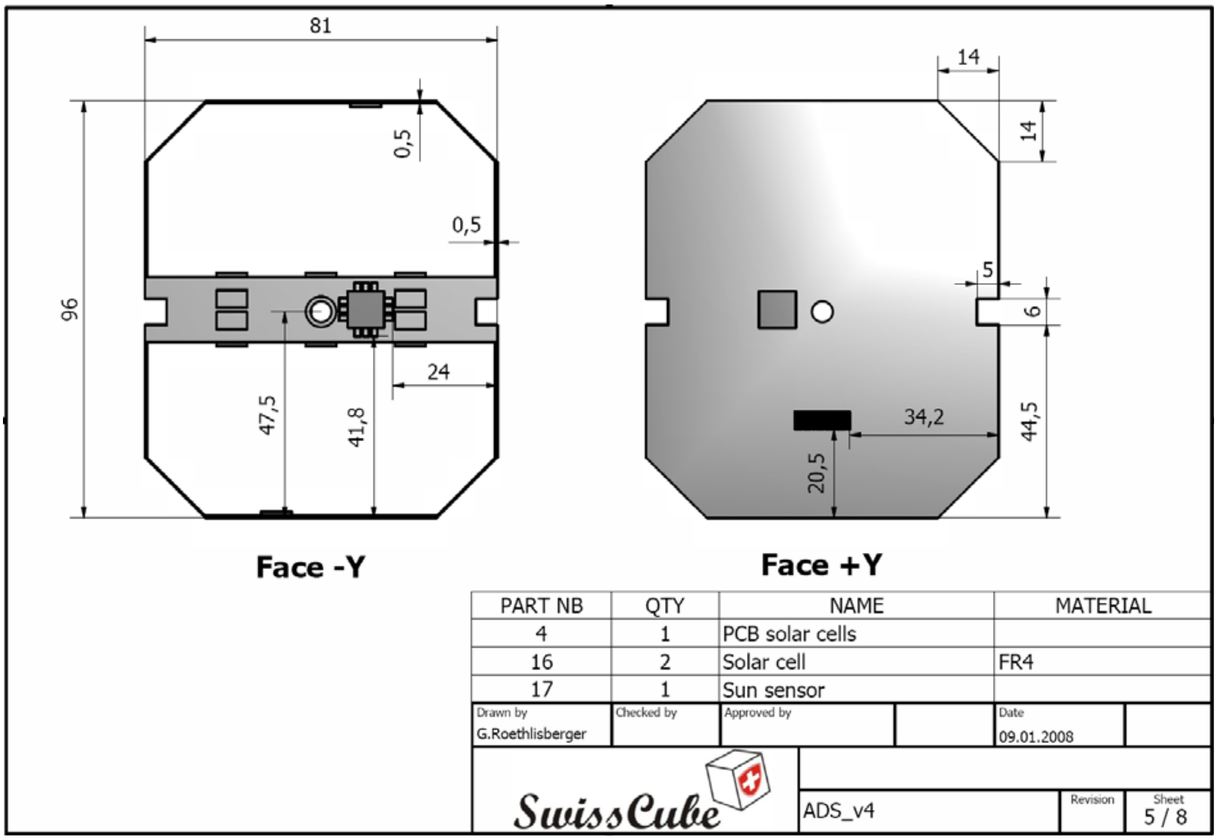


Figure 33 : Solar cells PCB layout.

14.5 Connectors location

RF cables will be soldered directly at the extremities of the both antennas. The other extremity of the RF cable will have a RF connector, in order to be connected to the COM board.

14.6 Miscellaneous

The antenna shall not point in +X direction in order to not disturb the FOV of the camera.

14.6.1 Electrical grounding

Both ADS PCBs have some electrical grounding areas. Every mechanical interface is connected to the ground. In Figure 32 and Figure 33 every black area that is not an Omnetics connector footprint is an electrical grounding area.

15 BATTERY SUBASSEMBLY

Under high vacuum, the battery block can undergo a physical expansion. To counteract this effect on SwissCube, it is enclosed in a milled aluminum box. Beside the need to protect the cell from the harsh environment, this is also a solution to provide mechanical interface between the battery cell and the satellite structure.

According to the results of thermal simulations and tests, the batteries will be insulated from the aluminum box with something like Kapton tape. An active thermal control of the battery subassembly will avoid extremely cold temperature for the both batteries. A dissipation system will be located onto a copper foil, itself between the both batteries. For more info about this active thermal control, see the electrical fabrication plan document.

15.1 Physical properties

The outer dimension of the box shall be 89.0 x 40.8 x 17.5 mm (height x width x thickness). The inner dimensions of the box shall be 66.0 x 39.0 x 11.7mm, (height x width x thickness) enough space for two batteries and a copper-beryllium foil (for the active thermal control).

The mass of the battery box shall be no more than 18.5 grams.

15.2 Material

The battery box should be made of aluminum Certal© (see Appendix B).

The main physical properties of this aluminum alloy are:

- Density $2.76\ g\cdot cm^{-3}$
- CTE $23.6\ ppm\ K^{-1}$
- Thermal conductivity $120\text{-}150\ W\cdot m^{-1}\cdot K^{-1}$
- Electrical conductivity $18\text{-}22\ MS\ m^{-1}$

15.3 Surface characteristics

The battery box will undergo a chromating surface treatment named Alodine 1200 S. The surface characteristics are:

- thickness of the layer 2-3 µm
- Roughness TBD Ra
- Vickers hardness TBD Vickers
- Heat capacity TBD $J \cdot mol^{-1} \cdot K^{-1}$
- Emissivity ε = TBD
- Absorptivity coefficient α = TBD
- Thermal conductivity TBD $W \cdot m^{-1} \cdot K^{-1}$
- Breakdown voltage TBD V/m

The contact area between the battery box and the monobloc frame and PCB spacers is 190 mm^2.

15.4 Fixation and mounting techniques

The box shall be attached to the structure at the -X side by the PCB-Screws as showed in Figure 29. Spacers in POM will be used in order to thermally isolate the battery box from the satellite structure.

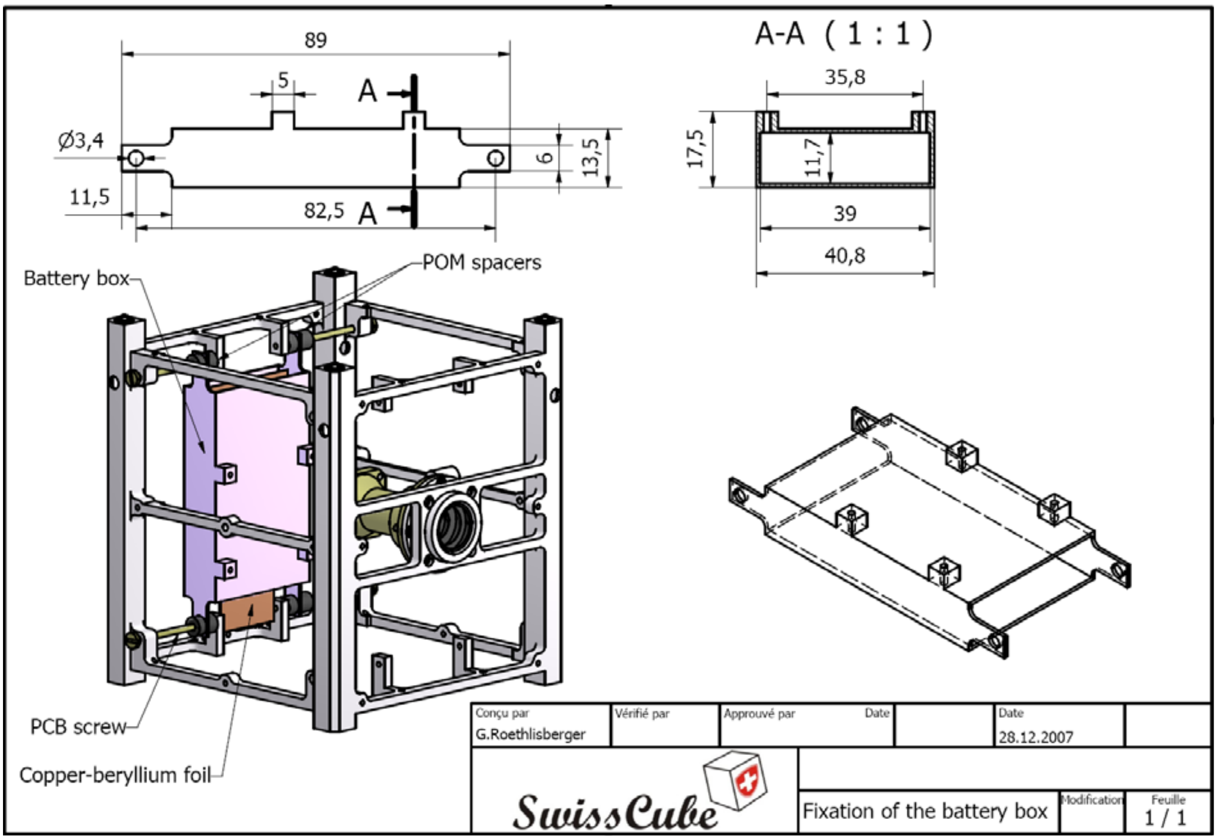


Figure 34 : Battery box dimensions and fixation technique.

15.5 Connectors location

The electrical connection of the battery assembly is defined in §7.4.1.

15.6 Miscellaneous

16 SCREWS

This section describes the various screws used in the SwissCube satellite.

16.1 M2 screws ISO 7380

To fix the side plates lens head screws (ISO 7380) made of stainless steel A4 shall be used (see Figure 35 and Appendix F). The Connection Board shall be attached to the Motherboard using this kind of screw.

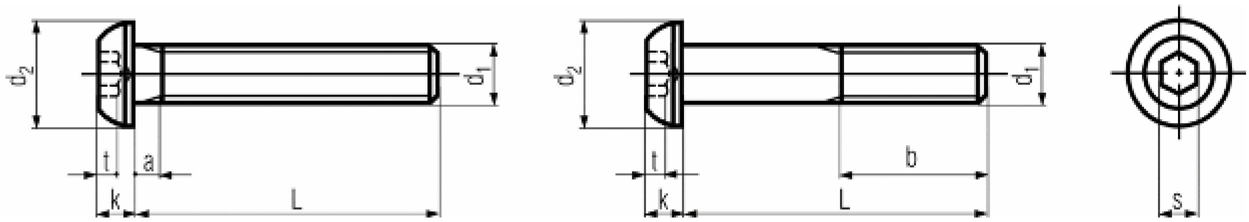


Figure 35 : Dimensions of lens head M2-screws (ISO 7380).

These parts are distributed by BOSSARD. All of these screws have a length of 5 mm except the ones for the top plate (+Z-face) which have to be 10 mm length. The other dimensions of these screws are listed in Table 2.

Table 2 : Parameters of M2 screws ISO 7380.

L	d_1	d_2	b	k	s	t
5	M2	3.5	-	1.3	1.3	0.6
10	M2	3.5	-	1.3	1.3	0.6

16.2 PCB screws

The PCB stacks and the battery box shall be fixed with special screws. The dimensions are showed in Figure 36. The material is stainless steel for the STM, and shall be Titanium (see Appendix D) for the EQM as well as FM.

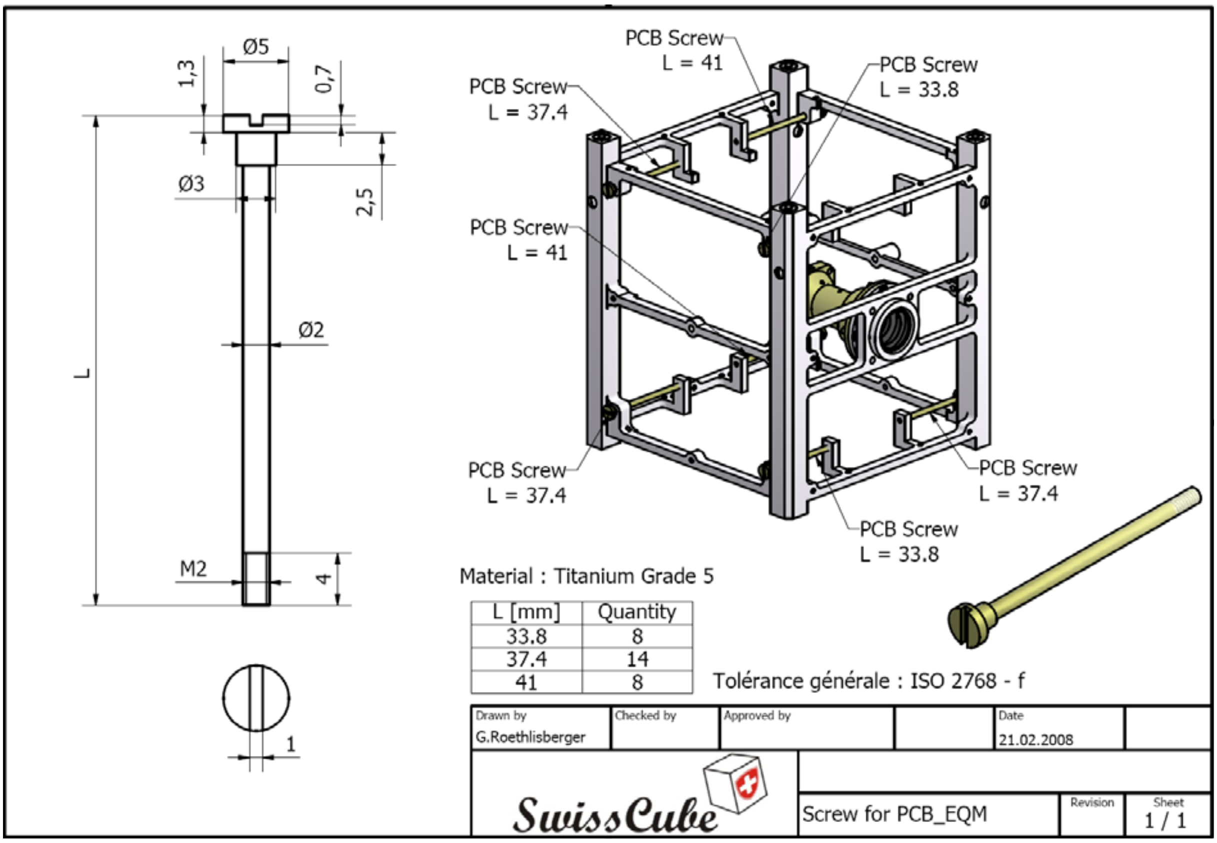


Figure 36 : Dimension and location of PCB-Screws.

Appendix A PCB substrate

Matsushita Electric Works Electronic Materials (Europe)
Specification Sheet

Specification sheet #:		IPC-4101A/92	
Reinforcement:	**1:**	Woven E-Glass	**2:** N/A
Resin System:	**Primary:**	Epoxy	
	Secondary 1:	Multifunktional Epoxy	**Secondary2: N/A**
Flame retardant mechanism:		Phosphorous	**Minimum UL94 Requirerment:** V-1
Fillers:		N/A	
ID Reverence:	**UL/ANSI:**	FR-4	**Mil-S-13949: N/A**
	ANSI:	FR-4/92	
Glass transition (TG):		110 °C - 150 °C	

Product Name: UL-Designation	**Laminate:**	**R-1566 / R-1566W** R-1566	**Prepreg:** **R-1551 / R-1551W** R-1551

1.Laminate		IPC Specification < 0,5 mm	IPC Specification > 0,5 mm	Units	Typical values < 0,50 mm	Typical values ≥0,5 mm	Test methode IPC-TM-650 (or as noted)
Physical property							
Peel strength, minimum A. Low profile and very low profile copper foil-all copper foil	18µm	0,7	0,7	N/mm	-	-	2.4.8 2.4.8.2 2.4.8.3
B. Standard profile copper foil	35µm	-	-		-	-	
1. after thermal stress		0,8	1,05		1,5	1,6	
2. at 125 °C		0,7	0,7		1,4	1,5	
3. after process solutions		0,55	0,8		1,5	1,6	
Moisture Absorptions, maximum		-	0,8	%	-	0,11	2.6.2.1
Flexural strength, minimum	A. Length direction	-	415	N/mm²	-	595	2.4.4
	B. Cross direction	-	345			412	
Flammability (laminate and prepreg as laminated)		V1 min.	V1 min.	rating	V0	V0	UL 94
CTE (pre/post Tg)		-	-	ppm/°C	-	-	2.4.24
Z		-	-		-	40/180	
X		-	-		-	13	
Y		-	-		-	15	
Young´s modulus X / Y		-	-	GPa	-	N/A	2.4.18.3
Poisson´s ratio X / Y		-	-	-	-	N/A	ASTM
Density		-	-	g/cm³	2,0	2,0	
Decomposition Temperature		-	-	°C	-	330	TGA
Electrical property							
Volume resistivity, minimum	A. 96/35/90	10^6	-	MΩ-cm	$5*10^7$	-	2.5.17.1
	B. after moisture resistance	-	10^6		-	N/A	
	C. at elevated temp. E-24/125	10^3	10^3		N/A	N/A	
Surface resistivity, minimum	A. 96/35/90	10^4	-	MΩ	$5*10^8$	-	2.5.17.1
	B. after moisture resistance	-	10^4		-	N/A	
	C. at elevated temp. E-24/125	10^3	10^3		N/A	N/A	
Dielectric breakdown, minimum		-	40	kV	-	> 50	2.5.6
Permitivity, maximum (laminate and prepreg as laminated)	at 1 MHz	5,4	5,4	-	N/A	4,95	2.5.5.2/3/9
	at 1 GHz	-	-	-	N/A	4,7	
Loss tangent, maximum (laminate and prepreg as laminated)	at 1 MHz	0,035	0,035	-	0,014	0,014	2.5.5.2/3/9
	at 1 GHz	-	-	-	0,011	0,011	
Arc resistance, minimum		60	60	sec	NI	NI	2.5.1
Electrical strength, minimum (laminate and prepreg as laminated)		30	-	kV/mm	49	-	2.5.6.2
CTI (comparative tracking index)		-	-	V	-	500	IEC 112
Thermal Property							
Thermal stress 10 sec at 288 °C, minimum	A. unetched	Pass	Pass	Rating	Pass	Pass	2.4.13.1
	B. etched	Pass	Pass		Pass	Pass	
Tg by DSC (TMA / DMA)		110 min	110 min	°C	152,7	153(145/180)	2.4.25
Thermal conductivity		-	-	W/mK	-	0,62	Laser flash
Specific heat		-	-	J/kgK	-	950	DSC
2. Prepreg Property		IPC-Specifikation		Units	Typical values		
Shelf life, minimum (from date of delivery)	A. condition <20 °C and <50 % rel. H.	90		Days	60		AABUS
	B. condition < 5 °C	180			180		
Volatile content, maximum		0,75		%	meets requirements		2.3.19
Prepreg parameters		-	-	-	AABUS		AABUS

AABUS = As Agreed Between User and Suppier

Note:

Test data contained in this data sheet represents typical values and does not constitute any warrenty or guarantee. For review of critical specification tolerances, please contact a Matsushita Electric Works representative. Matsushita Electric Works reserve the right to change these typical values as a natural process of refering our test equipment and technics.

Appendix B Aluminum Certal

Technical Datasheet

CERTAL®

EN AW-7022 / AlZn5Mg3Cu

Edition September 2001

ALCAN ROLLED PRODUCTS

Alcan Aluminium Valais Ltd t +41 27 457 51 11
CH-3960 Sierre, Switzerland f +41 27 457 65 15

BRIEF DESCRIPTION

Certal® thick plates have been optimised to provide excellent **machinability, shape stability** and **high strength.** Certal® is therefore ideal for industrial tools. Applications include injection and blow-moulds for plastic bottles, plastic containers and shoes as well as heating plates, mechanical guides, tooling supports, jigs and fixtures.

PROCESSING METHODS

Weldability

• TIG/MIG	possible
filler alloy	AA 5183
	AA 5356
• by resistance	good
Surface Treatments	
Anodizing	
• technical	good
• decorative	not adequate
Polishing	excellent
Hard Chroming	good
Chemical Nickel-Plating	good
Chemical texturing	well adapted
Machinability	excellent

AVAILABILITY

Certal® plates are delivered in temper T651 (quenched – stretched – artificially aged) in the following dimensions :

Thickness	Max. width
8.0 - 70 mm	2020 mm
71 - 90 mm	1820 mm
91- 120 mm	1520 mm
121- 140 mm	1020 mm

For thicknesses above 140 mm, the alloy Certal® SPC is recommended.

CHEMICAL COMPOSITION (weight %)

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti +Zr
max. 0.5	max. 0.5	0.5 1.0	0.1 0.40	2.6 3.7	0.1 0.3	4.3 5.2	max. 0.2

PHYSICAL PROPERTIES (nominal values)

Density	2.76 g/cm^3
Elastic Modulus	72000 MPa
Lin. thermal expansion coefficient (20°-100°C)	23.6 10^{-6} K^{-1}
Thermal conductivity (Temper T651)	120 - 150 W/mK
Electrical conductivity (Temper T651, 20°C)	18 - 22 MS/m

MECHANICAL STRENGTH

Min. tensile properties (Temper T651)[1)]

Thickness (over ... to)	Rm [MPa]	Rp0.2 [MPa]	A50 [%]
12.5 - 25 mm	540	460	8
25 - 50 mm	530	460	7
50 - 100 mm	500	420	6
100 - 140 mm	490	400	6

1) These guaranteed values are much higher than EN AW-7022 T651 values

Typical strength for various thicknesses

Thickness (over ... to)	Rm [MPa]	Rp0.2 [MPa]	A50 [%]	HB
8.0 - 25 mm	555	495	9	170
25 - 100 mm	550	495	8	165
100 - 140 mm	545	490	7	165

Appendix C Tantalum foil

Material Test Report

Manufacturer:NINGXIA NON-FERROUS METALS SMELTERY
ADD: P.O.BOX105, SHIZUISHAN CITY, NINGXIA 753000.P.R.CHINA
TEL:86-952-2019416 FAX:86-952-2012018 E-mail:nniec@public.yc.nx.cn

Manufacturer's job no.: INSPECTOR 1	Date: Dec.13,2007
Customer: COMETEC	P.O.: 911 158
Specification : ASTM B 708-98	Type:RO5200
Name of material: Ta Foil	Method of manufacturer: Electro-beam melted
Condition :Annealed	Surface: Up to grade
Size:0.1×170×Coil (mm)	Quantity: 1 Coil Net Weight:8.0kg
Lot No.: W2007-11-19-071213	Material No.:TD7008
Material Certificates EN 102043.1B	

1.Chemical Requirements and Analysis(PPM) Max, weight

Element	Requirements	Analysis Ingot
C	100	16
O	150	36
N	100	20
H	15	5
Nb	1000	<30
Fe	100	<5
Ti	100	<1
W	500	10
Mo	200	<10
Si	50	<10
Ni	100	<5
Ta	Remainder	Remainder

2. Chemical Requirements and Analysis of Finish Product (PPM) max, weight

Element	Requirements	Analysis Finish Product
O	250	36
N	100	20
H	15	5
C	200	16

3.Mechanical Properties

	Requirement	Results
Ultimate Tensile Strength min,psi(Mpa)	30000(207)	30668(211.5)
Yield strength min,psi (Mpa)(0.2% offest)	20000(138)	21750(150.0)
Elongation min,% (1 inch GL)	20	38.0

4. Dimension ,Flatness and Surface

The product is up to standard.

Quality Control Representative
Signature:

质量检验章

Appendix D Titanium Grade 5

TITAN Grade 5 (6Al-4V) W-Nr. 3.7165

Die Legierung Ti-6Al-4V ist die am meisten verwendete der Alpha-Beta Gruppe und ist die bekannteste aller Titanlegierungen. Bearbeitetes Material wird in der Luftfahrtindustrie, Medizin und anderen Anwendungen eingesetzt, bei denen eine gute Festigkeit im Verhältnis zum Gewicht, sowie gute korrosionsbeständige Eigenschaften gefordert werden. Weiter ist sie giesbar und findet vermehrt Anwendungen auch bei Sportgeräten.

Ti-6Al-4V alloy is the most widely used titanium alloy of the alpha-plus-beta class, and is also the most common of all titanium alloys. The alloy is castable and is utilized “as cast” in sporting goods. The wrought material is used in aerospace, medical, and other applications where moderate strength, good strength to weight, and favorable corrosion properties are required.

Produktformen Product Forms	Blech, Band, Stab, Draht, Gussteile, Schmiedestücke, Ringe und Knüppel	Sheet, Plate, Strip, Bar, Rod, Wire, Castings, Forgings, Rings and Billet
Normen und Bezeichnungen Major Specifications	UNS R56400 W-Nr.: 3.7165 ASTM B 265 / AMS 4911 (Blech, Band), ASTM B 348 / AMS 4928 (Stab) MIL-T-9046	UNS R56400 W-Nr.: 3.7165 ASTM B 265 / AMS 4911 (plate, sheet, strip), ASTM B 348 / AMS 4928 (bar) MIL-T-9046
Chem. Zusammensetzung Chemical Composition, %	**Grenzwerte** Ti .... Rest O .... 0.20 V .... 3.5/4.5 Fe .... 0.40 AL ... 5.50 - 6.75 H ... max. 0.015 N .... 0.05 C 0.08	**Limiting** Ti .... Remainder O .... 0.20 V .... 3.5/4.5 Fe .... 0.40 AL ... 5.50 - 6.75 H ... max. 0.015 N .... 0.05 C 0.08
Physikalische und thermische Eigenschaften Physical Constants and Thermal Properties	Dichte, lb/in³ .... 0.160 g/cm³ .... 4.43 Schmelzbereich, etwa. °F .... 3000 °C .... 1648 Beta Transus °F +/- 25 .... 1784 °C +/- 4 .... 980 Ausdehnungsbeiwert, 10^{-6} in/in • F 32 - 212°F .... 5.0 32 - 1200°F .... 5.9 32 - 600°F .... 5.3 32 - 1500°F .... 6.1 32 - 1000°F ..... 5.6 um/m • °C 0 - 100°C .... 9.1 0 - 649°C .... 10.7 0 - 316°C .... 9.6 0 - 816°C .... 11.0 0 - 538°C ...... 10.1 Wärmeleitfähigkeit, Btu • in/ft²•h•°F .... 3.9 W/m•°C .... 0.56 Elastizitätsmodul, 10^6 psi .... 16.5 Torsionsmodul, 10^6 psi .... 6.1 Spezifische Wärme, Btu/lb•°F .... 0.135 J/kg•°C .... 565.2 Glühtemperatur ganz °F .. 1300-1525°/15 min., -2 Std., AC °C ...... 704-838°/15 min., -2 Std., AC spannungsarm °F .... 900-1200°/1-4 Std., AC °C .... 495-659°/1-4 Std., AC Schmiedetemperatur Vorschmieden °F .... 1750 - 1800° °C .... 962 - 989° Fertigschmieden °F .... 1650 - 1750° °C .... 812 - 962°	Density, lb/in³ .... 0.160 g/cm³ .... 4.43 Melting Range, approx. °F .... 3000 °C .... 1648 Beta Transus °F +/- 25 .... 1784 °C +/- 4 .... 980 Coefficient of Expansion 10^{-6} in/in • F 32 - 212°F .... 5.0 32 - 1200°F ...... 5.9 32 - 600°F .... 5.3 32 - 1500°F ...... 6.1 32 - 1000°F .... 5.6 um/m • °C 0 - 100°C .... 9.1 0 - 649°C .... 10.7 0 - 316°C .... 9.6 0 - 816°C .... 11.0 0 - 538°C .... 10.1 Thermal Conductivity, Btu • in/ft²•h•°F .... 3.9 W/m•°C .... 0.56 Elasticity-Tension Modulus, 10^6 psi .... 16.5 Elasticity-Torsion Modulus, 10^6 psi .... 6.1 Specific Heat, Btu/lb •°F .... 0.135 J/kg • °C .... (565.2) Annealing Temp full °F ...... 1300-1525°/15 min., -2 hrrs, AC °C .... 704-838°/15 min., -2 hrs, AC stress relief °F .... 900-1200°/1-4 hrs, AC °C .... 495-659°/1-4 hrs, AC Forging Temp Blocking °F .... 1750 - 1800° °C .... 962 - 989° Finishing °F .... 1650- 1750° °C .... 812 - 962°
Typische mechanische Eigenschaften Typical Mechanical Properties	**(Geglüht)** — ksi / MPA Zugfestigkeit, RT .... min. 130 / min. 895 Streckgrenze, RT .... min. 120 / min. 826 Dehnung, % RT .... min. 10 (Bruch) Einschnürung, % Bar 25	**(Annealed)** — ksi / MPA Tensile Strength, RT .... min. 130 / min. 895 Yield Strength, RT .... min. 120 / min. 826 Elongation, % RT .... min. 10 Reduction of Area, % Bar 25

Appendix E Stainless Steel 1.4310

MatWeb Data Sheet

AISI Type 301 Stainless Steel (1.4310)

Material Notes:

Type 301 is a high strength grade of steel. Its resistance to atmosphere corrosion and its bright, attractive surface make it an excellent choice for decorative structural applications.

Component	Value	Min	Max
Carbon, C			0.15
Chromium, Cr		16	18
Iron, Fe		70.7	78
Manganese, Mn			2
Nitrogen, N			0.1
Nickel, Ni		6	8
Phosphorous, P			0.045
Sulfur, S			0.03
Silicon, Si			1

Properties	Value
Physical	
Density, g/cc	8.03
Mechanical	
Hardness, Brinell	217
Tensile Strength, Ultimate, MPa	515
Tensile Strength, Yield, MPa	205
Elongation at Break, %	40
Modulus of Elasticity, GPa	212
Electrical	
Electrical Resistivity, ohm-cm	7.20E-05
Magnetic Permeability	max 1.02
Thermal	
CTE, linear 20°C, µm/m-°C	16.6
Specific Heat Capacity, J/g-°C	0.5

Appendix F Stainless Steel 316

AISI Type 316 Stainless Steel

Material Notes:
Molybdenum content increases resistance to marine environments. High creep strength at elevated temperatures and good heat resistance. Biocompatible. Fabrication characteristics similar to Types 302 and 304.

Component	Value	Min	Max
Carbon, C	0.08		
Chromium, Cr			18
Iron, Fe	62		
Manganese, Mn	2		
Molybdenum, Mo			3
Nickel, Ni			14
Phosphorous, P	0.045		
Sulfur, S	0.03		
Silicon, Si	1		

Properties	Value	Comments
Physical		
Density, g/cc	8	
Mechanical		
Hardness, Rockwell B	79	
Tensile Strength, Ultimate, MPa	580	
Tensile Strength, Yield, MPa	290	
Elongation at Break, %	50	in 50 mm
Modulus of Elasticity, GPa	193	in tension
Electrical		
Electrical Resistivity, ohm-cm	7.40E-05	at 20ºC
Magnetic Permeability	1.008	at RT
Thermal		
CTE, linear 20°C, µm/m-°C	16	0 - 100ºC
Specific Heat Capacity, J/g-°C	0.5	from 0-100°C (32-212°F)
Thermal Conductivity at Elevated Temperature, W/m-K	16.3	100ºC

Appendix G EPO-TEK 920

EPOXY TECHNOLOGY

DATA SHEET

EPO-TEK

920

Thermally Conductive Epoxy

Rev. II
5/98

TYPICAL PROPERTIES

(To be used as a guideline only)

NUMBER OF COMPONENTS .... Two

MIXING RATIO PARTS BY WEIGHT
Part "A" (mix thoroughly) 100
Part "B" (hardener) 3
Part "A" and Part "B" (hardener) should be thoroughly mixed until color is uniform.

CURE SCHEDULE (minimum bond line temperature - use one of the following)
150°C .... 5 minutes
120°C .... 10 minutes
100°C .... 20 minutes

PHYSICAL PROPERTIES
Color .... off white
Consistency .... smooth, flowing paste
Viscosity (@ 23°C/20 rpm) ..... 12,000 - 25,000 cPs
Glass Transition Temp. (Tg)
cured @ 150°C/1 hour .... > 90°C
Coefficient of Thermal Expansion
Below Tg .... 36×10^{-6} in/in/°C
Above Tg .... 157×10^{-6} in/in/°C
Lap Shear Strength (Al to Al) .... 3,300 psi

ELECTRICAL - THERMAL PROPERTIES
Volume Resistivity .... 1.5×10^{15} ohm-cm
Dielectric Strength .... 490 V/mil
Dissipation Factor (1 MHz) 0.035
Dielectric Constant (1 MHz) 4.8
Thermal Conductivity .... 1.1 W/m°K

POT LIFE .... 8 hours

SHELF LIFE
One year when stored at room temperature.

DO NOT REFRIGERATE

EPO-TEK 920 is a two component thermally conductive epoxy designed for dissipating heat from electronic components. It has good electrical insulating properties and can be used as an adhesive, coating or a sealing compound. Specific recommendations and assistance is available for potting applications.

EPO-TEK 920 is a smooth flowing paste with good wetting properties. It has excellent handling characteristics and is readily applied with a spatula, brush, plastic applicators or with commercial dispensing equipment.

EPO-TEK 920 is designed for use in production applications with the production engineer in mind. In addition to a long pot life, EPO-TEK 920 can be cured at low temperatures in a relatively short time. Another unique feature is that a definite built-in color change occurs when the system is cured. The color ranges from a definite strong tan to a deep red depending upon the thickness of the sample and the curing cycle that is used. This color changing characteristic of the cured epoxy is unique and can be very desirable in production applications. Another important property is that the hardener is non-staining and does not require heating-up due to crystallization.

EPOXY TECHNOLOGY, INC. 14 Fortune Drive Billerica, MA 01821-3972 USA
PHONE: 978.667.3805 1.800.227.2201 **FAX:** 978.663.9782

Appendix H Berylco

NGK BERYLCO FRANCE

Quai Emile Praf _ BP 17 - 44220 COUERON - TEL 33 (0)2 40 38 67 50 - FAX 33 (0)2 40 38 09 95 - http://www.ngkbf.com

CERTIFICAT DE CONTROLE & DE CONFORMITE

CERTIFICATE OF INSPECTION AND CONFORMITY
Certificate 3.1 according to EN 10204

N°CDE CLIENT *Customer order n°*	Client - *Customer*	Référence NGK *NGK BF reference*
Fax du 12.06.06	GLUCYMET Gibelinstrasse 27 04503 Solothurn/SCHWEIZ SUISSE	2006-02143

ALLIAGE: CuCo2Be

Produit: Rlx B10 ½ HT 0,3 mm
Spécification client: Glucymet (EPFL)

Largeur : *Width* 37.00

Poids: *Weight* 0.40

COMPOSITION CHIMIQUE- *Chemical Composition*

	TOLERANCES *Required* Mini	Maxi	N° COULEE *Heat n°* A7731-000000007	
Be	0.400	0.700	0.530	%
Co	2.000	2.800	2.470	%
Fe		0.200	0.020	%
Ni		0.300	0.016	%

CARACTERISTIQUES du METAL LIVRE - *Proprieties as Supplies*

CHARGE RUPTURE Tensile Strength	750	900	787	N/mm²
ALLONGEMENT Elongation	5		14	%
DURETE VICKERS Hardness	215	265	239	HV
LIMITE ELASTIQUE Yield Strength	650	850	718	N/mm²

Appendix I Polyoxyméthylènes (POM)

dynatec et son équipe sont à même de vous trouver des solutions parfaitement adaptées à vos besoins.

	Désignation selon DIN	Méthode ISO (IEC)	UNITÉ	POM H
	Couleurs			blanc / noir
	Poids moléculaire (selon Margolies)		$10^6 g*mol^{-1}$	-
	Densité	1183	$g*cm^{-3}$	1,43
ABSORBTION	Conditionné dans l'eau à 23° C pendant 24/96 heures (1)	62	mg	18/36
		62	%	0,21/0,43
	Climat normal 23° C, 50% d'humidité relative		%	0,20
	Conditionné dans l'eau à 23°C	-	%	0,85
PROPRIETES THERMIQUES	Température de fusion	-	°C	175
	Température de transition vitreuse	-	°C	-
	Conductibilité thermique à +23°C	-	W/(m*K)	0,31
	COEFFICIENT DE DILATATION THERMIQUE			
	Valeur moyenne entre +23°C et + 60°C	-	k^{-1}	$95*10^{-6}$
	Valeur moyenne entre +23°C et 100°C	-	k^{-1}	$110*10^{-6}$
	Valeur moyenne entre +23°C et 150°C	-	k^{-1}	-
	Valeur moyenne au-delà +150°C	-	k^{-1}	-
	Tenue à la déformation thermique (A=1,8N/mm²)	75	°C	115
	Température Vicat (VST/B50)	306	°C	-
	TEMPÉRATURE MAXIMALE D'UTILISATION EN CONTINU			
	de courte durée (2)	-	°C	150
	Pendant 5000/20000 heures (3)	-	°C	105/90
	Température minimale d'utilisation en continu (4)	-	°C	-50
	COMPORTEMENT AU FEU (5)			
	«Index d'oxygène»	4589	%	15
	Selon UL 94 (à 1,5/3/6 mm)	-	-	-/HB/HB
PROPRIETES MÉCANIQUES à +23°C (*)	Essai de traction (éprouvette de type 1-B)			20 mm/min.
	Contrainte de traction	527	$N*mm^{-2}$	78
	Contrainte de rupture	527	$N*mm^{-2}$	-
	Allongement spécifique	527	%	-
	Allongement de rupture	527	%	35
	Module d'élasticité (vitesse: 1mm/min.)	527	$N*mm^{-2}$	3600
	Essai de traction en continu (6)	899	$N*mm^{-2}$	15
	ESSAI DE COMPRESSION (VITESSE: 1 MM/ MIN.) (7)			
	à 1% de déformation	604	$N*mm^{-2}$	22
	à 2% de déformation	604	$N*mm^{-2}$	40
	à 5% de déformation	604	$N*mm^{-2}$	75
	RÉSILIENCE (8)			
	Résilience entaille Izod	180	$kJ*m^{-2}$	10
	Résilience Charpy	179	$kJ*m^{-2}$	>200
	Résilience entaille Charpy	179	$kJ*m^{-2}$	10
	DURETÉ			
	Dureté à la bille	2039-1	$N*mm^{-2}$	160
	Dureté Rockwell	2039-2	-	M88
	Dureté Shore	868	-	-
	Coefficien de frottement cinématique (10)	-	-	0,15-0,35
PROPRIETES ÉLECTRIQUES à +23°C (*)	Tension de claquage (11)	(243)	$KV*mm^{-1}$	20
	Résistivité	(93)	Ohm*cm	$>10^{14}$
	Résistance de surface	(93)	Ohm	$>10^{13}$
	Coefficient diélectrique à 100 Hz	(250)	-	3,8
	Coefficient diélectrique à 1 MHz	(250)	-	3,8
	Coefficient de perte (tan) à 100 Hz	(250)	-	0,003
	Coefficient de perte (tan) à 1 MHz	(250)	-	0,008
	Comparaison au fluage	(112)	CTI	600