Aalto-1
Experiment Interface Document

Aalto University

School of Electrical Engineering

	Name	**Signature**	**Date**
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Change Log

Date	Version	Pages	Description of change
17.6.2011	1	all	Initial release
24.08.2011	2	all	PDR version
28.9.2011	3	all	Minor updates and corrections
1.11.2011	4	all	PDR RID revision
30.3.2012	5	all	• BUS pin layout changed (IMPORTANT) • Updates in Science Team • general clean-up • CORRECTED COORDINATE SYSTEMS, IMPORTANT!! (figures 3.3 and 3.4)
08.01.2013	6	3, 2.4	• ”3 System description” chapter shortened to include only system description. New chapter ”4 Payload engineering requirements and interfaces” created. • ”2.4 Killer requirements” combined with Technological requirements (2.3.1)
16.10.2013	7	17,21-23	Updated the pin configuration figure, minor updates and corrections to payload section. Added a reference to most recent pinout document. This version was updated for payload CDR. Corrected naming of figures 2.5 and 2.6

Contents

1 Introduction

1.1 Scope

This document's purpose is to give a comprehensive executive overview on the Aalto – 1 satellite and its mission to any outside parties. It also works as an introduction to personnel joining the project.

1.2 Applicable Documents

1.3 Reference Documents

1. "CubeSat Design Specification", Rev. 12, 1.8.2009
2. "Cubesat Kit PCB Specification", Rev. A5
3. "PC/104 Specification", v. 2.5, Nov 2003
4. "Launch Services Program Level Poly Picosatellite Orbital Deployer (PPOD) and CubeSat Requirements Document", NASA Launch Services Program, Rev. Basic, 24.7.2009
5. "General Environmental Verification Standard (GEVS)", GSFC-STD-7000, 4/2005
6. ECSS-Q-ST-30-02C - Failure modes, effects (and criticality) analysis (FMEA/FMECA), 6.3.2009
7. ECSS-Q-ST-30-11C - Derating - EEE components, 31.7.2008
8. ECSS-Q-ST-70-08C - Manual soldering of high-reliability electrical connections, 6.3.2009
9. A1-M-MA-01-v2 Document Format Description and Document Control, version 2, 20.12.2011
10. A1-THE-TN-02-V1 Thermal Interface Document
11. AALTO – 1 NANOSATELLITE – TECHNICAL DESCRIPTION AND MISSION OBJECTIVES, Geoscientific Instrumentation, Methods and Data Systems.
12. A1-SYS-IF-01-v6 Satellite Bus Pinout
13. A1-OBH-DS-03-v6 OBC Communication Protocol

1.4 Abbreviations and Acronyms

Aalto-1	The student satellite developed in this project. The name covers both, the project and the satellite.
Aalto ELEC	Aalto University School of Electrical Engineering
ABCL	As-Built Configuration Data List
ADACS / ADCS	Attitude determination and control system
ADS	Antenna Deployment System
AIT	Assembly, Integration and Test
BCR	Battery Charge Regulator
CIDL	Configuration Item Data List
COTS	Commercial-off-the-shelf
CSK	CubeSat kit
CubeSat	a common nanosatellite standard

ECSS	European Cooperation for Space Standardization
EID	Experiment Interface Document
EM	Engineering Model
EPB	Electrostatic Plasma Brake
EPS	Electrical Power System
FMECA/FMEA	Failure modes, effects (and criticality) analysis
GSFC	Goddard Space Flight Center
HISPICO	Highly Integrated S-Band transmitter for Pico- and Nanosatellites
ICD	Interface control document
ITAR	International Traffic in Arms Regulations
LEO	Low - Earth orbit
LV	Launch Vehicle
MIL	Military grade component
MPPT	Maximum Power Point Tracker
NCR	Nonconformance Report
NRB	Nonconformance Review Board
OBC	On-Board Computer
P-POD	Poly-PicoSatellite Orbital Deployer
PAP	Product Assurance Plan
PCB	Printed Circuit Board
PCM	Power Conditioning Module
PDM	Power Distribution Module
PDR	Preliminary Design Review
PC/104	Stackable embedded computer bus standard
PFM	Proto-Flight Model
RBF	Remove Before Flight
RD#	Reference Document #
S/C	Spacecraft
S-Band	Radio frequencies between 2 and 4 GHz
SBC	Single board computer
SPEC	Spectrometer
T&C	Telemetry and Command
TBC	To Be Confirmed
TBD	To Be Defined
TVT	Thermal-Vacuum Test
TXRUV	ISIS VHF/UHF transceiver for small satellites
UHF	Ultra High Frequency, 300 MHz - 3 GHz
VHF	Very High Frequency, 30 MHz - 300 MHz

2 System Interfaces

2.1 Mission and System Overview

Aalto-1 is a three-unit (3U) CubeSat [RD1] with 3-axis stabilization.

It carries three very different payloads, all having specific attitude and communication requirements. The general interface diagram of the system is shown in Figure 2.1.

The satellite’s mission consists of two particular phases: a technology demonstration phase, following the initial commissioning phase. During this phase, the technology behind the two main payloads, the AaSI and the RADMON will be demonstrated.

After this, the actual science phase can begin. This phase is divided into two particular subphases, during the first of which the remote sensing payloads AaSI and RADMON will be operated, while the latter will be dedicated to the plasma brake operation. This division of the science phase is primarily due to the different and demanding attitude knowledge and control requirements of each payload.

The whole mission is aimed to last 2 years (TBD).

More on the details of the mission can be found in release [RD11].

Dimensions (X, Y, and Z, see Figure 2.3 and Figure 2.4) of the satellite are 100.0 mm x 100.0 mm x 340.5 mm. The PCB-boards will be stacked into two different stacks: the long stack and the short stack (Figure 2.11 & Figure 2.12). The stack in the –Z end (the short stack) is rotated 90 degrees. The long stack will house the radios, EPS, OBC, AaSI and ADACS while the short stack houses the RADMON and EPB.

The PCB's will follow the CubeSat Kit (CSK) layout in order to maximize compatibility to commercially available subsystems. The interior of the satellite is also divided into slots: each cube has several slots. Dimensions of a single slot are identical to the dimensions of a single PCB defined by the CSK standard. The Satellite is powered by solar panels fixed on the satellite's frame. The standard CubeSat structure is compatible with the Poly-Picosatellite Orbital Deployer (P-POD), which is developed by California Polytechnic State University and is used to launch and deploy the Cubesats of right format from the launch vehicle. Aalto -1 is also compatible with the ISIS deployer, ISIPOD.

The satellite is divided into several task-specific subsystems which are as follows:

- Onboard Computer System (OBC)
- Navigation System (iADCS + GPS)
- Communication System (COM)
- Electrical Power System (EPS)
- Structural Frame System (STR)
- Payload Systems (PL ; AaSI, RADMON, PB)

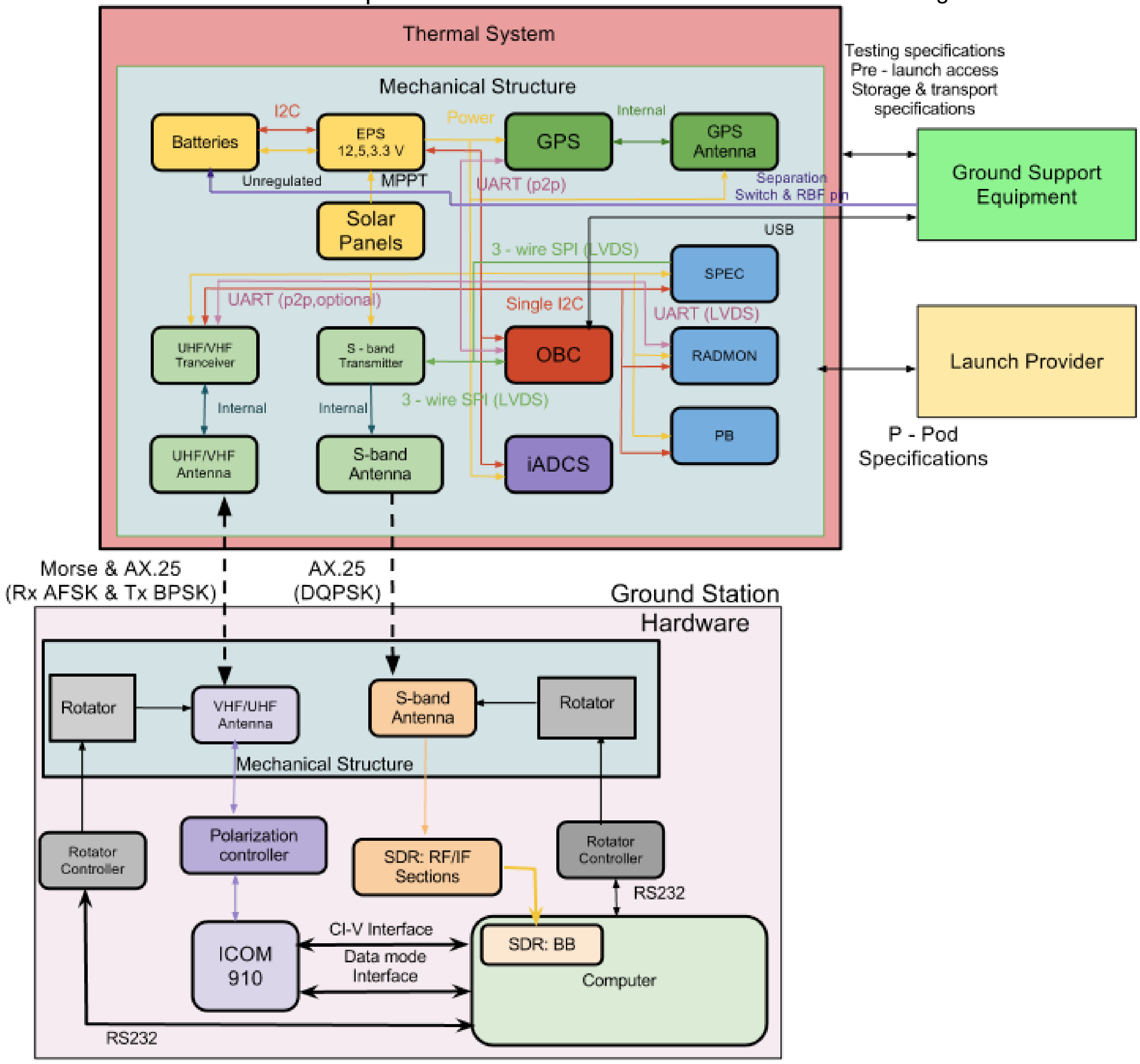

Figure 2.1: Aalto – 1 general interface diagram.

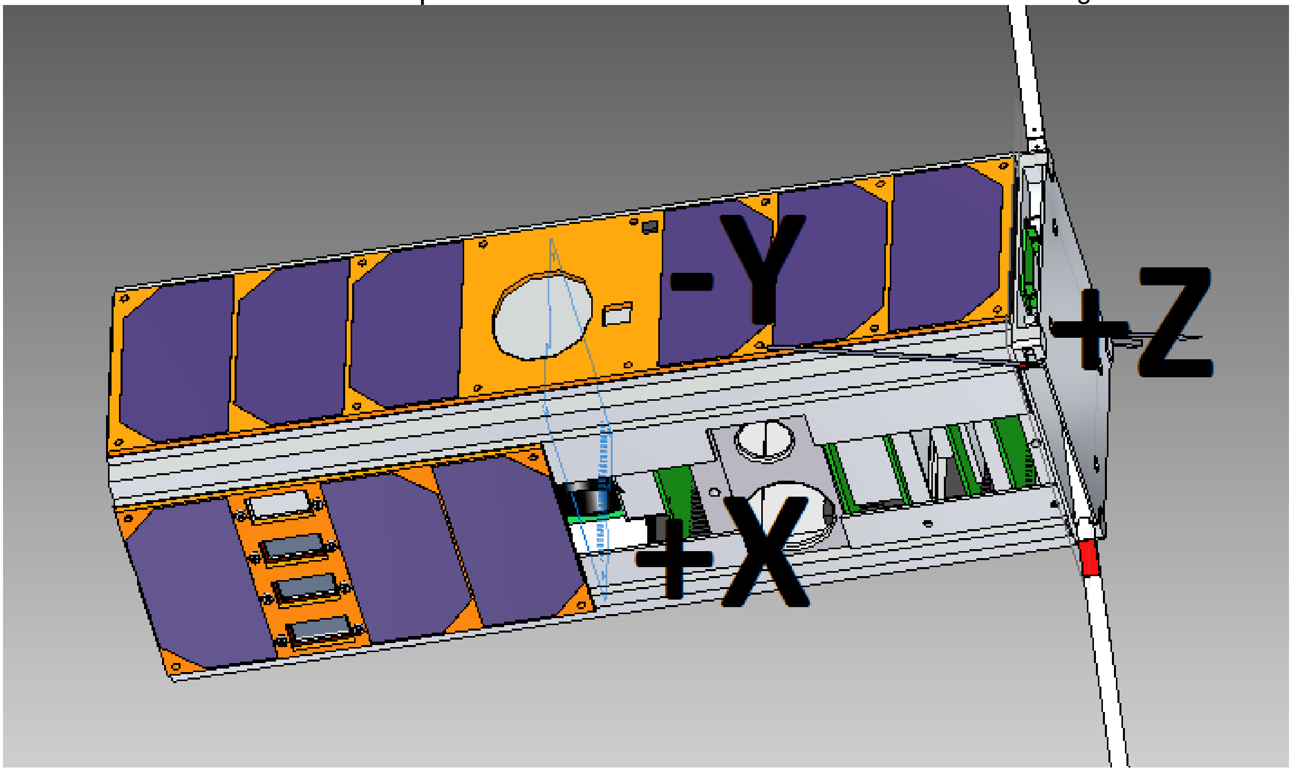

Figure 2.3: Outer frame of the satellite

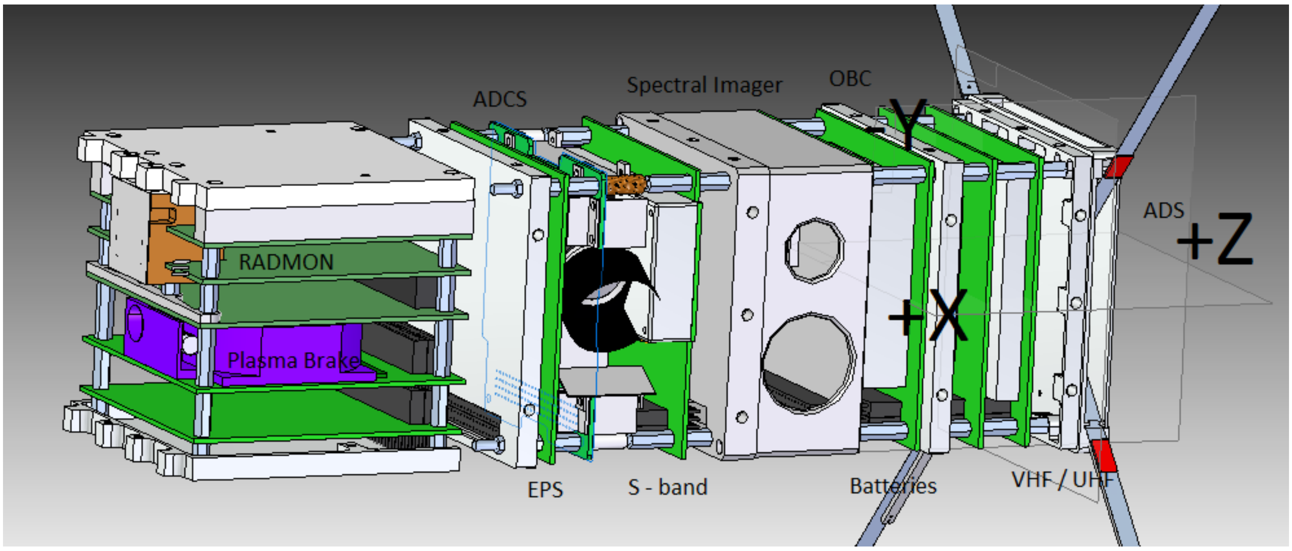

Figure 2.4: Stack model of the Aalto-1 satellite

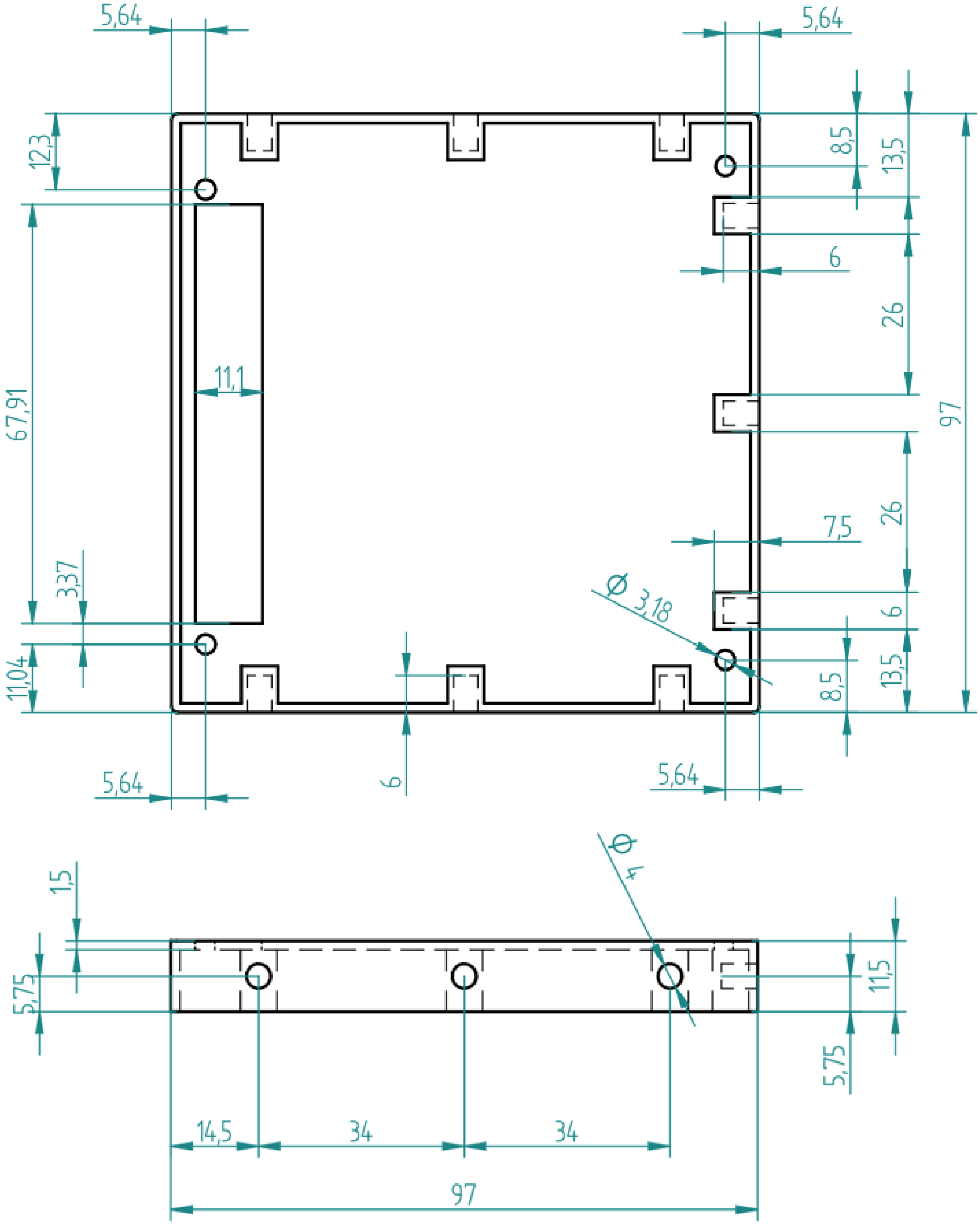

Figure 2.5: Long stack support plate

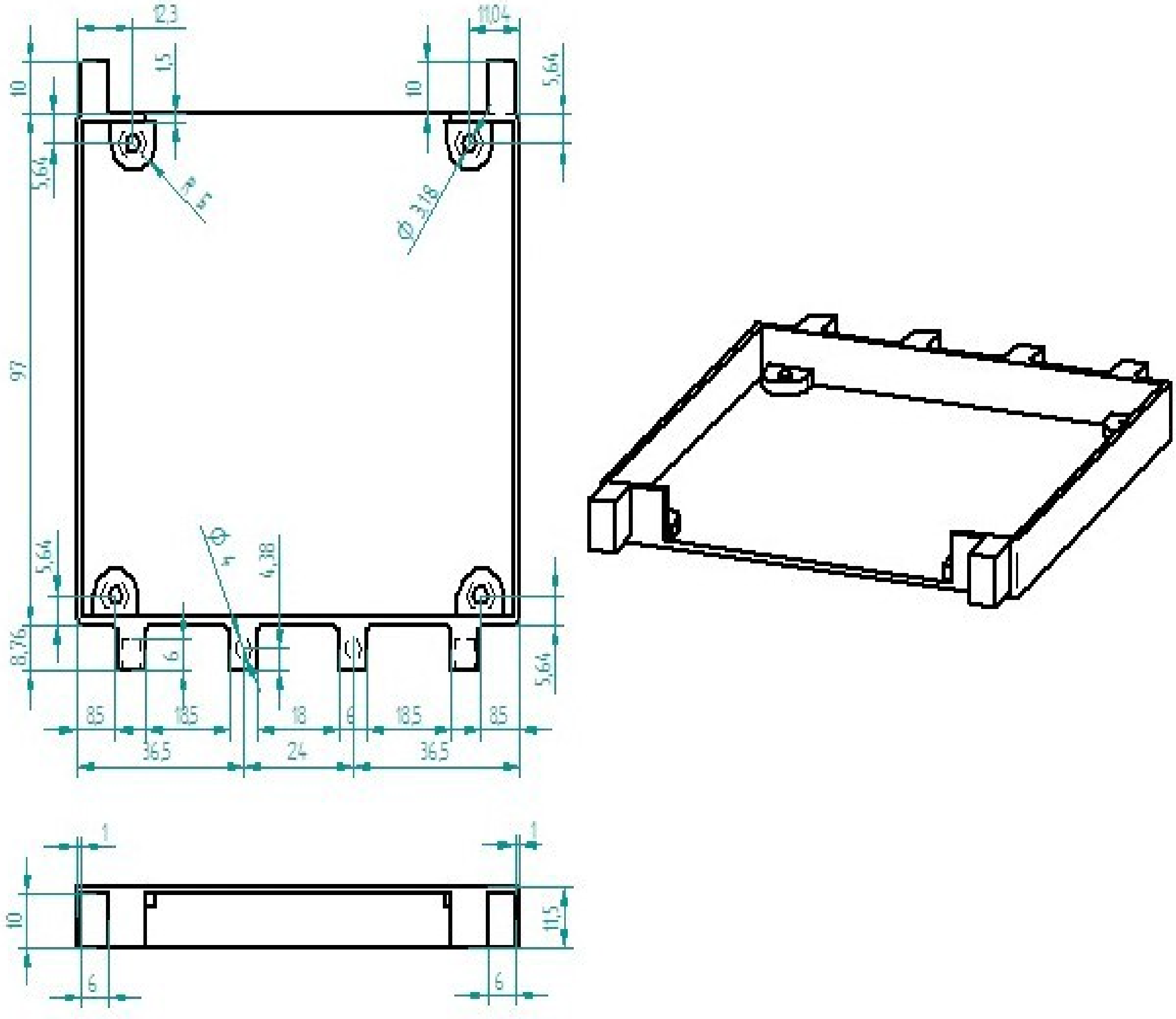

Figure 2.6: Short stack support plate

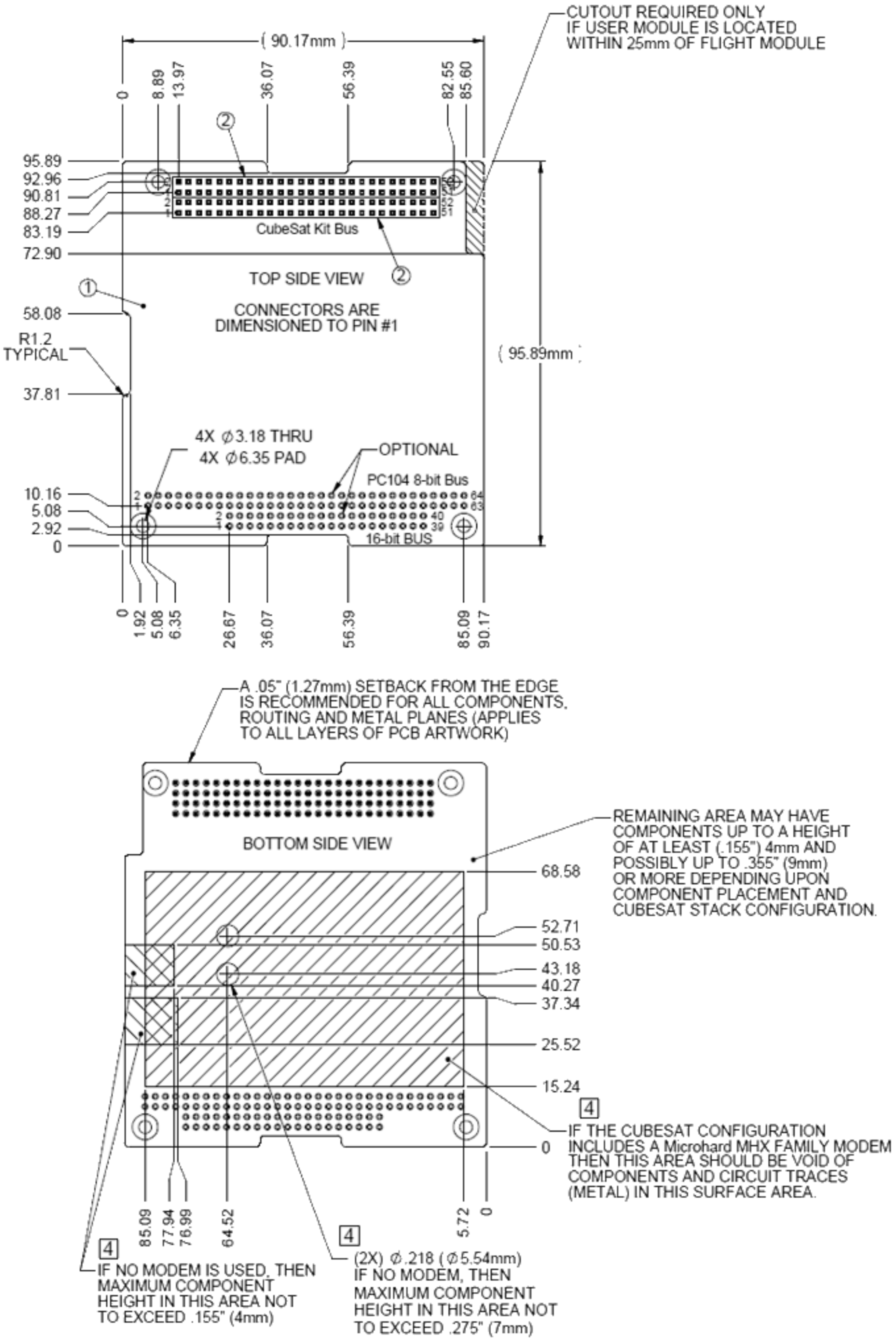

Figure 2.7: CubeSat kit PCB-specification, all values in millimeters. For more information see RD2

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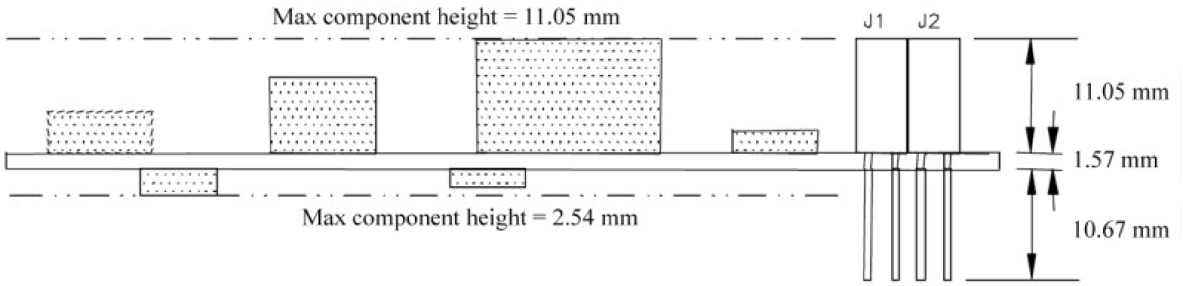


Figure 2.8: PC/104 & CubeSat kit PCB-specification for component heights. See RD2 & RD3 for more information.

System	Standby power (W)	Peak power (W)
ADS	0	7
TOTAL	**0**	**7**
COM		
VHF/UHF	0,2	1,55
S-band	0	5
TOTAL	**0,2**	**6,55**
GPS		
Active Antenna	0,03	0,03
GPS Receiver	0,015	0,1
TOTAL	**0,045**	**0,13**
OBC	0,1	2
TOTAL	**0,1**	**2**
ADCS	0,66	1,8
TOTAL	**0,66**	**1,8**
Payload		
SPEC	0	4
RADMON	0	1,5
EPB	2,3	3
EPB completely off	0	0
TOTAL	**2,3**	**8,5**
TOTAL	**3,305**	**25,98**

Table 2.1: Summary table for all the subsystem power requirements.

System with 20% margin	**Quantity**	**Mass (g)**	**Total Mass (g)**
Structure (20%)			
Support plate,long	2	36	72
frame+x215	1	96	96
Support plate, short	2	66	132
rods	4	14,4	57,6
Screws	65	2,4	156
frame-x	1	108	108
frame u +y	1	264	264
Frame u -y	1	252	252
Headplate	1	72	72
TOTAL			**1209,6**
ADS (20%)			
VHF antenna	2	2,4	4,8
UHF antenna	2	1,2	2,4
Structure	1	135,6	135,6
TOTAL			**142,8**
COM			
VHF/UHF transmitter (10%)	1	99	99
S-band & GPS board (10%)	1	82,5	82,5
S-band board (20%)	1	36	36
S-band antenna (20%)	1	60	60
TOTAL			**277,5**
EPS			
Batteries (10%)	1	281,6	281,6
Control board (10%)	1	91,3	91,3
Solar panels(10%)	4	143	572
TOTAL			**944,9**
OBC (20%)	1	60	60
TOTAL			**60**
ADCS (10%)	1	411,4	411,4
TOTAL			**411,4**
Payload			
SPEC	1	655,09	655,09
RADMON	1	600	600
EPB	1	360	360
TOTAL			**1615,09**
SUM TOTAL			**4661,29**

Table 2.2: Summary tables for all the subsystem masses with 20 percent margin (10% for all COTS systems).

2.2 Satellite Bus

2.2.1 Overview

Aalto-1 uses a CubeSatKit-standard connector and a PCB-layout. The standard is derived from the PC/104-standard. The connector is a stack-through connector divided in to two headers and forms the backbone of the Aalto-1 bus. In the long stack the satellite bus is located on the +y side of the satellite (see Figure 2.4 and Figure 2.11). In the short stack the satellite bus is located in the +z side of the stack (Figure 2.12). The inner header is removed from the short stack PCB's. The short stack will be connected to the long stack by TBD. All pins are not necessarily connected to the short stack headers. The pin layout for Aalto-1 satellite is shown in Figure 2.9. The main data bus between the OBC and satellite subsystems will be I2C, with UART and 3 – wire SPI, see Figure 2.1.

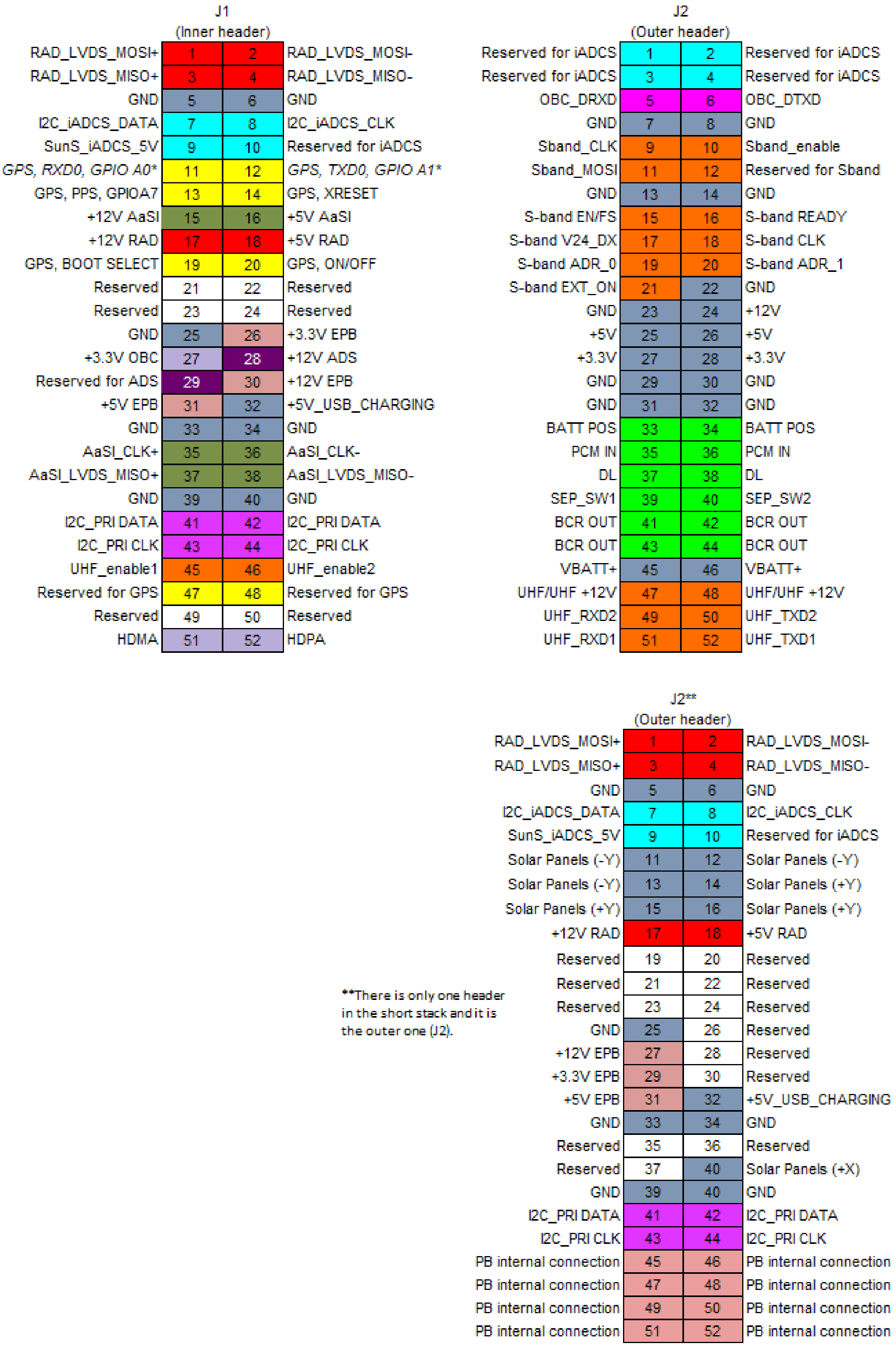
The detailed description of the stack pin configurations can be found in Aalto-1 Interface Sheet and in document [RD12].

2.2.2 Bus protocol

See document [RD13] for more details.

2.3 Module Specification

All single slot modules must follow the CSK PCB standard (Figure 2.7) unless stated otherwise. The standard slot height is 15.16 mm (Figure 2.8), but different connectors can be used if necessary, as long as they are compatible with the standard connector. If a module is larger than one slot, then the outer dimensions must follow the CSK PCB specifications. The outer parts of the module must also be compatible with the stack support plate specifications (Figure 2.5 and 2.6). The PCBs are divided into the long stack and the short stack, which can be seen in Figures 2.11 and 2.12. The dimensions for each module can also been seen from these figures. The stack support plates are different in the long stack and the short stack, so it must be kept in mind in which stack the module is located. The satellite bus must always go through the module uninterrupted.



	J1 (Inner header)		
RAD_LVDS_MOSI+	1	2	RAD_LVDS_MOSI-
RAD_LVDS_MISO+	3	4	RAD_LVDS_MISO-
GND	5	6	GND
I2C_iADCS_DATA	7	8	I2C_iADCS_CLK
SunS_iADCS_5V	9	10	Reserved for iADCS
*GPS, RXD0, GPIO A0**	11	12	*GPS, TXD0, GPIO A1**
GPS, PPS, GPIOA7	13	14	GPS, XRESET
+12V AaSI	15	16	+5V AaSI
+12V RAD	17	18	+5V RAD
GPS, BOOT SELECT	19	20	GPS, ON/OFF
Reserved	21	22	Reserved
Reserved	23	24	Reserved
GND	25	26	+3.3V EPB
+3.3V OBC	27	28	+12V ADS
Reserved for ADS	29	30	+12V EPB
+5V EPB	31	32	+5V_USB_CHARGING
GND	33	34	GND
AaSI_CLK+	35	36	AaSI_CLK-
AaSI_LVDS_MISO+	37	38	AaSI_LVDS_MISO-
GND	39	40	GND
I2C_PRI DATA	41	42	I2C_PRI DATA
I2C_PRI CLK	43	44	I2C_PRI CLK
UHF_enable1	45	46	UHF_enable2
Reserved for GPS	47	48	Reserved for GPS
Reserved	49	50	Reserved
HDMA	51	52	HDPA

	J2 (Outer header)		
Reserved for iADCS	1	2	Reserved for iADCS
Reserved for iADCS	3	4	Reserved for iADCS
OBC_DRXD	5	6	OBC_DTXD
GND	7	8	GND
Sband_CLK	9	10	Sband_enable
Sband_MOSI	11	12	Reserved for Sband
GND	13	14	GND
S-band EN/FS	15	16	S-band READY
S-band V24_DX	17	18	S-band CLK
S-band ADR_0	19	20	S-band ADR_1
S-band EXT_ON	21	22	GND
GND	23	24	+12V
+5V	25	26	+5V
+3.3V	27	28	+3.3V
GND	29	30	GND
GND	31	32	GND
BATT POS	33	34	BATT POS
PCM IN	35	36	PCM IN
DL	37	38	DL
SEP_SW1	39	40	SEP_SW2
BCR OUT	41	42	BCR OUT
BCR OUT	43	44	BCR OUT
VBATT+	45	46	VBATT+
UHF/UHF +12V	47	48	UHF/UHF +12V
UHF_RXD2	49	50	UHF_TXD2
UHF_RXD1	51	52	UHF_TXD1

	J2** (Outer header)		
RAD_LVDS_MOSI+	1	2	RAD_LVDS_MOSI-
RAD_LVDS_MISO+	3	4	RAD_LVDS_MISO-
GND	5	6	GND
I2C_iADCS_DATA	7	8	I2C_iADCS_CLK
SunS_iADCS_5V	9	10	Reserved for iADCS
Solar Panels (-Y)	11	12	Solar Panels (-Y)
Solar Panels (-Y)	13	14	Solar Panels (+Y)
Solar Panels (+Y)	15	16	Solar Panels (+Y)
+12V RAD	17	18	+5V RAD
Reserved	19	20	Reserved
Reserved	21	22	Reserved
Reserved	23	24	Reserved
GND	25	26	Reserved
+12V EPB	27	28	Reserved
+3.3V EPB	29	30	Reserved
+5V EPB	31	32	+5V_USB_CHARGING
GND	33	34	GND
Reserved	35	36	Reserved
Reserved	37	40	Solar Panels (+X)
GND	39	40	GND
I2C_PRI DATA	41	42	I2C_PRI DATA
I2C_PRI CLK	43	44	I2C_PRI CLK
PB internal connection	45	46	PB internal connection
PB internal connection	47	48	PB internal connection
PB internal connection	49	50	PB internal connection
PB internal connection	51	52	PB internal connection

**There is only one header in the short stack and it is the outer one (J2).

Figure 2.9: Satellite bus pin layout, both long and short stacks.

2.4 Bus connector specification

The satellite bus uses the standard CSK connector. The connector is a modified version of the pc104 stack-through connector, with 52 pins in two different headers. The CSK connector is made from two Samtec ESQ-126-39-G-D connectors, i.e. both headers have their own connector (see Figure 2.10). The overall pin layout is shown in Figure 2.9 as well as [RD12].

CSK Connector dimensions:

- length: 66.55 mm
- width: 10.00 mm
- height: 11.05 mm

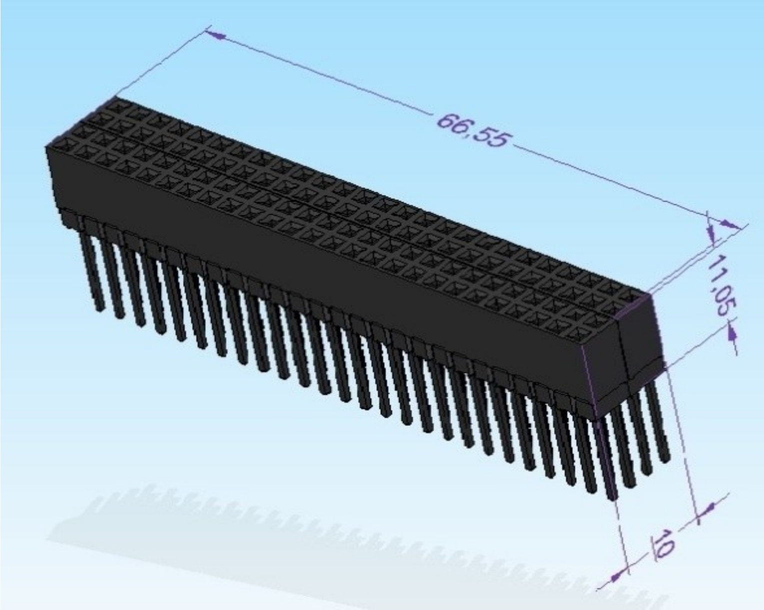


Figure 2.10: The CSK connector (2x Samtec ESQ-126-39-G-D)

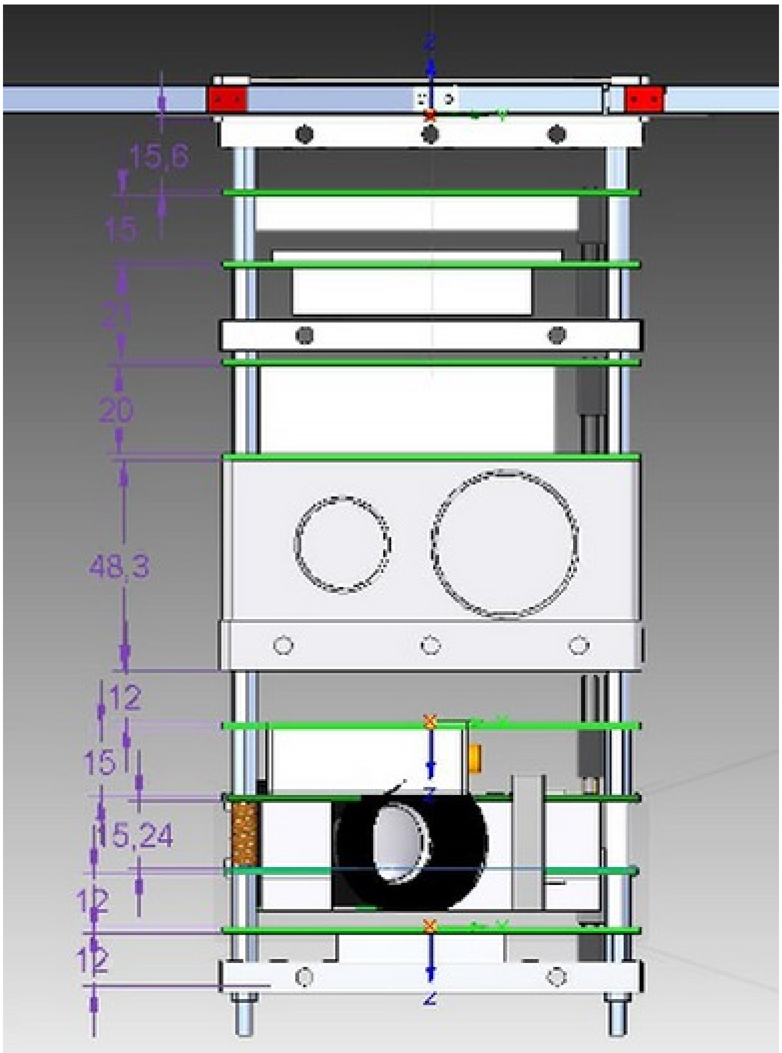


Figure 2.11: The long stack with subsystem dimensions. All values in millimeters.

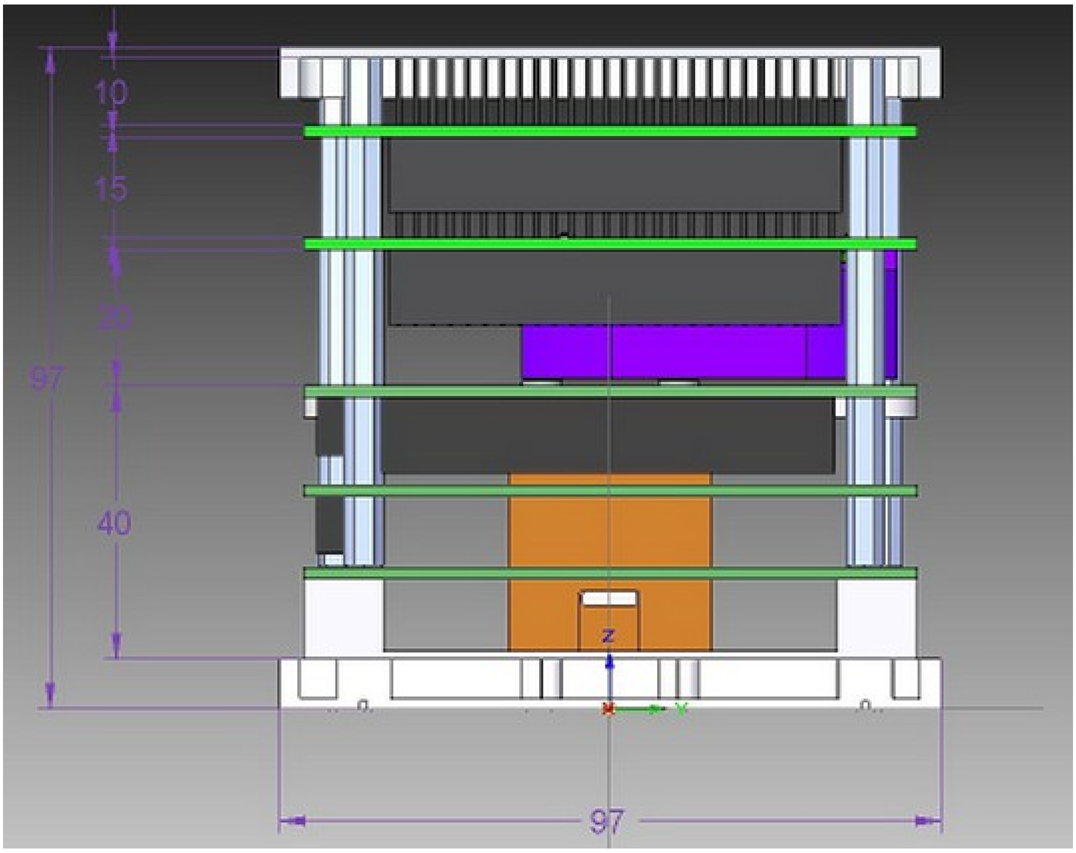


Figure 2.12: The short stack with dimensions. All values in millimeters.

2.5 Communications

The satellite will house three radio links: one for VHF/UHF frequencies which are used for downlinking/uplinking telemetry and command, and one in the S – band frequency of 2.4 – 2.45 GHz, which in turn will be used as a higher bandwidth data downlink. The VHF / UHF and S – band satellite radios both will be built in – house, and will consist mainly of the same components.

2.5.1 Data Rate

Bandwidth	Maximum data rate	500 km	900 km
VHF	1.2 kbit / s	70 kbytes / 24 hours	120 kbytes / 24 hours
UHF	9.6 kbit/s	560 kbytes / 24 hours	960 kbytes / 24 hours
S - Band	0.5 Mbit / s	29 Mbytes / 24 hours	49 Mbytes / 24 hours

Table 2.3: The maximum data rate per channel, as well as the bandwidth available for a 24 hours period, for a 500 km and 900 km orbit altitude.

VHF/UHF

The VHF / UHF link is full – duplex, with which the satellite and the ground segment can up – downlink at the same time.

S-band

With the S-band downlink the maximum data rate is ca. 500 kbaud/s, with a Minimum Shift Keying (MSK) modulation scheme, with an output power of 30 dBm.

3 Payload Engineering Requirements and Interfaces

3.1 Aalto-1 Spectral Imager (AaSI)

Overview

The Spectral Imager on board Aalto-1 will act as the main payload of the satellite. It will be connected to the satellite by the satellite bus.

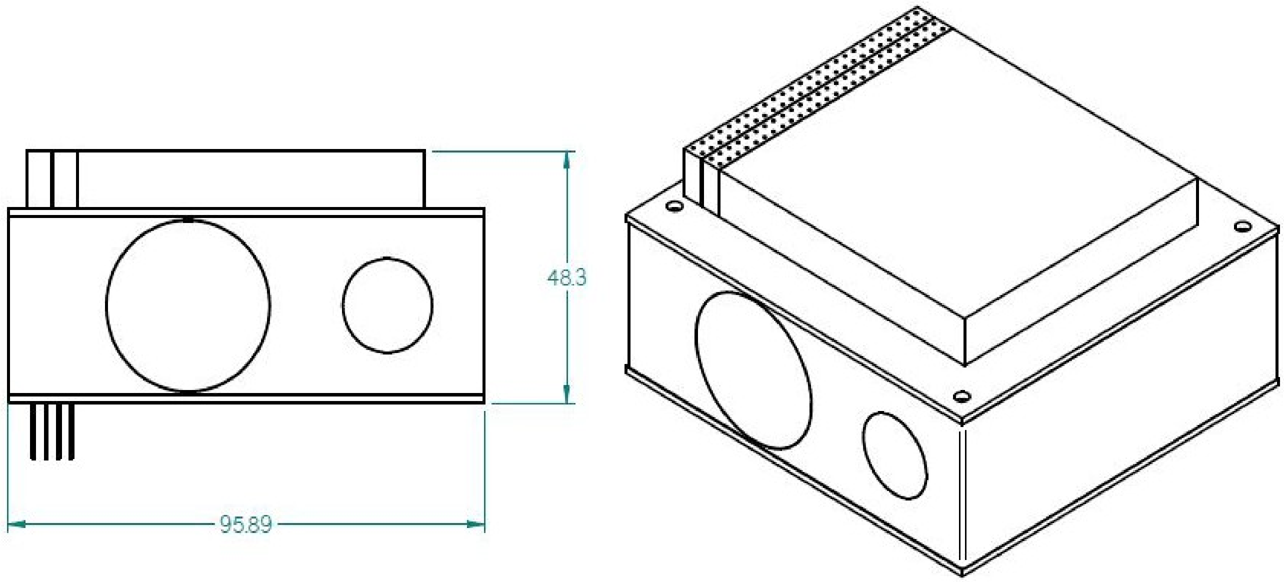


Figure 3.1: The AaSI spectrometer accomodation.

Accommodation

The AaSI-module will be located in the long stack. It will be the fourth system in the stack (Figure 3.1). The module x and y outer dimensions must be 97 mm x 97 mm (Figure 2.7) and the module maximum height (z-dimension) must be less than 48.30 mm. One stack support plate shall be integrated to the AaSI structure.

Electrical Interface

Available pins for the spectrometer are shown in Figure 2.9 and in more detail in [RD12]. A complete description of the data interfaces is given in RD13

Command and telemetry interfaces

AaSI receives commands and imaging parameter values from the OBC over the platform-wide I2C bus, in which the OBC is the master. Housekeeping data is sent to the OBC over the same bus. For all data transfers the OBC is the master. Data transfers are register-based – each parameter is assigned its specific register that is addressed by the OBC for writing or reading. Register addresses are 8-bit values. The registers contain 16-bit data (TBC).

Data interface

The image data is transferred from the AaSI buffer memory to the OBC via an SPI-over-LVDS interface. The OBC is the master, thus generating the clock and select signals. The data transfer is simplex, no data is sent from the OBC to the AaSI over this I/F.

The bit rate is 45 Mbit/s, determined by the clock frequency of the OBC microcontroller. Data is transferred as 16 bits per pixel. A full buffer memory, 16Mpix, can be transferred to the OBC in 5.7 seconds (minimum).

Mechanical Interface

The long stack support plate shall be a part of the spectrometer module mechanical frame. The preliminary mass is 656 grams, based on discussion with VTT.

Thermal Interface

The acceptable temperature range shall be from -30 to +40 °C (TBC).

Power

Power demands according to VTT are 12 V, 4.0 W (5 V, 3.0 W) during image acquisition, and a minimum of 0 W in idle/standby conditions.

3.2 Compact Radiation Monitor (RADMON)

Overview

The RADMON will act as a secondary payload, and it will be connected by the satellite bus. The module will be built by Universities of Helsinki and Turku.

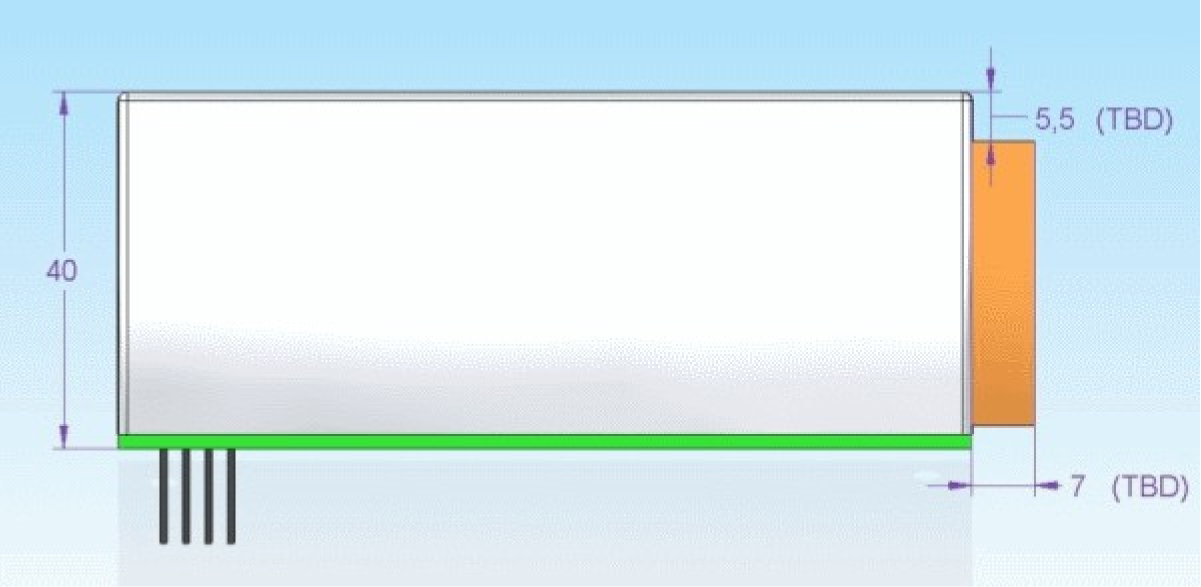


Figure 3.2: The RADMON accomodation.

Accommodation

The RADMON is located in the short stack (last system in the stack), so the PCB-stack is rotated 90 degrees in relation to the long PCB-stack. The RADMON module (Figure 3.2) y and z dimensions must be 90.17 mm x 95.89 mm and the maximum module height (x-dimension) must be less than 40 mm. The outermost PCB's must also be compatible with the short stack support plate specification (Figure 2.6) and the CSK standard. The detector unit must not protrude more than 7 mm (TBC) from the PCB to the -z direction and the gap between the detector and the support plate must be more than 0 mm (i.e. it cannot go inside the support plate).

Electrical Interface

Available pins for RADMON are shown in Figure 2.9 and in more detail in [RD12]. The RADMON will have dedicated +5V and +12V power lines.

Command, telemetry and data interfaces

RADMON shall transfer two – ways telemetry, commands as well as payload data through a dedicated UART–over–LVDS line. The platform–wide I2C line will be used as a backup, in which the OBC is the master. See more details in [RD13].

Mechanical Interface

The RADMON module shall be fixed to the stack support plates by TBD and the RADMON detector shall be fixed to the satellite frame by the short stack support plate.

Thermal Interface

The acceptable temperature range shall be from -30 to +40 °C (TBC).

Power

The RADMON shall use as peak power 1.5 W. The RADMON module must shut down completely when either of the voltage lines is shut down.

3.3 Electrostatic Plasma Brake (EPB)

Overview

The Electrostatic Plasma Brake will act as a de-orbiting device, and it will be connected by the satellite bus.

Accommodation

The EPB is located in the short stack, meaning the stack is rotated 90 degrees in relation to the main PCB-stack. The Plasma Brake module y and z dimensions must be 90.17 mm x 95.89 mm and the x-dimension must be under 45 mm. The outermost PCB's must also be compatible with the short stack support plate specification [TBC] (Figure 2.5) and the CSK standard.

Electrical Interface

Available pins for the EPB are shown in Figure 2.9 and in more detail in [RD12]

Command, telemetry, and data interfaces

The EPB shall transfer two–ways telemetry, commands as well as payload data through the platform-wide I2C line, in which the OBC is the master. See more details in [RD13].

Mechanical Interface

The EPB shall be fixed with screws within the remainder of the stack, as seen in Figure 2.12. The motor of the EPB is fixed with screws to its designated PCB.

Thermal Interface

The acceptable temperature range shall be from -30 to +40 °C (TBC).

Power

The Electrostatic Plasma Brake shall use as peak power 3 W, with an ON-state power usage of 2.3 W when not being deployed.

4 Ground Segment

4.1 Ground Station

The primary ground station for the Aalto-1 mission will be located in Otaniemi, Finland. It is mainly operated by the Department of Radio Science and Engineering of the Aalto University School of Electrical Engineering (Aalto ELEC). The ground station will also be part of the GENSO network.

Currently the UHF/VHF ground-station is operational, and has been used to both send and receive signals to LEO radio amateur satellites. The satellite tracking is performed using Gpredict, an open-source real-time satellite tracking software.

4.1.1 Configuration

The ground station has antennas for UHF/VHF frequency bands, and will be capable of receiving and transmitting in both bands using a software defined radio FunCube Pro, and will have one for receiving and transmitting in S – band through a software defined radio [TBD].

4.1.2 Ground Support Equipment

The Ground Support equipment includes tools for satellite diagnostics, servicing and transportation.

5 Environmental Requirements and Conditions

5.1 Thermal Environment

The thermal environment for the satellite is described in more detail in the thermal interface document (RD10, A1-THE-TN-02-V1 Thermal Interface Document). The preliminary simulations (A1-THE-TN-03-V1) show that the temperatures inside the satellite shall be between -40°C and +80°C. (TBC)

5.2 Radiation Environment

TBD

6 Verification Requirements

6.1 Verification Concept

The verification objectives of the instruments are to qualify the design, to ensure that the instrument is acceptable for use in its spacecraft environment and to confirm instrument performance during the mission.

Verification can be accomplished by **Analysis, Tests** and **Inspection**.

6.2 Analysis

Analyses to be performed before manufacturing the Protoflight models are:

- FMECA according to ECSS-Q-ST-30-02C
- Electrical components derating and worst case analysis according to ECSS-Q-ST-30-11
- Structural stress analysis

Thermal analysis is not required on instrument level (thermal requirements will be verified by TVT). Thermal analysis will be done on satellite level.

6.3 Instrument Level Testing

6.3.1 Overview

Requirements derived in this document based on GSFC-STD-7000 may be superseded by launch provider requirements as soon as the launch vehicle (LV) is identified.

Testing shall be performed to meet all launch provider requirements. According to CubeSat Design Specifications document if launch vehicle environment is unknown, GSFC-STD-7000 (http://standards.gsfc.nasa.gov/gsfc-std/gsfc-std-7000.pdf) shall be used to derive testing requirements. All flight hardware shall undergo protoflight and acceptance testing.

At least the following tests shall be applied to the instruments on unit level:

- Random Vibration
- Shock test
- Thermal Vacuum Test
- Visual Inspection

This is the minimum amount of tests and may be superseded by launch provider requirements. Other tests can be added as seen necessary by the instrument teams.

6.3.2 Random Vibration Test Levels

Test levels derived from GSFC-STD-7000:

Table 6.1: Generalized Random Vibration Test Levels

Frequency [Hz]	Qualification	Acceptance
20	0.026	0.013
20 - 50	+6 dB/oct	+6 dB/oct
50 - 800	0.16	0.08
800 - 2000	-6 dB/oct	-6dB/oct
2000	0.026	0.013
Overall	14.1 Grms	10.0 Grms

6.3.3 Thermal-Vacuum Cycling

Thermal-Vacuum Qualification according to GSFC-STD-7000:

Temperature Cycling

For spacecraft four (4) thermal-vacuum cycles shall be performed. During the cycling, the hardware shall be operating and its performance shall be monitored.

Duration

Spacecraft shall be exposed for a minimum of twenty-four (24) hours at each extreme temperature cycle.

Pressure

The chamber pressure after the electrical discharge checks are conducted shall be less than 1.33 x 10 -3 Pa.

Hot and Cold start demonstrations

Start-up capability shall be demonstrated to verify that the test item will turn on after exposure to the extreme temperatures that may occur in orbit. Turn-on capability shall be demonstrated under vacuum at least twice at both the low and high temperatures, as applicable.

Temperature

Maximum expected temperature range is TBD with thermal analysis.

6.4 Calibration

The instrument team shall prepare a calibration plan adapted to the scientific requirements of the instrument and mission. The instruments shall be delivered fully calibrated.

6.5 System Level Assembly, Integration and Testing

The instruments teams shall provide following models: Electrical Model (EL), Mechanical mock-up (no functionality) and Protoflight Model (PFM). EL and mechanical mock-up can be combined to one model.m Test requirements derived from CubeSat requirements are not very clear or exact, but generally they require vibration testing (random and sometimes sine), thermal cycling and bakeout in vacuum, and possibly shock. Test requirements will become more exact when launch vehicle is identified.

Satellite level test requirements according to CubeSat Design Specifications:

Random Vibration - Random vibration testing shall be performed as defined by LV provider, or if unknown, GSFC-STD-7000.

Thermal Vacuum Bakeout - Thermal vacuum bakeout shall be performed to ensure proper outgassing of components. The test cycle and duration will be outlined by LV provider, or if unknown, GSFC-STD-7000.

Visual Inspection - Visual inspection of the CubeSat and measurement of critical areas shall be performed per the 3U CAC (3U CubeSat Acceptance Checklist) as appropriate.

Qualification - CubeSats may be required to survive qualification testing as outlined by the LV provider. If LV environments are unknown, GSFC-STD-7000 (NASA GEVS). Qualification testing will be performed at developer facilities. **Additional testing may be required if modifications or changes are made to the CubeSats after qualification testing.**

Protoflight - All CubeSats shall survive protoflight testing as outlined by the LV provider. If LV environments are unknown, GSFC-STD-7000. Protoflight testing will be performed at developer facilities. **CubeSats SHALL NOT be disassembled or modified after protoflight testing**. Disassembly of hardware after protoflight testing shall require the developer to submit a DAR and adhere to the waiver process prior to disassembly. Additional testing shall be required if modifications or changes are made to the CubeSats after protoflight testing.

Acceptance - After delivery and integration of the CubeSats into the P-POD, additional testing shall be performed with the integrated system. **The P-POD Integrator shall coordinate and perform acceptance testing.** After acceptance testing, developers may perform diagnostics through the designated P-POD diagnostic ports, and visual inspection of the system shall be performed by the P-POD Integrator. The P-POD SHALL NOT be de-integrated at this point. If a CubeSat failure is discovered, a decision to deintegrate the P-POD will be made by the developers, in that P-POD, and the P-POD Integrator based on safety concerns. The developer is responsible for any additional testing required due to corrective modifications to deintegrated P-PODs and CubeSats.

Below is one example of CubeSat and launch pod Qualification and Acceptance Test Flow. Diagram is from the "Program Level Poly Picosatellite Orbital Deployer (PPOD) and CubeSat Requirements Document" provided by CubeSat Program.

7 Management Requirements

7.1 Organization Management

The organization at the top level is managed according to requirements of financing institutions.

7.1.1 Organization

Aalto-1 project is a cooperation project where several Finnish universities, institutes and companies working towards the common goal, the first Finnish satellite. Cooperation can be regulated with additional agreements but the general framework is based on Memorandum of Understanding or oral agreements. Every participating party finances its own activities if not otherwise agreed.

The project is coordinated and managed by the Department of Radio Science and Engineering of the Aalto ELEC. The work is coordinated by professor of space technology Martti Hallikainen (responsible leader) and university teacher Jaan Praks (project coordinator).

The project will be guided by a steering group and advised by science team. The technical reviews will be carried out by expert review panel (nominated for each project phase separately). Student work is organized according to teaching and project work needs. Organization on student team level is kept as light as possible, student work in teams or individually on each topic.

Each instrument team shall nominate an **Instrument manager** to act as the project manager of instrument development. The Instrument manager shall act as a formal interface point for the instrument side.

7.1.2 Project Executives

Project Lead: Prof. Martti Hallikainen,

e-mail: martti.hallikainen@aalto.fi

Visiting address: C228b, Otakaari 5 A, Espoo

Project Coordinator: Jaan Praks,

e-mail: jaan.praks@aalto.fi,

skype: jaan.praks

gsm: +358505747975

Visiting address: C220, Otakaari 5 A, Espoo

7.1.3 Steering Group

Steering group is nominated by Aalto University. The Steering Group is responsible for general lines and financial side of the project. Steering group has meetings several times per year.

Steering group members:

- Tuija Pulkkinen, Chairman, Aalto University - School of Electrical Engineering
- Antti Räisänen, Aalto University - School of Electrical Engineering
- Keijo Heljanko, Aalto University - School of Science
- Martin Vermeer, Aalto University - School of Engineering

- Sami Franssila, Aalto University - School of Chemical Technology
- Yrjö Neuvo, MIDE Program

7.1.4 Science Team

The Science Team brings together teachers, experts from all over the consortium. The Science team is the main cooperation body of the project. Science Team is responsible for science and technology of the satellite. Experts and Science Team members are invited to the team upon request.

Associated Science Team Members currently are:

- Keijo Nikoskinen, Aalto University - School of Electrical Engineering
- Tomi Ylikorpi, Aalto University - School of Electrical Engineering
- Keijo Heljanko, Aalto University - School of Science
- Vesa Hirvisalo, Aalto University - School of Science
- Clemens Icheln, Aalto University - School of Electrical Engineering
- Heikki Saari, VTT
- Jarkko Antila, VTT
- Kai Viherkanto, VTT
- Pekka Janhunen, FMI
- Jouni Envall, FMI
- Petri Toivanen, FMI
- Maria Genzer, FMI
- Minna Palmroth, FMI
- Harri Haukka, FMI
- Hannu Koskinen, University of Helsinki
- Rami Vainio, University of Helsinki
- Juhani Peltonen, University of Turku
- Mikko Syrjäsuo, Aalto
- Pauli Stigell, TEKES
- Matti Anttila, SSF
- Ilkka Reis, RSI Oy
- Jussi Liikkanen, Turun ammatikorkeakoulu
- Merja Tornikoski, Aalto

7.1.5 Instrument Responsibilities

Spectrometer: Kai Viherkanto (VTT), kai.viherkanto@vtt.fi

Radiation monitor: Rami Vainio (University of Helsinki), rami.vainio@helsinki.fi

Electrostatic Plasma Brake: Pekka Janhunen (FMI), pekka.janhunen@fmi.fi

7.1.6 System Responsibilities (Subject to change)

Project Manager: Jaan Praks, jaan.praks@aalto.fi, +358505747975

Quality Manager: Maria Komu, maria.komu@fmi.fi

System Engineers: Antti Kestilä, antti.kestila@aalto.fi, Antti Näsilä, antti.nasila@aalto.fi

7.1.7 Student Teams

Student teams are the organization level where the most work is done. Student Teams are dynamically formed according to the need of teaching and the project. Project participants and their share of the work is documented in course reports. Student teams are instructed and guided by teachers and experts who coordinate their activities in Science Team meetings.

Student team list with contact information is maintained in project central document repository (Google drive).

7.2 Reviews

At least the following reviews shall be held for instrument PFMs and in system level (combined or separately):

- **Critical Design Review (CDR)** - The main objective of the CDR is to confirm the maturity and freeze the design for PFM manufacture.
- **Test Readiness Review (TRR)** - Gives a formal go-ahead for protoflight or acceptance test campaign. It is checked that the product conforms to its design and is ready to be tested, and the test facilities conform to the specifications, and the test procedures are approved.
- **Post Test Review (PTR)** - After testing Test Review Boards examine and evaluate unit and equipment level test results prior to formal acceptance of the hardware. The purpose of the Delivery Review is to check the product conforms to its specifications and is ready to be delivered, and that the relevant documentation is completed and available.

After satellite integration:

- **Flight Acceptance Review (FAR)** - Is held after system integration, satellite integration to launch pod and acceptance testing. After this review satellite is accepted for launch.

Additional reviews can be arranged when needed.

7.3 Documentation

All documentation shall be written in English and submitted as PDF files. Latest versions of all documents shall be available in the Aalto-1 Google Docs and Aalto-1 Dropbox. There shall be a document control system containing document name, reference number and release date of the documents. Each subsystem and payload is responsible for their documentation and shall deliver a list of documents to PA manager when requested.

Document naming system should be for example following (described in more detail in [RD9]:

Document identifier is defined as:

<Project name>- <Instrument/Subsystem>- <Document type>-<Number> -<Version>

Document number has two digits and starts always from 01. Version numbering starts from v1. All changes shall be clearly marked to the revisioned document. Draft versions are marked by adding “DRAFT” after the version number. This means the version number that will be the next released version. E.g. if v1 of the document has been released, the working copy shall be named as v2-DRAFT. In addition to the identifier the documents shall have a name that describes the contents of the document.

For example:

A1-RAD-DW-01-v1 Technical Drawing of Radiation Monitor

A1-Q-PL-02-DRAFT Product Assurance Plan

A1-SYS-EID-01-v2-DRAFT Experiment Interface Document

Table 7.1: Document types

Project name	Instrument/subsystem	Document type	Number	Version
A1 = Aalto-1	SYS = System Engineering	CI = Configuration Item	01	v1
	M = Management	DD = Design Document	02	v2
	Q = Product Assurance	DS = Design Specification	...	...
	AOC = Attitude and Orbit Control System	DW = Drawing/Diagram		DRAFT
	OBH = On-board computer Hardware	IF = Interface specification		
	OBS = On-board computer Software	ME = Memo		
	EPS = Electrical Power System	MN = Minutes of Meeting		
	GRD = Ground Segment	MA = Manual		
	SPE = Spectrometer	NC = Non-conformances		
	RAD = Radiation Monitor	PL = Plan		
	EPB = Electrostatic Plasma Brake	RP = Report		
	MEC = Mechanical Design	RS = Requirement Specification		
	THE = Thermal Design	SP = Technical Specification		
	COM = Radio Communication	TN = Technical Note		
		TP = Test Procedures		
		TR = Test Report		
		TS = Test Specification		
		LI = List		
		LO = Logbook		
		EID = Experiment Interface Document		

8 Product Assurance Requirements

8.1 Management

Product Assurance (PA) activities shall be coordinated within project organization. Quality manager can be designated to manage the PA activities.

8.2 Product Assurance Plan

A PA Plan shall be prepared to describe how the PA requirements defined here will be implemented. The PA Plan will serve as the master planning and control document for the PA programme, and shall be submitted to PDR.

8.3 Quality Assurance (QA)

Each instrument team shall establish or follow an already established Quality Assurance System. QA requirements are applicable to all Qualification and Flight models and facilities, equipment and tools interfacing directly with flight hardware or used in qualification testing. The QA approach shall be described in Product Assurance Plan.

Manufacturing, assembly, integration and tests of the systems and/or components shall be covered by logbooks.

Cleanliness level of Protoflight models is TBD.

Traceability databases shall be established and maintained.

8.4 Materials and Components

- All CubeSat materials shall satisfy the following low out-gassing criterion to prevent contamination of other spacecraft during integration, testing, and launch.
- Total Mass Loss (TML) shall be < 1.0 %
- Collected Volatile Condensable Material (CVCM) shall be < 0.1%
- No hazardous materials like Beryllium-Oxide, Cadmium, Zinc, Mercury and PVC shall be used on a CubeSat.
- Aluminum 7075 or 6061 shall be used for both the main CubeSat structure and the rails. If other materials are used the developer shall submit a DAR and adhere to the waiver process
- The CubeSat rails and standoff, which contact the P-POD rails and adjacent CubeSat standoffs, shall be hard anodized aluminum to prevent any cold welding within the P-POD

Plastic components are not preferred. Ceramic casings should be used when possible.

Declared material and component lists shall be prepared and then submitted to the PA Manager for approval before Critical Design Review.

8.5 Cleanliness

General cleanliness requirement for the project is ISO 8 (Class 100,000). The project does not have it's own cleanroom facilities in use at the moment, but it will be arranged. In some cases (e.g. RADMON calibration) cleanliness requirement can not be followed. In these cases the instrument/component/material needs to be carefully cleaned afterwards.

8.6 Non-conformance Reports and Waivers

A nonconformance is an observed condition of any article or hardware or software in which one or more characteristics do not conform to specifications. Including:

- Failures during tests
- Malfunctions
- Defects

Nonconformance system shall be maintained in line with The CubeSat Program when the lancher is not yet known. When the launcher is identified, NCR system will be defined by them. Nonconformance control shall be applied to Protoflight models.

For each deviation from the specifications or a failure during tests, a separate **Nonconformance Report (NCR)** has to be generated. The NCRs are classified as Major or Minor. The NCRs are classified as Major, if they have impact on:

- Safety of people or equipment
- Operational, functional or contractual requirements
- Reliability, maintainability, availability (severe impact on schedule)
- Functional or dimensional interchangeability between supposedly identical units
- Interfaces with hardware and/or software of another party
- Incorrect qualification/acceptance test procedures or non-compliant test results
- For EEE components the lot/batch rejection at the manufacturer’s facilities, if use-as-is is proposed, or the NCRs detected after delivery from the manufacturer

Other NCRs are classified as Minor.

Major NCRs shall be reported to the System Engineer and Quality Manager within 2 working days.

Nonconformance Review Board (NRB) should be held at the end of each major activity, which generated NCRs. The NRB shall include at least System Engineer, PA Manager and instument/subsystem representative. The NRB shall investigate the cause(s) of the nonconformance, and to make the decision about the disposition of the nonconformance. The need for a waiver is also identified and recommended by this NRB.

Waiver process from Aalto-1 project to launcer shall be as described in CubeSat Design Specifications document when the launcher is unknown. When the launcher is identified, the waiver process shall be defined by the launcher.

According to The CubeSat Program the developer shall fill out a "Deviation Waiver Approval Request (DAR)" if CubeSat is in violation of any requirements. From the CubeSat Design Specifications document revision 12:

"Upon completion of the DAR, the P-POD Integrator shall review the request, resolve any questions, and determine if there are any additional tests, analyses or costs to support the waiver. If so, the Developer, with inputs from the P-POD Integrator, shall write a Test Plan and perform the tests before the waiver is conditionally accepted by the P-POD Integrator. Waivers can only be conditionally accepted by the P-POD Integrator until a launch has been identified for the CubeSat. Once a launch has been identified, the waiver becomes mission specific and passes to the launch vehicle Mission Manager for review. The launch vehicle Mission Manager has the final say on acceptance of the waiver, and the Mission Manager may require more corrections and/or testing to be performed before approving the waiver. Developers should realize that each waiver submitted reduces the chances of finding a suitable launch opportunity."

8.7 Configuration Control

For each Protoflight unit, a Configuration Item Data List (CIDL) shall be prepared. The CIDL shall list all the documents applicable to the item. "As-built" changes shall be listed in the same document. CIDL shall be reviewed in Post-test review.

8.8 Safety

The payload and systems structures shall provide safety for attending personnel from any hazards. The payload and systems shall be explosion and fire-safe during its exploitation.

8.9 Manufacturing Requirements

- General rules concerning manufacturing of Protoflight model:
- Manufacturing plans and procedures shall be prepared
- Manufacturing readiness reviews shall be held before start of manufacturing process (TBC)
- All manufacturing activities shall be logged
- Proper cleanliness level shall be maintained
- Manufacturing shall be performed only by persons with adequate workmanship quality
- Manual PCB soldering shall require a valid certificate according to ECSS-Q-ST-70-08

8.10 Integration and Testing Requirements

- General integration and testing rules (protoflight/acceptance level):
- Assembly and integration plans shall be prepared
- Integration and tests shall be performed in a controlled environment (cleanliness, temperature, humidity, ESD). Proper cleanliness level shall be maintained.
- Only persons with adequate workmanship quality shall do the work on Protoflight models
- Test plans and procedures shall be prepared before tests and submitted to PA Manager for review
- Test equipment shall be properly calibrated
- Test readiness review (see also chapter “Reviews”) shall be held before the protoflight/acceptance tests to review the test plan, procedures, CIDL/ABCL and other relevant documents.
- All protoflight/acceptance test activities shall be logged. After the tests, test reports shall be prepared. The reports shall include at least a summary and evaluation of test results, a list of NCRs raised during the tests, used test equipment and setup – digital photos should be used where possible.
- Post-test review shall be held after the tests