SED – 5.3

Student Experiment Documentation

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Mission: REXUS 13

Team Name: SOLAR

Experiment Title: SOLAR - Soldering Alloys in Reduced Gravity

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Change Record

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1	*2012-02-16*	all	PDR
1.1	*2012-04-16*	all	
1.2	*2012-04-28*	all	Resubmission of PDR
2	*2012-06-11*	1.4, 2, 3, 4, 5, 6, 8 4.2.1, 4.3, 6.1.1	CDR
2.1	*2012-08-02*	1.2, 2, 3.5, 4, 5, 6.1, 6.3, 8	Resubmission of CDR
2.2	*2012-08-8*	1.2, 2, 4, 5, 6.1, 6.3, 8	Resubmission of CDR
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5.2	2013-10-23	4, 5.1, 5.2.1, 7.3, 7.4.2	Minor revision for correcting past tense grammar left out in v5.1
5.3	2013-10-27	4.4	Minor revision for final corrections

Keywords: REXUS, SED - Student Experiment Documentation, SOLAR, Soldering in reduced gravity, LTU - Luleå University of Technology

Abstract: SOLAR is a scientific experiment researching the effects of reduced gravity on soldering joints. The mission is to develop a method to perform in situ repairs of components in reduced gravity. The project is carried out by a group of students from Luleå University of Technology, Sweden.

CONTENTS

PREFACE

This document contains information for the Integration Progress Review of Project SOLAR. Project SOLAR is an experiment carried out by students at Luleå University of Technology (LTU) in Kiruna. The team worked towards finding a solution to the problems of soldering in reduced gravity, allowing rework on components in space.

The document follows ESA directions for Student Experiment Documentation (SED). The SED was updated continuously; however five versions are frozen.

- Version 1 before the Preliminary Design Review (PDR)
- Version 2 before the Critical Design Review (CDR)
- Version 3 before the Integration Progress Review (IPR)
- Version 4 before the launch campaign, Experiment Acceptance Review (EAR)
- Version 5 is the final version of the SED with analysis and experiment results.

This document is currently at version 5.

ABSTRACT

Large funding is required each year for maintaining the International Space Station (ISS) due to need for replacement of components. The cost of this maintenance could be reduced by repairing equipment on site. However, the current method of soldering joints in reduced gravity generates defective connections of components, thus making the repairs insufficient in outer space.

The main problem is to solder metals in reduced gravity without obtaining an increase of void fractions, which are inherent due to the lack of buoyant forces on flux and gases. Earlier tests done by NASA, in reduced gravity alone, show an increased amount of void fraction by up to three times as compared to solder created in normal earth gravity. The proposed solution for soldering in reduced gravity is to work in a low pressure environment which enables minimization of void fractions. In vacuum a repairing sequence can be simulated similar to the setting at the ISS but with a reduced pressure.

This was tested in an experiment, which was able to melt three samples in vacuum environment and three samples in pressurized environment. To ensure accurate data the solder joints were melted and cooled while in milligravity. This was carried out as the REXUS experiment SOLAR (Soldering Alloys in reduced gravity) in cooperation with several space agencies throughout Europe. The SOLAR experiment was launched with a sounding rocket from Esrange Space Centre, Kiruna (Sweden) in May 2013.

After the flight the samples have been analysed at the Kemi-Tornio University of Applied Sciences in Finland by using an Xray scanner to inspect the void fractions in two dimensions. The result of the reduced gravity soldering have been compared to the similar studies done in the SoRGE and CLEAR projects by NASA, and to the samples created in the pressurized environment of the SOLAR experiment. Suggestions on how to obtain improved soldering joints in space are given based on the final test results.

1 INTRODUCTION

1.1 Scientific/Technical Background

The aim of the SOLAR experiment was to further investigate the effect of reduced gravity on solders done in space. This research could possibly allow astronauts to repair components during future interplanetary missions or onboard the ISS.

The SoRGE project was started in 2000 and was the first major study done by NASA in this field. The experiment was carried out on the ISS to better understand the gravitational effect on solders done in space. SoRGE concluded that the chemical reaction produces gas during the heating process of the flux. With the absence of gravitational pull the gas gets trapped and frozen in the solder, which results in reduced conductivity and structural strength. The gas consists mainly of oxygen produced from the flux in the solder. Another source of the gas is the water vapour which gets produced in the process of melting the thin plastic layer of the Printed Circuit Board (PCB) [9].

To fully understand the problem found in SoRGE, NASA started the CLEAR project in 2005 to replace SoRGE. The goal of CLEAR is to develop a manually-operated electronics repair system that enables crew members to independently perform reparations in reduced gravity. A series of aircraft tests have been conducted to further investigate the effect of gravitation on solder. The aircraft tests allowed the research team to define and map the effect of gravitation of different magnitudes. The results show that the area of voids increases with decreasing gravity in relation to the total area of the solder. The CLEAR project is still (2012) collecting and providing NASA with data to develop and improve component reparations; however no solution has been found [10].

To solve the issue, the SOLAR project proposed a method for decreasing the area of voids. By allowing the gas bubbles to escape before the samples become solid, the area of voids could be reduced. The proposed method was to force the gas to the surface of the solder by using a pressure difference between the trapped gas and the surroundings. Due to the gas striving towards an equilibrium state, the pressure difference can be exploited to solve the problem found in previous experiments. By creating a low pressure soldering environment, an overpressure in the gas bubbles will occur, forcing them to escape the solder.

In this experiment a proposed solution was suggested. The low pressure environment in the thermosphere will provide the desired condition for the samples by allowing the intended section of the experiment to be connected to the outside environment. This approach were applied to two separate test chambers.

Currently (2013) crew members rely on removing or replacing, using backup systems or managing without the broken system [9]. The results of the SOLAR project could possibly conclude a suitable method for component repair in space. This would lead to reduced cost and payload weight of future space missions.

1.2 Experiment Objectives

The main scientific objective of project SOLAR was to investigate if the quality of solder joints produced in reduced gravity benefits by a vacuum environment.

The main technical objective of project SOLAR was to conduct a soldering process in reduced gravity.

The experiment could be regarded as successful if a valid void count can be obtained from at least 2/3 samples in each chamber.

1.3 Experiment Overview

The overall SOLAR experiment consists of four main segments; the soldering system, Experiment Control System (ECS), the SOLAR Ground Station (SGS) as well as the REXUS service module (RXSM). The main system is the soldering system which consists of two soldering chambers with different environments. The other segments will have supporting and controlling roles.

As mentioned above, the difference between the chambers is the soldering environment. While one chamber contained a pressurized environment, made as a reference sample, the other were performed in vacuum. The vacuum environment was used to obtain a greater pressure difference between the solder and its environment compared to the pressurized chamber. This would help the trapped gas inside the solder fluid to escape, thus reducing the amount of voids in the solder.

At the time of launch, the RXSM sent a launch signal initiating the ECS timer. This timer would make it possible to more accurately determine when the rocket had reached a predetermined altitude where reduced gravity was achieved. Once the timer limit was reached the ECS would signal the soldering system to start the heating process, where resistance wires would be heated to melt the samples. After the samples have melted the ECS will turn off the heating process. These events happened simultaneously in both chambers.

The downlink experiment data was continuously transmitted via the Esrange ground system to the SGS. The data collected from the pressure and temperature sensors were transmitted via the downlink to operate as a redundancy for the memory storage on-board.

When landed, the samples were collected and transported to an X-ray scanner at the University of Oulu in Finland.

A breakdown of the experiment structure is provided in chapter 4.1 Experiment Setup.

1.4 Team Details

1.4.1 Contact Point

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2 EXPERIMENT REQUIREMENTS

The chapter contains mission requirement of Project SOLAR. The requirements are subdivided into the following classes:

Table 1 - Requirement classes.

Functional (F)	Describes broadly what was to be attained, what functionality were desired
Performance (P)	Quantifies the performance needs for mission success
Design (D)	Requirements resulting from design factors, often conditions that the parts of the system must be able to endure
Operational (O)	Requirements relating to operation of the system

The requirement classifications are presented in the following form:

Table 2 - Requirement abbreviations.

M	Mechanics
E	Electronics
S	Software

2.1 Functional Requirements

Table 3 – Functional Requirements.

ID	Description	Response to
M.F.1	The solder shall reach a solid state before T+150s.	N/A
M.F.2	The vacuum chamber shall have a pressure close to the outside environment.	N/A
M.F.3	The solder sample shall have a well-defined melting point.	N/A
E.F.1	There shall be a downlink from the experiment to the EGS.	N/A

E.F.2	There shall be an on-board data storage for the gathered data on the experiment.	N/A
E.F.3	The experiment shall measure the temperature inside each of the chambers.	N/A
E.F.4	The experiment shall measure the pressure inside each of the chambers.	N/A
E.F.5	The battery pack shall be able to operate in the temperature profile inside the REXUS rocket.	N/A
E.F.6	The PDS shall provide accurate power to all subsystems.	N/A
E.F.7	The battery pack shall supply the resistance wires with enough power to reach the required temperature.	N/A
E.F.8	The power distribution system shall comprise a safety system enabling shut down of experiment on request.	N/A
S.F.1	The SGS shall be able to display information received from the experiment.	N/A
S.F.2	The microcontroller shall collect, decode and store data received on a memory card.	N/A
S.F.3	The microcontroller shall transmit data to the RXSM.	N/A
S.F.4	The experiment shall measure the mean temperature of the resistance wires in each chamber.	N/A
S.F.5	The experiment shall measure the pressure in each chamber.	N/A

2.2 Performance requirements

Table 4 – Performance requirements.

ID	Description	Response to
M.P.1	The experiment shall be able to work in an environment of -10 to +45 degrees centigrade.	M.D.7
M.P.2	The solder sample shall reach a temperature below 183 degrees centigrade before T+150s.	M.F.1
M.P.3	The pressure in the vacuum chamber shall not have a	M.F.2

	difference greater than +/-5% from the outside environment when soldering.	
M.P.4	The solder sample shall have a melting point of 183 +/- 1 degree centigrade.	M.F.3
E.P.1	The on-board data storage shall have a memory capacity of 1GB.	E.F.2
E.P.2	The temperature measurement inside each chamber shall be possible between -40 and +300 degrees centigrade.	E.F.3
E.P.3	The temperature measurement inside each chamber shall be made with an accuracy of +/-5 degrees centigrade.	E.F.3
E.P.4	The pressure measurement inside each chamber shall be possible between 0 and 110 kPa.	E.F.4
E.P.5	The pressure measurement inside each chamber shall be made with an accuracy of +/-3 kPa.	E.F.4
E.P.6	The battery pack shall be able to operate within a temperature range of -20 to +60 degrees centigrade.	E.F.5
E.P.7	The power circuits shall regulate the voltage to the level required by each component.	E.F.6
E.P.8	The battery pack shall be able to provide the resistance wires with a steady current of 11 A during the soldering process.	E.F.7
E.P.9	If no power is received from the service module, the active high switch for the battery pack/resistance wires system shall remain open.	E.F.8
S.P.1	The SGS shall be able to update the charts at the rate it is transmitted from the EGS.	S.F.1
S.P.2	The microcontroller shall collect, decode and store data at a rate of 10 Hz.	S.F.2
S.P.3	The microcontroller shall transmit downlink data at a rate of 10 Hz.	S.F.3
S.P.4	The mean temperature measurement of the resistance wires in each chamber shall be possible up to +400	S.F.4

	degrees centigrade.	
S.P.5	The mean temperature measurement of the resistance wires in each chamber shall be made with an accuracy of +/- 10 degrees centigrade.	S.F.4
S.P.6	The telecommunication link shall have a data rate of minimum 2kbps.	E.F.1
S.P.7	The pressure measurement inside each chamber shall be possible between 0 and 200 kPa.	S.F.5
S.P.8	The pressure measurement inside each chamber shall be made with an accuracy of +/-3 kPa.	S.F.5

2.3 Design Requirements

Table 5 – Design requirements.

ID	Description	Response to
M.D.1	The whole experiment shall withstand an acceleration of 20g.	N/A
M.D.2	The whole experiment shall be able to hold against vibrations of 12.7 G_{rms}	N/A
M.D.3	The weight of the experiment with experimental module shall not exceed 10 kg.	N/A
M.D.4	The experiment shall not produce a heat transfer to adjacent experiment of more than 10 degrees centigrade.	N/A
M.D.5	The resistance wire shall be in contact with the solder sample during flight.	N/A
M.D.6	The pressurized chamber shall be able to hold the pressure that is present at launch site with a maximum diff of +/-10 kPa during the soldering.	N/A
M.D.7	The experiment shall be resistant against thermal changes.	N/A
E.D.1	All components shall be selected to withstand vibrations of 12.7 G_{rms}.	N/A

E.D.2	All components shall be selected to fit into the mechanics design dimensions.	N/A
E.D.3	All components shall be selected to operate well within the expected limit with regard to safety margin and derating.	N/A
E.D.4	All components shall be selected to operate within the expected temperature range with a safety margin.	N/A
E.D.5	The cable feedthrough to the pressurized chamber shall be airtight.	N/A
E.D.6	The batteries shall be qualified for use on a REXUS rocket.	N/A
E.D.7	The batteries shall be easily accessible and rechargeable.	N/A
E.D.8	All communication between the two main systems shall be isolated through MOS-transistors.	N/A
E.D.9	The resistance wires shall be able to melt the soldering samples.	N/A
S.D.1	The system shall utilize a timeline to determine which stage it is in.	N/A
S.D.2	The ECS shall be able to operate autonomously.	N/A
S.D.3	The SGS shall be able to receive information from the experiment through the EGS.	N/A

2.4 Operational Requirements

Table 6 – Operational requirements.

ID	Description	Response to
E.O.1	The battery pack shall be switchable.	N/A
S.O.1	The ECS shall handle experiment control failures safely.	N/A
S.O.2	The ECS shall be able to operate autonomously.	N/A

3 PROJECT PLANNING

3.1 Team organization

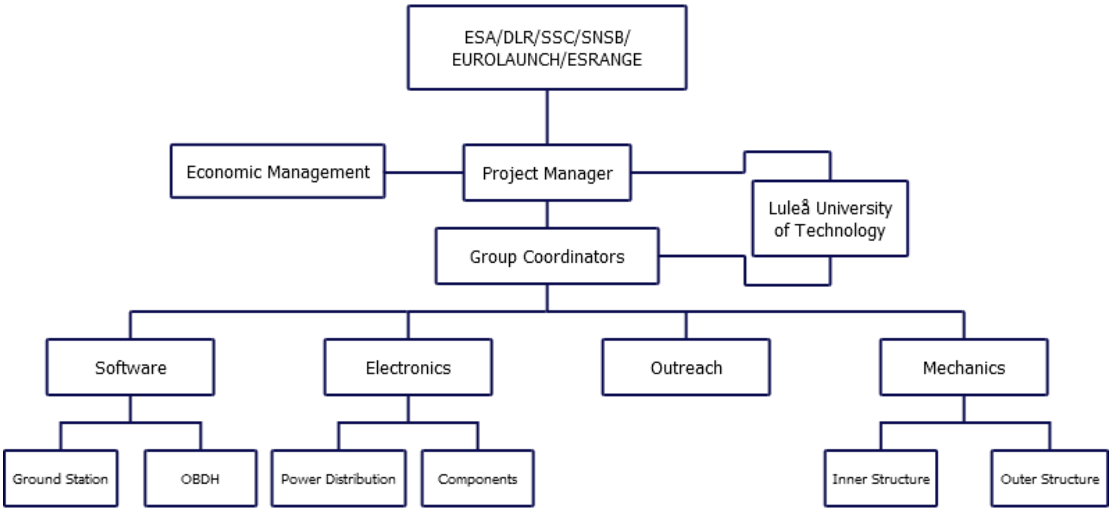


Figure 1 – Team organisation.

The SOLAR team was organized according to the block diagram above in Figure 1. All team members were students at LTU. Thirteen members were located at the Division of Space Science in Kiruna and one member was located in Stockholm. A majority of the fourteen team members were enrolled in a 15 ECTS module at LTU.

The project manager received progress rapports of each subsystem from the corresponding group coordinator, whom were responsible for supervising the team member's task completion. In order to maintain control of the project there were project meetings every second week where decisions were made on project level and where the progress of each group was presented. There were also weekly coordinator meetings where each group's progress was reviewed to ensure that the project follows the time plan. Decisions were also made regarding cross-group tasks and responsibilities. In addition, all groups had their own meeting before each work session for discussion of technical issues and task planning.

Since one team member was located in Stockholm the team organized regular Skype-meetings and thoroughly updated all progression online using Google Docs. For noncritical information the team used the internal Facebook page.

3.2 Work Breakdown Structure (WBS)

A more detailed version of the WBS for each group can be found in Appendix E – Work breakdown structure/gantt.

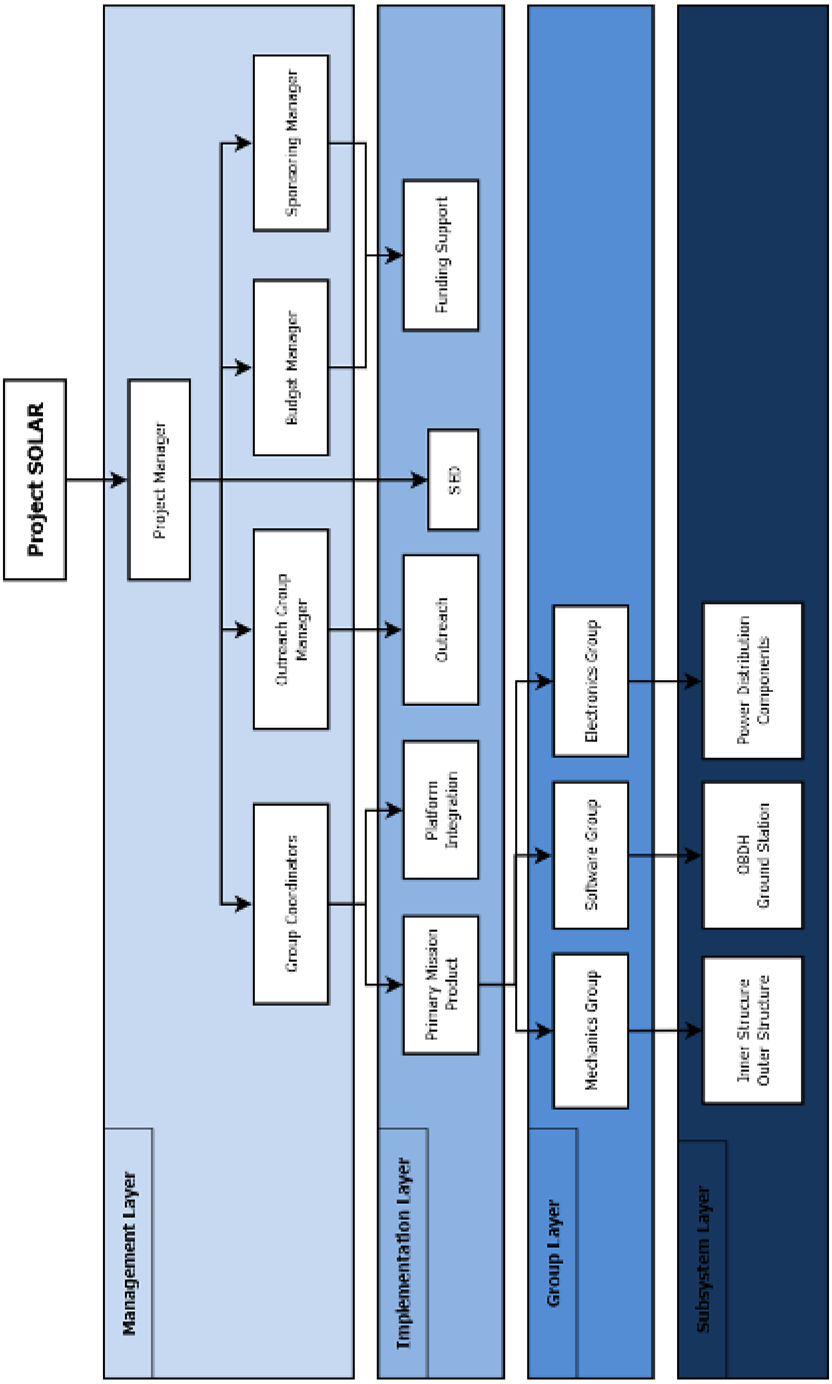


Figure 2 – Work Breakdown structure.

Table 7 – Detailed Work Breakdown Structure.

ID.nr	**Position**	**Description**	**Responsible team members**
1	Management Layer		
1.1	Project Manager	Responsible for the overall progress and organization of the project.	Anders Svedevall
1.2	Group Coordinators	Team member in charge of group progress and documentation, contact person for his group.	Björn Sjödahl Björn Paulström Adrian Lindqvist
1.3	Outreach Group Manager	In charge of how the project is marketed.	Maja Nylén
1.4	Budget Manager	Responsible for the financial administration of the project	Sara Widbom
1.5	Sponsoring Manager	Responsible for the progress of financial and hardware support	Anneli Prenta
2	Implementation Layer		
2.1	Primary Mission Product	The SOLAR experiments	Entire team
2.2	Platform Integration	The REXUS rocket	Entire team
2.3	Outreach	Team members in charge of general publicity and outreach plan	Maja Nylén Johan Strandgren Anders Svedevall
2.4	SED	Student Experiment Documentation	Entire team
2.5	Funding Support	Team members in charge of seeking funding.	Sara Widbom Anneli Prenta

3	Group Layer		
3.1	Mechanics Group	Worked with the mechanical parts of the experiment	Adrian Lindqvist Maja Nylén Sara Widbom Fredrik Persson Johan Strandgren Johanna Åstrand
3.2	Software Group	Worked with the software and data handling of the experiment	Björn Paulström Hamoon Shahbazi Robert Lindberg
3.3	Electronics Group	Worked with the power distribution and components of the experiment	Björn Sjödahl Anneli Prenta Emil Vincent Jens Kanje
4	Subsystem Layer		
4.1	Inner Structure	Worked with the inner structure and mounting of the PCB cards	Fredrik Persson Johanna Åstrand Sara Widbom
4.2	Outer Structure	Worked with the outer structure and attachment	Adrian Lindqvist Maja Nylén Johan Strandgren
4.3	OBDH Ground Station	The subsystem of software	Björn Paulström Hamoon Shahbazi Robert Lindberg
4.4	Components	Worked with the components	Anneli Prenta Emil Vincent
4.5	Power Distribution	Worked with power distribution of the experiment	Björn Sjödahl Jens Kanje Nordberg

The duration of project work tasks are presented in Figure 3. The tasks were planned with consideration to the amount of work load of the different phases and to the REXUS programme's fixed time plan.

A more extended version of the Gantt chart with each subsystem specified can be found in Appendix E

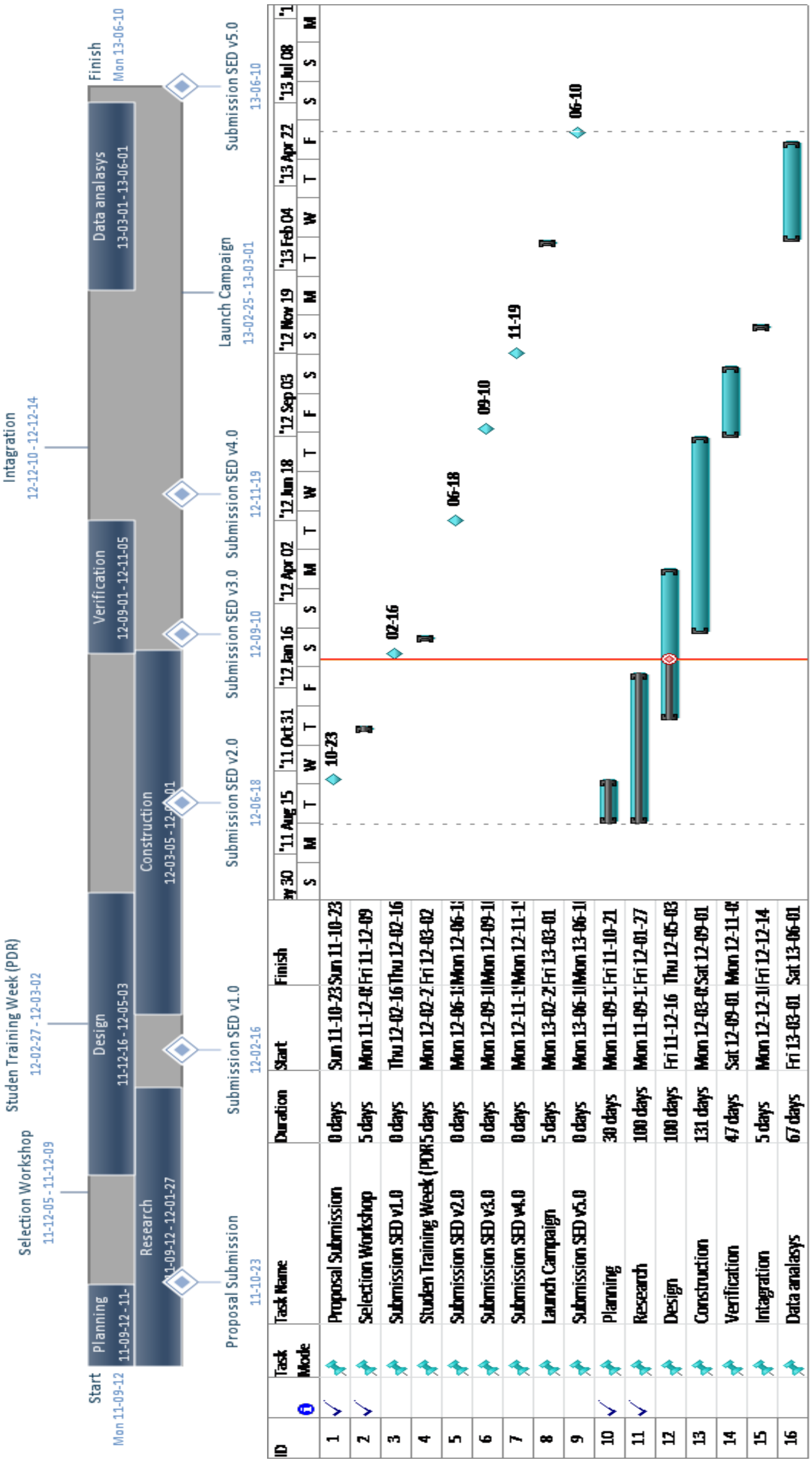


Figure 3 – Gantt chart.

3.3 Resources

3.3.1 Manpower

The Team consisted of 14 members with various specialities. Each team member was expected to spend about 10h a week working on the project and contributing with an equal amount of time to the project.

Anders Svedevall – Project manager

Anders, in his role as project manager, was responsible for the deadlines and organizing the team to ensure progress of the project. He was supported by the coordinators for the four subsystems in the role of managing the project and the team. Anders was also the contact person for external organisations.

Mechanics

Adrian Lindqvist – Mechanics Group coordinator

Adrian was responsible for the mechanics group in which he arranges weekly progress meetings to keep the team members updated and to assign tasks. He was also working with the outer structure of the experiment.

Maja Nylén

Maja was working on the vacuum and pressurized systems. She was also in charge of the outreach team.

Fredrik Persson

Fredrik worked with the mechanical design focusing on Modal-simulations.

Johan Strandgren

Johan worked with the inner structure, focusing on designing CAD-models. He was also working with the outreach.

Sara Widbom

Sara was the deputy project manager assisting the team in case of absent of the project manager. She worked mainly with the mechanical design focusing on thermal analysis. She was also the budget manager of the project and worked with the funding support.

Johanna Åstrand

Johanna was working on the inner mechanical design focusing on Modal simulations.

Electronics

Björn Sjödahl - Electronics Group coordinator

Björn, in his role as electronics coordinator, arranges weekly group meetings to ensure progress of the group and to keep the team member updated. He was working on the electrical design, power distribution system and electrical components.

Anneli Prenta

Anneli was working on the electrical design, power distribution system and electrical components. She was also the sponsoring manager.

Emil Vincent

Emil was working on the electrical design, power distribution system and electrical components focusing on electrical schematics.

Jens Kanje Nordberg

Jens was working on the electrical design, power distribution system and electrical components.

Software

Björn Paulström – Software Group coordinator

Björn controls the progress of the software group. He was focusing on the sensors and programming the power flow control.

Robert Lindberg

Robert worked mainly on software design and experiment components data focusing on programming the timeline/ statemachine.

Hamoon Shahbazi

Hamoon worked mainly on software design and experiment components data focusing on programming the main loop.

3.3.2 Budget

Due to the fact that the budget was so extensive it has been attached and can be found in Appendix D – Finances. Table 8 shows an overview of the budget.

Table 8 – Project budget overview.

Group	**Subsystem**	**Cost in SEK**	**All components bought**
Mechanics	Outer Structure	15575.08	Yes
Mechanics	Inner Structure	583.36	Yes
Mechanics	Attachments	1739.366	Yes
Electronics	Power Distribution	15800.23	Yes
Electronics	Components	2300.86	Yes
Software	OBDH - OnBoard Data Handling	499	Yes
Outreach	Outreach	6962.5	Yes
Team	Miscellaneous	28631	No
TOTAL		**72091.396**	
FUNDING			
Patron	**Status**	**Funds in SEK**	**Spent in SEK**
Department of Computer Science, Electrical and Space Engineering	Sponsorship recieved	20000	20000

Department of Computer Science, Electrical and Space Engineering	Sponsorship recieved	20000	
LKAB	Sponsorship recieved	14700	
Tribotec	Sponsorship for silicone adhesive recieved	1600	1600
Nybergs mek. & verkstad	Sponsorship recieved: reduced price	4577.5	4577.5
Tätring AB	Sponsorship recieved	894.08	894.08
Department of Computer Science, Electrical and Space Engineering	Sponsorship recieved (t-shirts)	2231.25	2231.25
SNSB	Sponsorship recieved	30000	
Department of Computer Science, Electrical and Space Engineering (studentrekryteringen)	Sponsorship recieved	2500	2500
TOTAL		**96502.83**	**6177.5**
BALANCE		**24411.434**	

3.3.3 External Support

3.3.3.1 Expert Advice and Facilities

The team had access to a specialized workshop at the Department of Computer Science, Electrical and Space Engineering (SRT) with qualitative instruments and equipment for both electrical and mechanical work. The Swedish Institute of Space Physics (IRF) is located in the same building as SRT. Several instruments for space applications were developed and built here and SOLAR was allowed to use some of their equipment when the project was built and tested.

The Team was supported by several experts in different categories at LTU and IRF.

Table 9 – Expert support.

Name	Title/Affiliation	Field of Expertise
Esa Vuorinen	University Lecturer, LTU	Characteristics and uses of materials
Alf Wikström	Engineering Physics Engineer, LTU	Wide expertise focusing on electronics and rocket projects
Kjell Lundin	Research Engineer, LTU	Wide expertise focusing on space instruments. Life long experience of space and rocket projects.
Victoria Barabash	University Lecturer, LTU	Space and atmospheric science, project management
Anita Enmark	University Lecturer, LTU	Software and data communication
Johan Borg	University Lecturer, LTU	Electronics
Rikard Qvarnström	PhD student, LTU	Electronics and soldering in general
Magnus Oja	Research Engineer, IRF	Mechanical construction and CAD
Jonny Johansson	University Lecturer, LTU	Electronics and project guidance
Gunnar Hellström	Assistant professor, LTU	Fluid dynamics and simulations

3.3.3.2 Sponsors

The team was in contact with several companies and in negotiation regarding financial and hardware support. Contacts had been made primarily with local companies in the purpose of accessibility to expert advice and for a closer relation. The team also contacted specialized companies whose products or services met our specific needs. A more detailed plan can be seen in Table 10.

Table 10 – Received support and on-going negotiation.

Company, department or institute	Financial or hardware request	Current status	Received support
Department of Computer Science, Electrical and Space Engineering, LTU	Financial support	Confirmed	20 000 SEK and negotiating for further funding.
Tribotec AB	Silicon for bonding and insulation	Confirmed	As requested
LKAB	Financial support	Confirmed	14 700 SEK
Nybergs Mek. & Verkstad	Financial or hardware	On-going	
Wiedland AB	Thermal insulation	Not applicable.	As requested
Tätringen Tekniska AB	o-rings and vacuum grease	Confirmed	As requested

3.4 Outreach Approach

The outreach team aimed towards meeting the interest from all possible angles by using a wide range of tools for the outreach programme. Due to the technical application of the SOLAR experiment the outreach team expected to interest both the industry and the academic sphere. Another goal was to intrigue the general public by pointing out the revolutionary aspect of a successful result. The outreach team had to create a solid outreach platform from which it would be possible to reach out to all of these sectors.

3.4.1 Website and Blog

Two of the most important tools for the public outreach plan were the SOLAR website and blog. The website was designed to make it possible for visitors to learn more about the experiment, the team members and the REXUS/BEXUS programme. Contact information, sponsors and media coverage was displayed along with easy access to the SOLAR blog, Twitter site and Facebook page.

The SOLAR website is accessible at http://solar.rymdteknik.com/

The SOLAR blog were updated continuously with posts, pictures and videos allowing visitors to follow the progress of the project. It also enabled a dialog with the audience through the comments tool.

The SOLAR blog is accessible at http://solar-rexus.blogspot.com/

Table 11 – Website structure

Home	Welcome! A very short presentation of the web site.
The project	A description of the REXUS programme and the experiment.
The team	Introduction and pictures of team members and their position in the project.
Sponsors	Here the sponsors of the project are displayed.
Media	A list of all appearance in media (television, radio, newspapers etc.) and shortcuts to the Facebook and Twitter pages
Gallery	Pictures and animations taken during the project.
Calendar	Time plan and important deadlines etc.
Contact us	Contact information.
Blog	Link to the SOLAR blog.

The activity on the blog increased considerably when each sub group got access to it and could post more updates regarding their area. This was enabled to try and reach a wider public.

3.4.2 Facebook and Twitter

The SOLAR team started a fan page on Facebook and a Twitter account. The fan page was an easy way to give quick updates about the project but it also enabled the team to inform when something new had appeared at the website or the blog. The plan was to invite students and other friends of the team in hope for a wide distribution. Twitter enabled the project to be seen by the public and organisations. It was also a suitable platform that allowed the team to follow and be followed by other REXUS teams.

The mission to get as many likes on facebook as possible ended after the launch campaign, almost 500 people had liked project SOLAR by then.

3.4.3 Publications

The Solar team has at the moment given five interviews. A short summary of each interview and publication is presented bellow in chronological order:

- **December 27th 2011** – An interview with the team member Björn Sjödahl was published in the local newspaper *Blekinge läns tidning*. The article is written about Björn's education where he had the chance to discuss the SOLAR project.
- **January 26th 2012** – An interview with the team manager Anders Svedevall was made by the press manager at LTU about the REXUS project. The article contains information about the team, the current status and the challenges ahead. A picture of the team was also attached. The article was published at the front page of LTU´s website, accessible for all students and staff, but also for external visitors of the website. The interview, including the picture of the team, was also sent to press agencies in Sweden with hopes to get published in as many ways as possible. The Swedish science magazine *Ny Teknik* responded to the press release with interest of publishing an article about the project.
- **February 29th 2012** – An interview with the peoject manager Anders Svedevall was published in the Swedish science magazine *Ny Teknik*. This article contains a more detailed overview of the experiment since their readers in general are interested in science and technology.
- **September 21st 2012** – An interview with the team members Maja Nylén and Robert Lindberg was published in the local newspaper *Norran*. The article is written about the members education and life in Kiruna and the SOLAR project was discussed.
- **September 25th 2012** – An interview with the project manager Anders Svedevall and team meamber Maja Nylén was published on the blog by the Swedish space website *Rymdkanalen.se*. The interview was regarding being part of a REXUS/BEXUS project and what the SOLAR project is about. The website linked to team SOLARS own blog at the end.

Otherwise, a couple of local newspapers also responded to the press release and published articles about the project. The project was written about and linked to at the websites of Swedish National Space Board and Rymdkanalen which are two Swedish space orientated organisations. The published articles can be found by following the links presented in Appendix B – Outreach and Media Coverage.

3.4.3.1 University and high school Outreach

The outreach team dedicated considerable time and effort to reach out to university and high school students by giving presentations. It was mainly because of the opportunity of inspiring younger students to find an interest in space science and technology. The goal for the presentations given at universities were to intrigue technology-orientated university students to participate in student projects, like the REXUS/BEXUS programme. It was very instructive and enabled the opportunity to develop your own ideas. At high schools the team aimed towards increasing the interest in technology and space science by giving presentations about the experiment, show pictures and tell them about the possibilities that are available along with university studies. The goal was not only to interest them in space science; it was also to make them realize the advantages of continuing their studies.

In Kiruna, where the major part of the team studied, there was a high school focusing on space science. The team wanted to give a presentation about the project and our education to show them the possibilities of continuing their studies focusing on space science and technology at a higher level. The team would also provide them with information about the REXUS/BEXUS-programme, how it works and the opportunities it results in.

On March 5th 2012, five team members travelled to Luleå and held a presentation for students in year 1-4 in the space engineering master programme. The presentation included information about the project, both basic and detailed. The focus was put on the scientific background, our proposal, what we intend to do with the samples after the mission, the preliminary design and team organisation. Parts of the outreach programme were also presented where we asked the audience to follow the project on website, blog, Facebook, and Twitter. The audience was informed about the REXUS/BEXUS programme, with basic information about each programme. They were also given a brief explanation in how and when to apply.

On September 17th and 21st, two presentations covering the project was made for younger master programme in space engineering students. The first presentation was held at Space Campus in Kiruna by two team members. For the second presentation, three team members travelled to LTU in Luleå. Both presentations was about the current status of the project and the plans for the future with the objective to inspire these younger students to apply for own REXUS/BEXUS projects.

On Septmber 28th, a group of younger master programme in space engineering students had the opportunity to visit and interact with the working process of team SOLAR at Space Campus in Kiruna. Each subsystem prepared stations for the students to visit and they had the opportunity to ask questions about the project.

Posters were be produced, with information about the project together with pictures, contact information and our sponsor’s logotypes. They were posted on bulletin boards at space campus in Kiruna, at LTU in Luleå, at IRF and on other places that the team found suitable.

Team polo-shirts were designed and delivered on October 19th 2012. Except team SOLAR´s own logo, the REXUS/BEXUS and LTU logos are viewed along the team name and the REXUS round 13/14. The design can be seen in Figure 4.

Figure 4– Team polo-shirt design.

A team patch was designed and were meant to be produced. This is because patches are popular among students at LTU but due to the lack of time this was never done. The design can be seen in Figure 5.

Figure 5 – Team patch design.

3.4.3.2 The Outreach Future

The team will continue to promote the project in the future by giving presentations. The project can also be used as a template for similar projects being carried out at Luleå University of Technology for future students.

3.5 Risk register

Table 12 – Risk ID.

MS	Mission (operational performance)
TC	Technical/Implementation
PE	Personnel
VE	Vehicle

The approach to risk assessment were performed according to the following method

- First, the risk in relevant categories was identified.
- The probability (P) and severity (S) of each risk were estimated according to their respectively scales:

Probability (P)

A. Minimum – Almost impossible to occur

B. Low – Small chance to occur

C. Medium – Reasonable chance to occur

D. High – Quite likely to occur

E. Maximum – Certain to occur, maybe more than once

Severity (S)

1. Negligible – Minimal or no impact
2. Significant – Leads to reduced experiment performance
3. Major – Leads to failure of subsystem or loss of flight data
4. Critical – Leads to experiment failure or creates minor health hazards
5. Catastrophic – Leads to termination of the project, damage to the vehicle or injury to personnel

- The risk index (P x S) was calculated and labelled according to the scheme in Table 13.

Table 13 – Risk index and magnitude scheme.

Probability (P)	1	2	3	4	5
E	low	medium	high	very high	very high
D	low	low	medium	high	very high
C	very low	low	low	medium	high
B	very low	very low	low	low	medium
A	very low	very low	very low	very low	low

Severity (S)

- Finally, actions to mitigate or remove the risks were proposed.

The abbreviations used in this section can be seen in Table 14.

Table 14 – Risk Register abbreviations.

OST	Outer Structure
IST	Inner Structure
OBDH	On-board Data Handling

SGS	SOLAR Ground Station
PDB	Power Distribution
CPS	Components
ORG	Organization
MEC	Mechanics
FLM	Fluid Mechanics

3.5.1 Mechanics Risk Register

Table 15 – Risk register for mechanics.

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
IST.MS10	Resistance wire not in contact with solder sample.	A	4	Very low	Accurate procedures.
OST.TC10	The pressurized chamber is not able to hold a pressure of 100 kPa.	C	2	Low	Qualification testing.
IST.MS20	Solder sample moves along the resistance wire due to vibrations.	B	1	Very low	Accurate procedures.
IST.MS30	Solder sample comes loose during soldering process.	A	3	Very low	Tests.
IST.MS40	Resistance wire contaminates the sample.	B	2	Very low	Contact the manufacturer for data sheet on the wire´s properties.
OST.MS20	There will be a short circuit in the base.	A	4	Very low	Correct design and accurate attachment of vital parts.
OST.MS30	Vacuum like environment will not be reached in the vacuum chamber.	A	4	Very low	Tests to determine inlet size to chamber
IST.MS50	Copper plate comes loose from soldering PCB due to vibrations.	A	4	Very Low	Accurate attachment and procedures.

IST.TC60	Pressure and/or temperature sensor comes loose from the sensor PCB due to vibrations.	B	1	Very low	Accurate attachments and procedures.
IST.TC70	All helicoils wears out.	A	1	Very low	Choose high quality components and tests thoroughly.
IST.MS80	Soldering PCB comes loose from the base.	A	3	Very Low	Accurate attachments and procedures.
OST.TC110	Pressurized chamber deforms due to pressure differences.	C	1	Very Low	Tests according to SSC pressure difference recommendations.
IST.MS100	Sensor PCB comes loose from the base.	A	2	Very Low	Accurate attachments and procedures.

3.5.1.1 Replaced or Removed Risks Register, Mechanics

Table 16 – Risk register for replaced or removed risks for Mechanics from SED -1.0.

ID From SED -1.0	Risk (& consequence if not obvious)	Action
MEC.TC10	Solder iron in wrong position due to vibrations.	Risk removed.
FLM.TC20	The pressurized chamber is not enough airtight to produce an reliable reference sample.	Risk replaced by OST.TC10.
FLM.TC30	Argon gas flow damages the samples due to rapid cooling.	Risk removed.
MEC.TC40	Solder comes loose from the PCB card due to the solder iron.	Risk removed.
MEC.TC50	Solder comes loose from PCB card due to vibrations.	Risk replaced by IST.MS30.
MEC.TC60	Compression springs stuck in position.	Risk removed.
MEC.TC70	Extension spring stuck in position.	Risk removed.
MEC.TC80	Nichrome wire fails to burn off nylon thread.	Risk removed.

3.5.2 Electronics Risk Register

Table 17 – Risk register for electronics.

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
CPS.TC10	Critical components are	C	1	Very low	Stock spare

	destroyed during testing.				components.
CPS.MS20	Manufacturing delays or late delivery.	C	2	Low	Order in advance with a good margin.
PDB.TC10	Battery pack short circuits or overload.	A	4	Very Low	Protective electronics built into the battery pack.
CPS.MS30	Decreased functional characteristics of components due to vibrations.	B	2	Very low	Vibration tests.
CPS.TC40	Power peak discharge interrupts or damages critical components	A	3	Very Low	Use DC/DC converters with a stabile power output and multiple filters..
CPS.MS50	Decreased functional characteristics of components due to temperature variations.	B	2	Very low	Select components which can handle a wide range of temperature and testing.
CPS.TC60	The resistance wires breaks during the heating process.	A	4	Very low	Review and test thoroughly.
CPS.MS70	Failure of critical components during flight.	B	3	Low	Testing.
PDB.TC20	Current overload in cables.	A	3	Very low	Use cables with proper gauge and good characteristics.
PDB.MS50	Power to the resistance wires from the battery pack turns on before reaching milligravity.	A	4	Very Low	Install safety system such as switches, and test thoroughly.
CPS.MS80	Energy discharge interrupts or damages the microcontroller.	A	3	Very Low	All communications done through optocouplers, filters and switches.
CPS.MS90	Sensors providing false readings.	B	1	Very low	Testing.
PDB.MS60	Connectors get detached due to vibrations during launch.	A	3	Very Low	Use connectors with screw lock.
PDB.MS70	One subsystem failure affects the other.	B	2	Very low	Make sure the subsystems can be isolated and shut down on request.
PDB.MS100	Battery voltage drops and hence the required temperure is not reached.	B	2	Very low	Ensure full charge before launch and avoid long time exposure to cold environment

3.5.2.1 Replaced or Removed Risks Register, Electronics

Table 18 – Risk register for replaced or removed risks for Electronics from SED -1.0.

ID From SED -1.0	Risk (& consequence if not obvious)	Action
CPS.MS50	Camera malfunction due to high temperatures.	Risk removed.
PDB.MS60	Not enough power to maintain the heat of the soldering tips after launch.	Risk removed
PDB.MS70	Batteries completely discharges before completing their task.	Risk replaced by PDB.MS40.
PDB.MS30	Battery pack fails to recharge before flight.	Risk removed.
PDB.MS40	Batteries completely discharge before completing their task.	Ensure full charge before launch and avoid long time exposure to extreme cold.

3.5.3 Software Risk Register

Table 19 – Risk Register for software.

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
SGS.MS10	Either SGS or EGS loses power, or crashes for any reason, thus disabling the data downlink.	A	1	Very low	No action: Data is saved on-board.
OBDH.MS10	Data storage onboard not working.	A	2	Very low	Data from downlink can be used as backup and secondary storage.
OBDH.MS20	Program crashes before the shutdown stage.	A	4	Very low	Massive testing to minimize the risk that the fully automated system will crash. In case of crash the system will restart.
OBDH.MS30	Unsatisfactory performance of tasks allocated to microcontroller.	A	4	Very low	Unacceptable risk: Test and optimize the program code.

3.5.3.1 Replaced or Removed Risks Register, Software

Table 20 – Risk register for replaced or removed risks for Software from SED -1.0.

ID From SED -1.0	Risk (& consequence if not obvious)	Action
OBDH.MS20	Data storage onboard not working.	Risk replaced by OBDH.MS10.
OBDH.MS30	Program crashes before the shutdown stage.	Risk replaced by OBDH.MS20.
OBDH.MS40	Unsatisfactory performance of tasks allocated to microcontroller.	Risk replaced by OBDH.MS30.

3.5.4 Rocket related Risk Register

Table 21 – Risk register for the rocket and other experiments.

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
OST.VE40	Heat spread to rocket.	A	1	Very low	simulation, tests.
OST.MS50	Heat spread to other experiments.	A	4	Very Low	simulation, tests.
OST.MS60	Explosion due to overpressure in airtight container.	A	4	Very Low	Follow restrictions and recommendations. Do tests and simulations.
OST.VE70	Entire experiment comes loose from the experimental bulk head	A	5	Low	Test and qualified attachments and procedures.
OST.VE80	Parts from the experiment comes loose from the experiment bulkhead.	A	4	Very Low	Test and qualified attachments and procedures.

3.5.4.1 Replaced or Removed Risks Register, Rocket

Table 22– Risk register for replaced or removed risks for the rocket and other experiments from SED -1.0.

ID From SED -1.0	Risk (& consequence if not obvious)	Action
FLM.VE10	Heat spread to rocket.	Risk replaced by OST.VE40.
FLM.MS20	Heat spread to other experiments.	Risk replaced by OST.MS50.
FLM.VE30	Spread of argon gas to rocket.	Risk removed.

FLM.MS40	Spread of argon gas to other experiments.	Risk removed.
FLM.MS50	Gas explosion due to argon gas.	Risk removed.
FLM.MS60	Gas explosion due overpressure in airtight container.	Risk replaced by OST.MS60.

3.5.5 Human safety Risk Register

Table 23 – Risk register for human safety.

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
IST.PE90	Burn from resistance wires during tests.	A	4	Very low	Handle with care. Always keep the box closed while testing.
PDB.PE80	Electric shock from electronics during tests.	B	2	Very low	Control all couplings and handle with care.
OST.PE90	Risk of hurting body parts when lifting or dropping the experiment due to its weight.	B	2	Very low	Handle with care.
PDB.PE90	Risk of NiMH battery explosion during charging.	A	4	Very Low	Handle with care. Always follow the restrictions for the battery.

3.5.5.1 Replaced or Removed Risks Register, Human safety

Table 24 – Risk register for replaced or removed risks for human safety from SED -1.0.

ID From SED -1.0	Risk (& consequence if not obvious)	Action
FLM.PE10	Gas explosion due to argon gas.	Risk removed.
FLM.PE20	Frostbites due to argon gas leakage.	Risk removed.
MEC.PE30	Burn from solder iron during tests.	Risk replaced by IST.PE90.
STR.PE40	Frostbites.	Risk removed.
PDB.PE50	Electric shock from electronics during tests.	Risk replaced by PDB.PE80.

3.5.6 Project planning Risk Register

Table 25 – Risk register for Project planning.

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
ORG.PE10	Loss of personnel through illness	C	1	Very low	Knowledge of other team member´s work
ORG.PE20	Loss of personnel through injuries	B	1	Very low	Knowledge of other team member´s work
ORG.PE30	Loss of personnel through withdrawal	B	2	Very low	Knowledge of other team member´s work and backup plan on bringing in a replacement.
ORG.MS40	Inaccessible contact with mentors	B	2	Very low	Acceptable risk, no action.
ORG.MS50	Removal of simulation tools only licensed by LTU	A	4	Very low	Obtain own license.
ORG.MS60	Experimental funding not accessible	A	4	Very Low	Investigate reason and arrange meeting with responsible.
ORG.MS70	Agreements on usage of experimental equipment and work areas are withdrawn	B	4	Low	Find alternative equipment and work areas.
ORG.MS80	Necessary expertise in the team is insufficient	B	3	Low	Find external expertise and educate the team.
ORG.PE90	Inadequate team collaboration	A	3	Very low	Meetings.

3.5.7 Manufacturing and Integration Risk Register

Table 26 – Risk register for Manufacturing and Integration.

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
OST.MS100	Late delivery of components and materials to Mechanics.	C	3	Low	Investigate backup solutions.
CPS.MS100	Late delivery of components and materials to Electronics.	C	3	Low	Investigate backup solutions ahead.
OBDH.MS40	Late delivery of components and materials to Software.	C	2	Low	Investigate backup solutions ahead.
ORG.MS100	Order complications due to regulations abroad.	A	2	Very low	Investigate regulations and

					alternatives.
ORG.MS110	Damages to critical components.	A	3	Very Low	Investigate backup solutions.
ORG.MS120	Delivered object does not fulfil requirements.	B	1	Very low	Investigate backup solutions.
ORG.MS130	Wrong component or material delivered.	A	2	Very low	Investigate backup solutions.

3.5.8 Time plan Risk Register

Table 27 – Risk register for the time plan.

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
OBDH.TC50	Not enough time for melting samples.	A	4	Very low	Strict time plan, time-tests and trustworthy heating elements.
OBDH.TC60	Not enough time for cooling samples.	A	4	Very low	Strict time plan, tests and trustworthy cooling method.
OBDH.TC70	Melting of the samples starts too early.	A	4	Very Low	Strict time plan.
OBDH.TC80	Cooling phase of the samples starts too late.	A	4	Very Low	Strict time plan.

3.5.8.1 Replaced or Removed Risks Register, Time plan

Table 28 – Risk register for replaced or removed risks for the time plan from SED -1.0.

ID From SED -1.0	Risk (& consequence if not obvious)	Action
OBDH.TC10	Not enough time for melting samples.	Risk replaced by OBDH.TC50.
OBDH.TC20	Not enough time for cooling samples.	Risk replaced by OBDH.TC60.
OBDH.TC30	Melting of the samples starts too early.	Risk replaced by OBDH.TC70.
OBDH.TC40	Cooling phase of the samples starts too late.	Risk replaced by OBDH.TC80.

4 EXPERIMENT DESCRIPTION

4.1 Experiment Setup

For a quick overview of the SOLAR experiment please refer to chapter 1.3 – Experiment Overview.

The SOLAR experiment was divided into four segments; the soldering system, the Experiment Control System (ECS), the SOLAR Ground Station (SGS) as well as the REXUS service module (RXSM). The main objectives of the experiment was to perform an automated soldering process in reduced gravity and by investigating the resulting samples, the applicability of the tested soldering processes for space use can be inferred.

In this chapter each system will be briefly outlined. For a more detailed description of each system please refer to 4.4 Mechanical Design, 4.5 Electronics Design, 4.7 Power System and 4.8 Software Design. An overview of the experiment setup can be seen in Figure 6.

Data sampling started pre-launch and continued throughout the experiment. At the time of launch the RXSM sent a LO launch signal initiating the ECS timer. The timer was used as a reference for determining when the desired gravity was reached and the experiment had to be executed.

At a predetermined time, the ECS signaled the soldering system to produce a current flow through the resistance wires, which heated and melted the samples. After a predetermined time heating the solder, another signal was sent from the ECS to stop the current flow, thus allowing the samples to cool before exiting the reduced gravity phase.

The prior processes described in this section are applicable for both chambers and occured simultaneously. One of the chambers was to be air filled with a pressure of 100 kPa, henceforth called the pressurized chamber. The other chamber was aimed to have a pressure of about 0.4 mbar, which is an acceptable value for vacuum in this experiment, henceforth called the vacuum chamber. To achieve vacuum, there were two holes in the experiment module and one in the vacuum soldering chamber. To make sure the soldering procedure was applicable in a vacuum environment the procedure has been successfully tested prior to launch.

A pressure sensor and a temperature sensor was located in each soldering chamber. The pressure and temperature sensors provided data to show if the soldering was done within given parameters. While descending, the data continued to be provided by the sensors inside the chambers within a given amount of time after landing. When the samples have been collected they were transported to the University of Oulu in Finland for analysis. This was performed using an X-ray scanner of model Feinfocus FXS – 160.23.

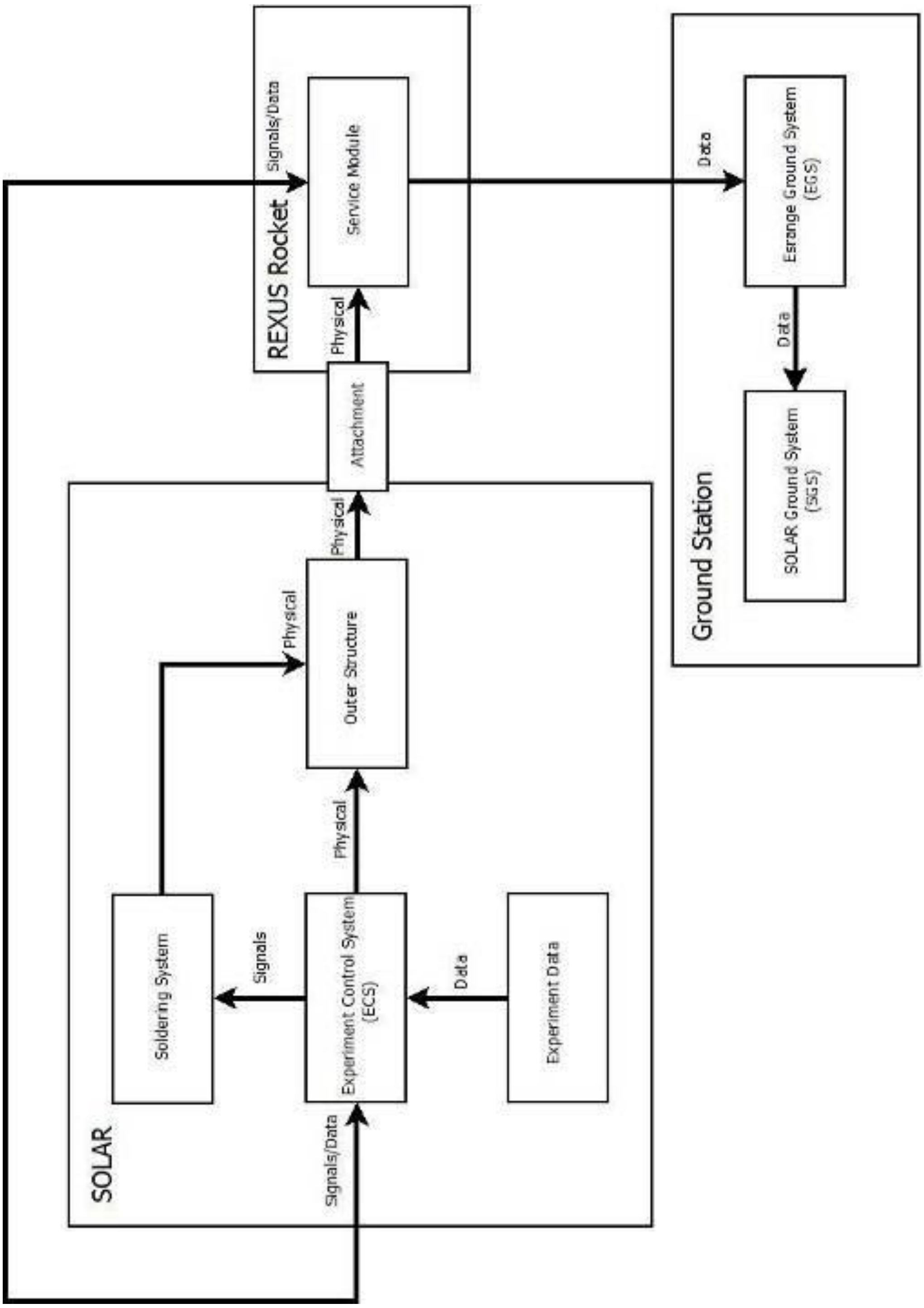


Figure 6 – Experiment setup overview.

4.2 Experiment Interfaces

4.2.1 Mechanical

The experiment consisted of five parts that were attached to the bottom mounted bulkhead; the vacuum chamber, the pressurized chamber, the electronics box, the battery pack housing and the D-SUB contact holder. Each chamber was attached to the bulkhead using eight M4x30 screws with corresponding spring washers. The screws went through the hat, base and finally into the bulkhead where it was fastened. An overview of the chamber attachment can be seen in Figure 7.

Figure 7 - Overview of the chamber attachment to the bulkhead.

The electronics box was attached to the bulkhead using three angle braces in two different shapes. The box was attached with 9 M4x8 screws. Each screw went through a spring washer, the angle brace and finally into the bulkhead where it was fastened. To achieve power the D-SUB 15 contact from the RXSM was connected to the electronics using an inlet hole in the electronics box wall. There were three more holes in the electronics box wall aswell, two for the D-SUB 24 contacts which provides the chambers with power and one for the D-SUB 4 contact from the battery pack. An overview of the electronics box attachment and the contact inlets can be seen in Figure 8.

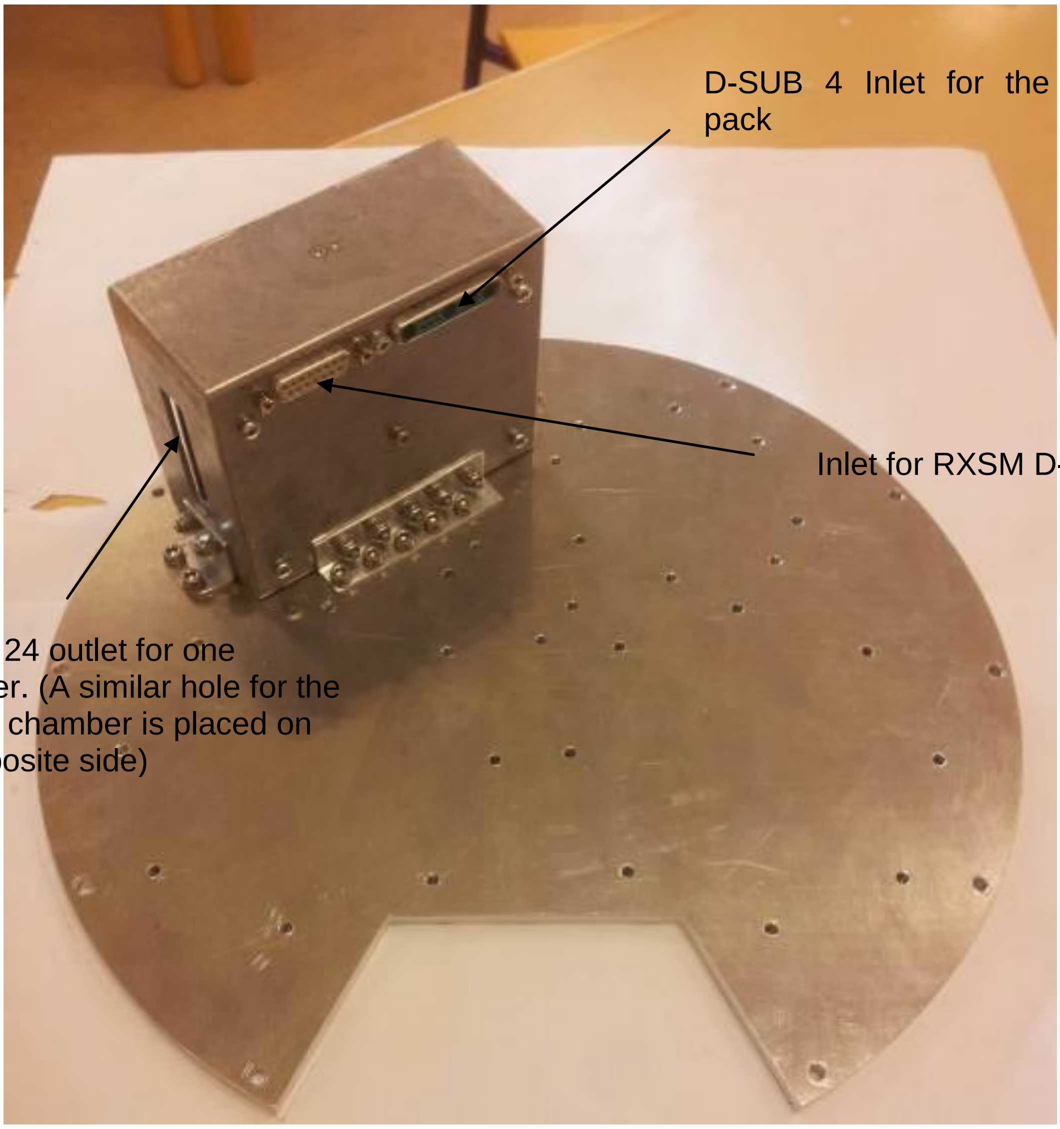


Figure 8 - Overview of the electronics box attachment to the bulkhead and the inlets and outlets for the different contacts.

To clarify the electronics box attachment to the bulkhead, a footprint view of the electronics box including the dimensions of the angle braces can be seen in Figure 9.

Figure 9 - Footprint view of the electronics box.

The battery pack housing was attached to the bulkhead using a customized housing. The housing had the shape of angle bars at the bottom to simplify the attachment to the bulkhead. There were eight M4x8 screws with corresponding spring washers going through the battery housing and into the bulkhead where they were fastened. An overview of the attachment for the battery pack housing can be seen in Figure 10.

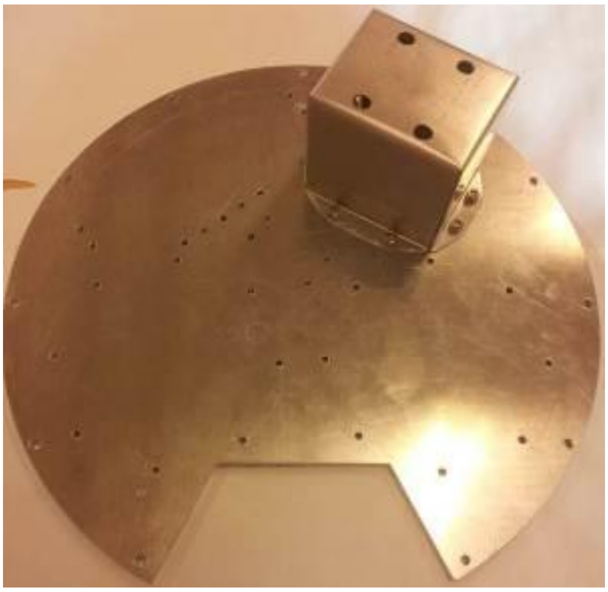


Figure 10 - Overview of the battery pack attachment to the bulkhead.

The d-sub contact holder worked as a link beween the electronics box and the chambers. The D-SUB holder was attached to the bulkhead using four M4x8 screws with corresponding spring washers. An overview of the D-SUB contact holder attachment can be seen in Figure 11.

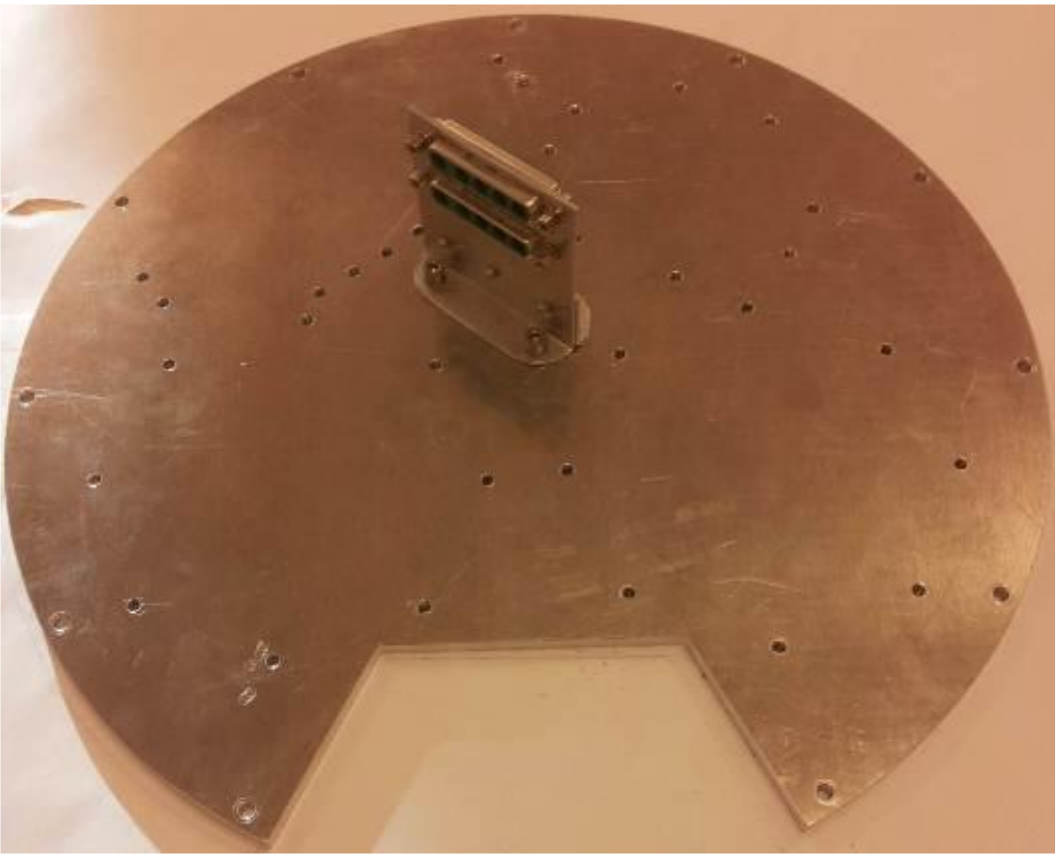


Figure 11 - Overview of the D-SUB contact holder attachment to the bulkhead.

An overview of all parts attached to the bulkhead can be seen in Figure 12 and Figure 13.

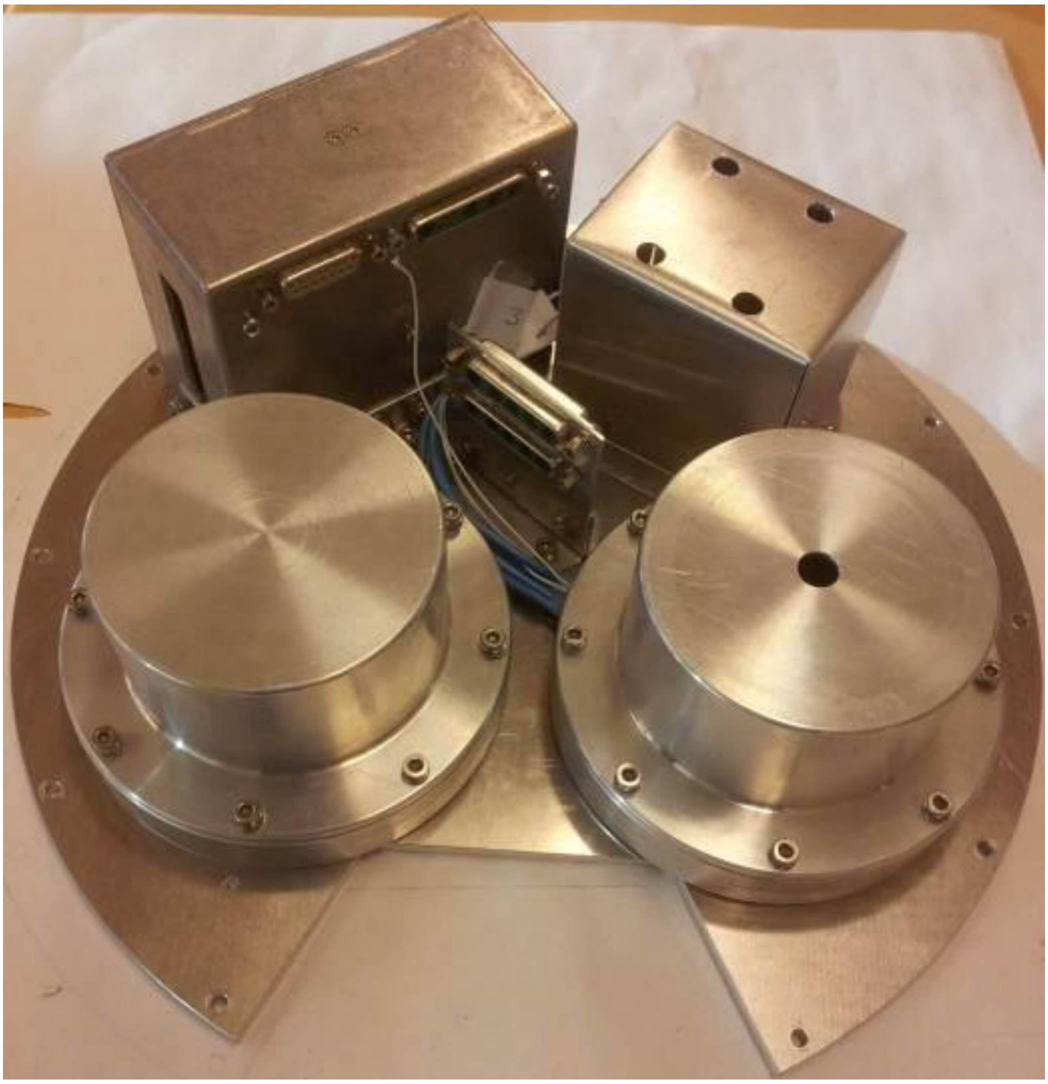


Figure 12 - Overview of all parts attached to the bulkhead.

Figure 13 - Overview of all parts attached to teh bulkhead seen from above.

The bulkhead was attached to the rocket module using the pre designed holes. There was a hole in the bulkhead for the cable feed through. The hole had a radial length of 71.6 mm and a depth of 70.2 mm from the bulkhead edge. The D-SUB contact bracket was placed above the cable feed through hole, 20 mm below the bottom of the radax flange at the top of the module. The feed through hole was placed at the 180 degrees line. To enable vacuum in the vacuum chamber fast enough there were two venting holes in the rocket module wall, the holes had a diameter of 10 mm. To prevent a huge amount of hot gasses entering the rocket module, two types of protection caps was used. One type on the outside and the other one on the inside, covering each hole. The protection caps can be seen in Figure 15 and Figure 16. The venting holes are placed between our own electronics and the cable feed through 180 degrees from each other, to minimize the risk of electronics failure due to hot gasses that may enter the module. SSC was consulted regarding the D-SUB bracket and protection cap attachment to the rocket module. An overview of the bulkhead mounted to the rocket module can be seen in Figure 14.

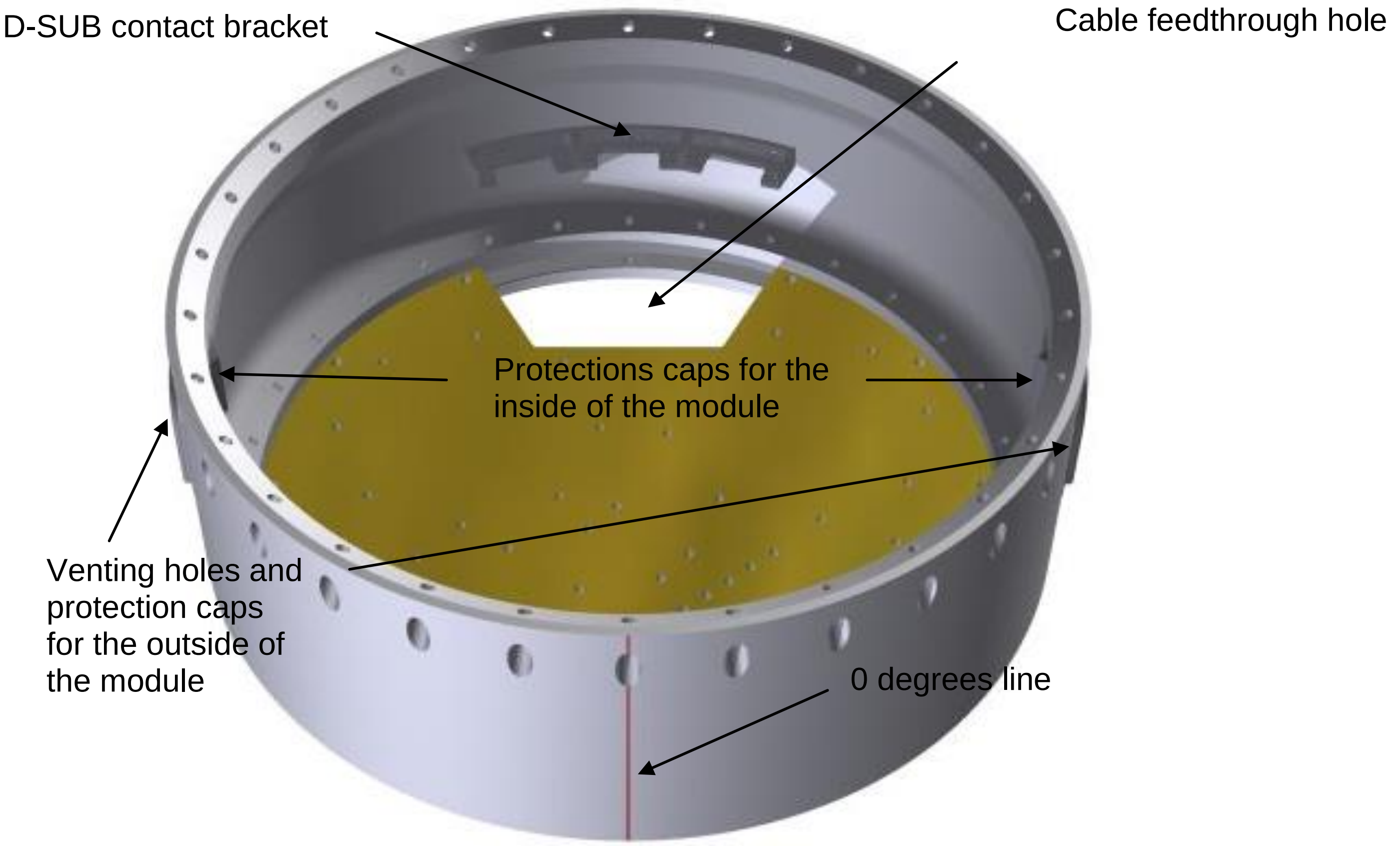


Figure 14 - Overview of the rocket module and the bulkhead interface.

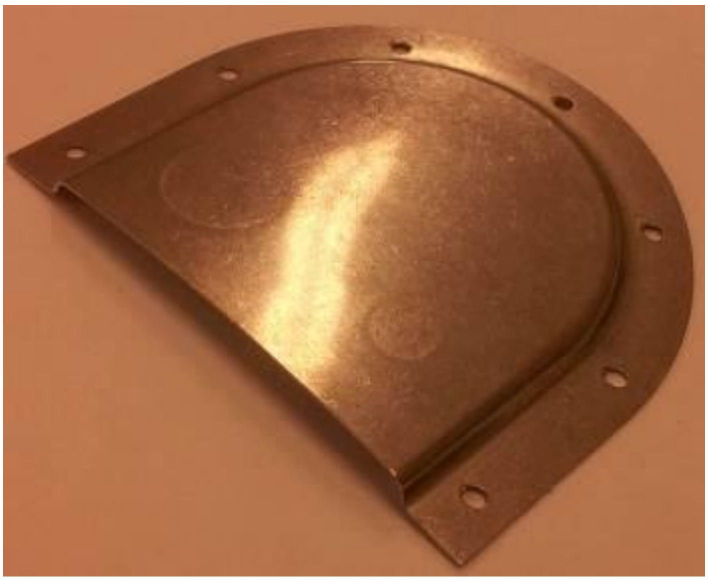


Figure 15 – The protection cap attached to the rocket module on the ouside.

Figure 16 - The protection cap attached to the rocket module on the inside.

All bolted connections to the bulkhead was strengthened using helicoils and loctite 243.

The bulkhead seen in the pictures above is not the real one, but a simplified copy that we had manufactured ourselves to use during the testing phase.

4.2.2 Electrical

A D-SUB 15 connector was the main interface to the RXSM. It was able to provide or send:

- Lift-off (LO) to the experiment.
- A power source with 28 V/ 1 A as described in the REXUS manual to the experiment.
- Data, which was transmitted to the ground station via downlink, from the experiment. Also an uplink was required for testing of the system, but only while the payload was on the launch pad.

For a full wiring diagram of the electrical system, please see 8.2Appendix F .

For detailed values, see section 6.1.3. The safety system preceding the DC/DC converters can be seen in Figure 39. The interfaces within the experiment and between the subsystems are described throughout sections 4.5 and 4.7. The safety interlock of the battery powered subsystem is described in section 4.7.2.

4.2.3 Thermal

The experiment was not to be insulated since the experiment only heat the rocket module a couple of degrees centigrade, simulated in Autodesk Simulation Multiphysics 2012, which did not affect other experiments or the rocket itself. The temperatures in May, when the launch was scheduled, did not affect the experiment in case of extended stay on launch platform and the temperatures that the rocket could experience did not affect the experiment. See section 4.6 for details regarding the simulations.

4.3 Experiment Components

Table 29 shows the calculated dimensions and mass of the experiment, including the protection caps, the bulkhead and the 120 mm rocket module i.e all parts seen in Figure 60 - Figure 62. It also shows the centre of gravity and the moment of inertia.

Table 29 - Experiment summary table

Experiment mass [kg]	7.816
Experiment dimensions (rxh) [m]	0.156x0.105
Experiment footprint area (on bulkhead) [m^2]	0.0378
Experiment volume [m^3]	0.00283
Experiment centre of gravity position (x, y, z) [mm]	(-30.320, -5.091, -1.338)
Experiment moment of inertia (I_x, I_y, I_z) [$kg \cdot m^2$]	(0.145, 0.0939, 0.0868)

Regarding the experiment dimensions, the radius is the radius of the bulkhead and the height is the distance between the lowest part of the bulkhead and the top of the electronics box. The footprint area is the total footprint area for all experiment parts attached to the bulkhead.

A clarification of the centre of gravity position can be seen in Figure 60 - Figure 62.

A component list can be found in Appendix D – Finances.

4.4 Mechanical Design

Tables over the design dimensions are presented inTable 30 and Table 31, a more detailed drawing of each structure can be found in 8.2Appendix F .

Table 30 – Dimensions of the outer structure

Structure	**Dimensions (lxwxh) (mm)**	**Dimensions (Øxh) (mm)**
Chamber		125x72
Hat		125x52

Base		125x20
Electronics box	120x57x95	
Battery pack housing	77x60x75	
D-SUB holder	60x31x60	

Table 31 – Dimensions of the inner structure

Inner structure	**Dimensions (lxwxh) (mm)**	**Dimensions (Øxh) (mm)**
Soldering PCB	32x50x1.6	
Sensor PCB	26x54x1.6	
Main PCB	75x11x1.6	
Copper plate	6x32x0.5	
Slit	11x31x10	
Hole in chamber	8x16	
Resistance wire		0.2x20

4.4.1 Layout

The layout of the experiment consisted of five structures as seen in Figure 17; two chambers, an electronics box, a holder for two D-SUB's and a housing for the battery packs. All of the parts were made in aluminium and were attached directly to the bulkhead except for the electronics box that used angle bracers. Each attachment point used stainless steel M4 screws, one spring washer per screw, loctite 243 and helicoils to ensure that nothing would get loose during the flight. More about the interface for each structure can be found in section 4.2.1.

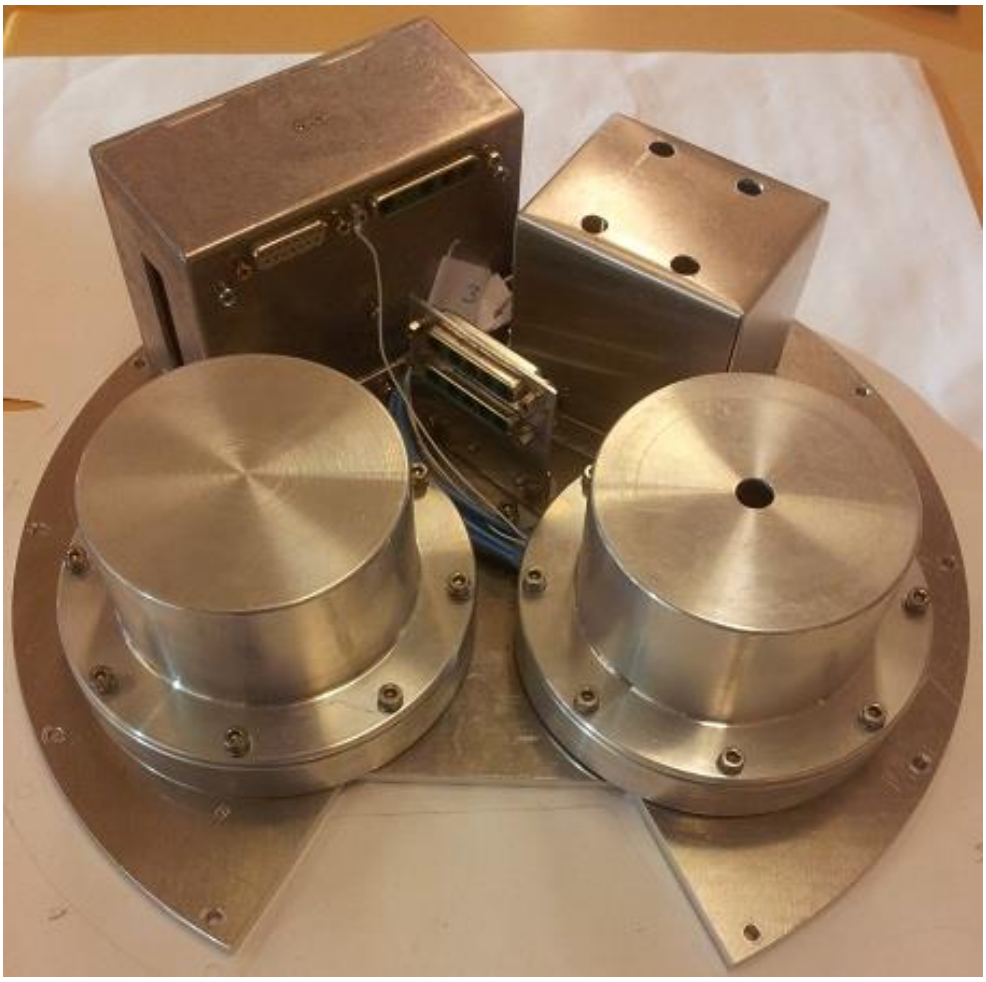


Figure 17 – Layout of the experiment.

4.4.2 The Chambers

A condition for the chambers was that it should be easy to change parts inside them, with this in mind the chambers had been designed to be as simple as possible. Each chamber consists of two parts; a top and bottom part. The top part is called hat; seen in Figure 22 and the bottom is referred to as base, Figure 23.

Figure 18 – View of the chambers

4.4.2.1 Soldering system

An overview of the internal layout in the chambers can be seen in Figure 19. On top of the right PCB, referred to as soldering PCB are two small copper plates placed. These plates were induced with power from four wires that were led into the chamber through a hole in the base. Three resistance wires were wired between the copper plates. These wires were attached by twisting their ends around three separate M2 screws and then screwed into the copper plates. This allowed a power through the resistance wire which would heat up and after a couple of seconds melt the solder.

Soldering is a process in which two or more metals are joined together by melting a filler metal (solder) into the joint. Because of this a component pin was used together with a resistance wire and joined together by melting the solder.

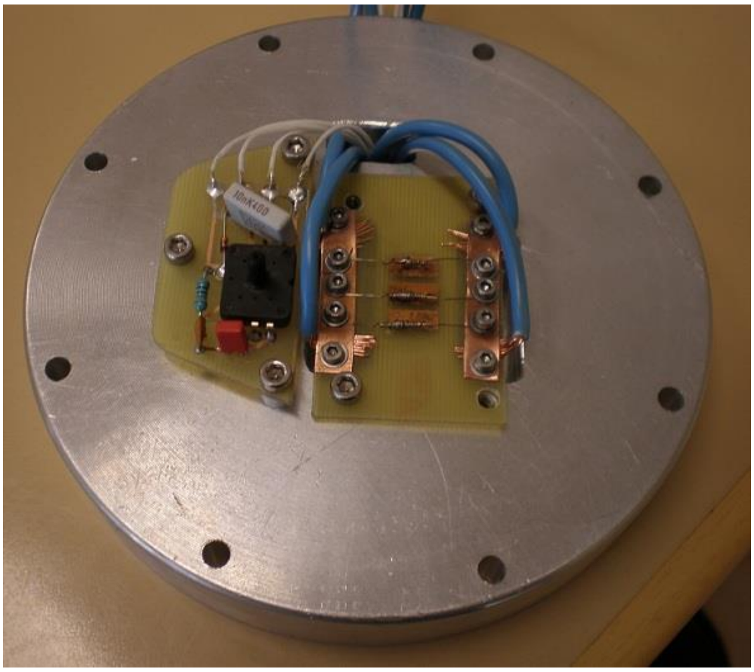


Figure 19 – Internal layout of the chambers.

Setup: For each solder sample, the solder was wired around the component pin, with the resistance thread wired around it. For further details, please see procedures in 8.2Appendix G .

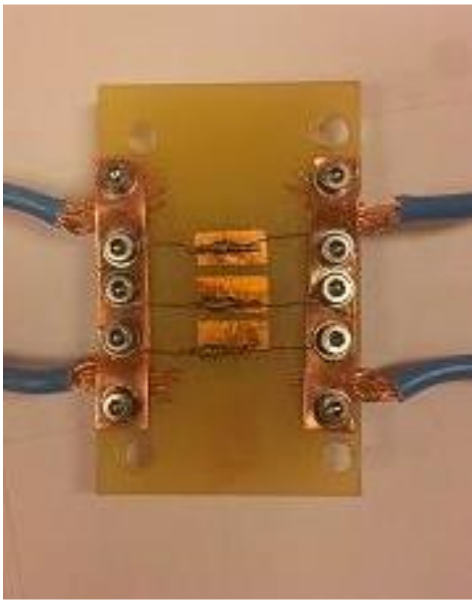


Figure 20 – Overview of the soldering PCB.

To create redundancy in the system there were two wires that lead power to the copper plates from from the D-SUB holder. The wires in to the system as seen in Figure 20 were connected to the first and fifth screw with tube lugs on the left, and the power exited through wires connected to the screws on the opposite side.

Beneath each copper plate there was a slit in the base which prevented the screws from creating a short circuit to the rest of the experiment. The distance between the copper plates was 20 mm whereof the component pin was centered between them.

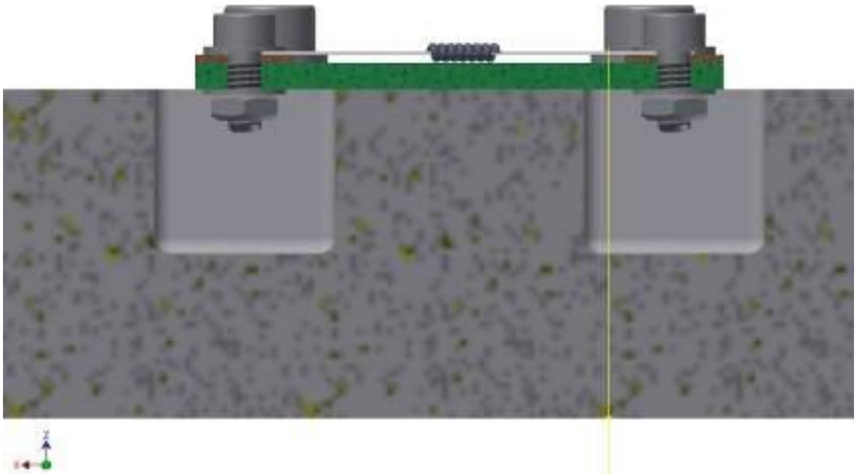


Figure 21 – Cross section view of the base and the slit.

4.4.2.2 Hat

The hat was made in one piece. For the pressurized chamber there was a track under the hat, as seen in Figure 22. An O-ring was placed in the track and acted as a sealant between the hat and base.

Figure 22 – Hat with the track visible where the O-ring was placed.

The vacuum chamber had a hole in the centre of the hat with a diameter of 10 mm. This enabled a vacuum like environment in the chamber once milli gravity was reached.

When the resistance wires started their melting process of the solder, they emited some heat to the surrounding thus increasing the pressure in the chamber. Though, because of the size of the hat, this process was expected to be negligible because the heat emittance from the wires were not that high and they would only have power for a short duration. To simplify the manufacturing process both hats had the same height.

4.4.2.3 Base

The base was also made in one piece. There was a duct on the bottom side of the base; this was where the cables would be led into the chamber and through a hole. The duct can be seen in Figure 23. For the pressurized chamber, this duct and hole was insulated with a silicon with the cables. This method was also tested in a vacuum chamber and proved to be functioning.

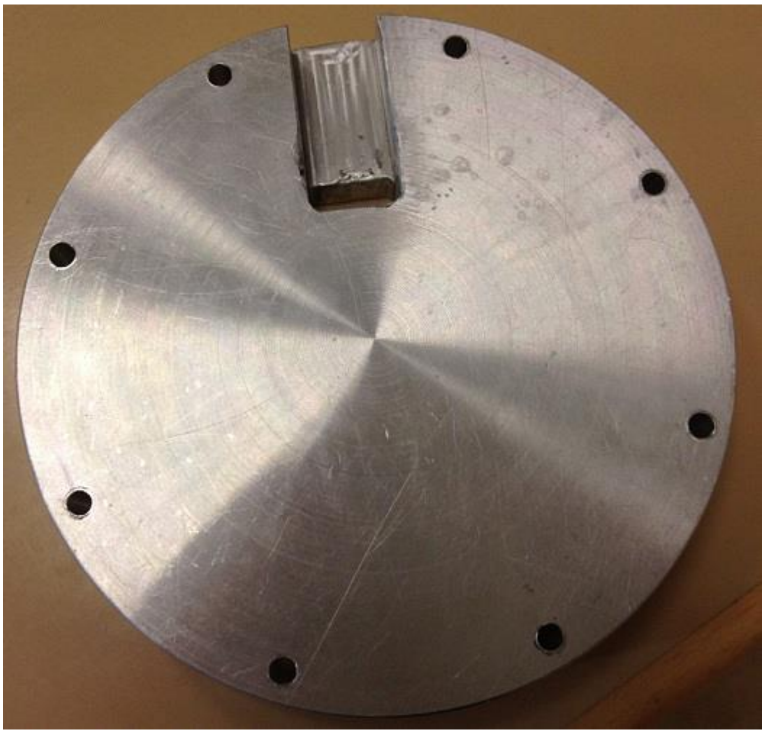


Figure 23 – Base showing the duct for cables and hole.

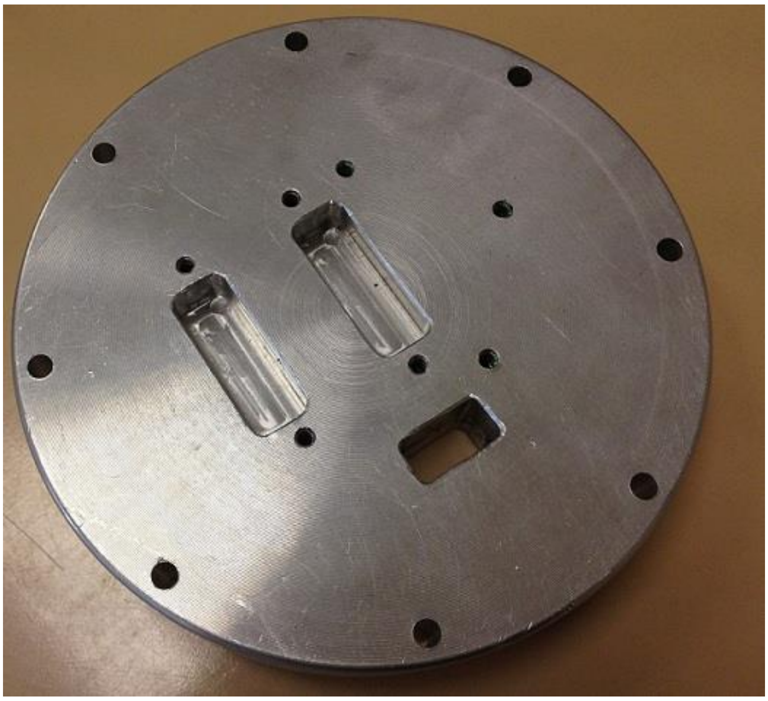


Figure 24 – Top side of base.

On the top side of the base there were two PCB's attached to it, sensor PCB and soldering PCB. The soldering PCB was attached with four stainless steel M3 screws to the base over the two slits, which can be seen in Figure 24. The sensor PCB was placed adjacent on the left of the soldering PCB and held a pressure sensor and a temperature sensor. The sensor PCB was attached to the base with three stainless steel M3 screws and elevated 5 mm from the base using spacers. The overview of the PCB's attached to the base is seen in Figure 19.

4.4.2.4 Seal of pressurized chamber

To keep the pressurized chamber airtight so the pressure can remain at its initial pressure during the flight, three sealing methods were used. The first one, mentioned in section 4.4.2.2 consisted of a toroidal O-ring with a cross section diameter of 2.62 mm, which was placed between the hat and the base using the track in the hat. This O-ring was also covered in vacuum grease. The second one was the sealing of the hole in the base where the cables came in. This hole with the cables was insulated using a silicone adhesive. Tests had been done using these two methods combined and had proven to be successful at keeping the pressure in the chamber within the requirements of ± 10 kPa for about 1:45 minutes, this test can be found in 8.2Appendix H ([H.OST2]2012-10-16).

Third method was to insulate the cables that were connected to the D-SUB holder with a silicone adhesive to prevent that air escaped trough the cables. Tests had been done using these three methods combined and had proven to be better and increased the time to 10 minutes, this test can be found in 8.2Appendix H ([H.OST2]2012-10-27).

4.4.2.5 Maintaining constant pressure in pressurized chamber

A well working sealant was essential to minimize the risk of pressure decrease inside the chamber, as mentioned in section 4.4.2.4. However, a completely closed system that is being exposed to temperature variations, in this case a temperature increase caused by the soldering process, might even experience a pressure rise. Estimations had been made that the temperature variations caused by the resistance wires most probably would not generate any significant pressure rise and the hence the focus was on improving the sealing methods.

4.4.3 Electronics box and battery pack housing

The electronics box was standing on its side to save space, see Figure 25. It had two D-SUB 24 connectors, one D-SUB 15 and one D-SUB 4 connector for the batteries. A supplementary structure had been made that would hold two D-SUB 24 and worked as a link between the chambers and the electronics box. This made it easier to access the D-SUB 24. This structure is reffered to as the D-SUB holder and can be seen in Figure 11. There was one rectangular hole on the sides of the electronics box where the D-SUB 24 contacts could be fed through and then be connected to the D-SUB holder. From the D-SUB holder there were eight separate cables led to each chamber, supplying the soldering and sensor PCB's with power.

The battery housing contained two small battery packs. Inbetween the batteries and between a battery and the wall there were small slices of insulation that would help in protecting the batteries from the cold and vibrations that occur. The batteries and the insulation was packaged using zip ties that would be fastened to the top of the battery housing. The cables from the batteries went through two holes in the housing that had rubber glands to protect the cables from damage. On the side of the battery housing that is facing away from the experiment, a venting hole was placed too. The battery pack housing can be seen in Figure 25.

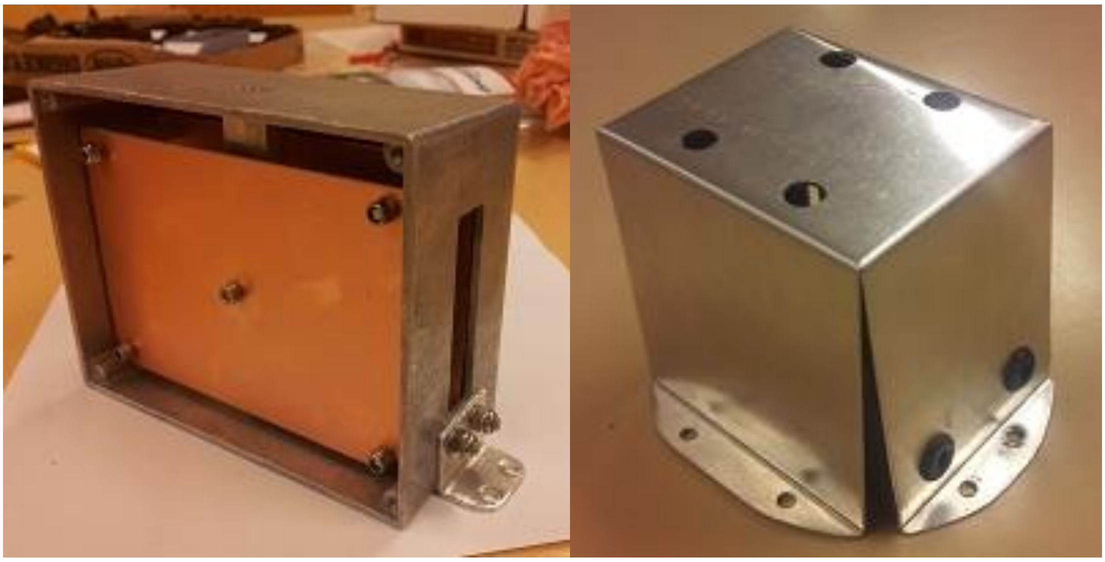


Figure 25 – Electronics box and battery pack housing.

4.4.3.1 Internal layout of electronics box

The Inside of the electronics box contained two PCB's, these are referred to as the Main PCB's and were placed on top of each other using four spacers with a length of 25 mm, see Figure 26. The upper PCB in Figure 26 was also attached to a rod that crosses the box. Each PCB was attached to the box using five stainless steel M3 screws with two spring washers/screw, a lock nut and loctite 243. The lid was attached to the box using four countersunk stainless steel screws that were screwed 8 mm into the box.

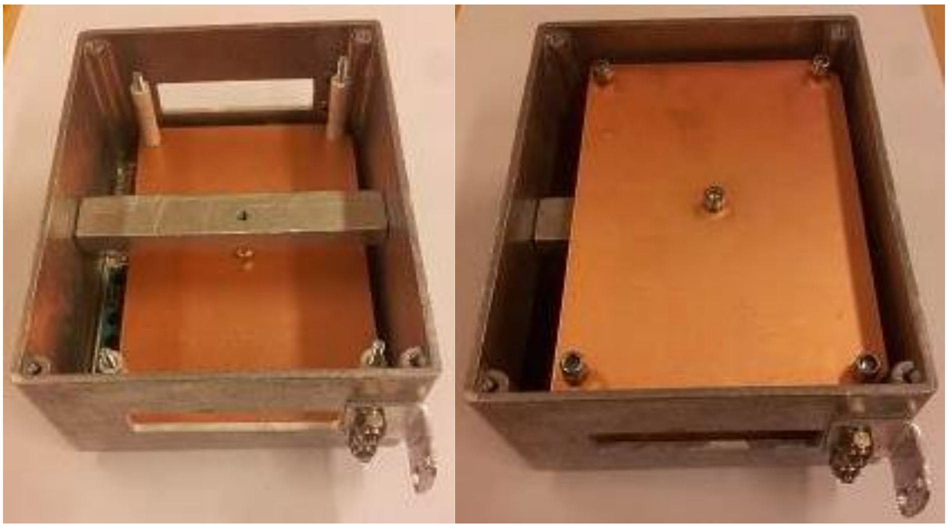


Figure 26 – Internal layout of the electronics box.

4.4.4 Structural Analysis

To verify that the structure can withstand the strains and stresses during flight, analysis can be an important tool during the design phase. It is a powerful tool for decreasing the overall project time and for saving money, as actual physical testing can be very expensive and time consuming. For the simulations in this section Autodesk Inventor Professional 2012 was used. The simulations conducted were static simulations to find the stress acting on the structure, and also modal simulations to find the natural frequencies. In both of these simulations a fixed constraint was put in the screw holes for the attachments to the rocket to simulate the connection between the rocket and payload.

4.4.4.1 Static simulation

The static simulation was conducted by placing an acceleration of 20g on the structure. This represents the demands put on the payload during the flight. The strain on the structure caused by the 20g acceleration was close to negligible, a maximum displacement of about 0.003 mm as can be seen in Figure 27. Most of the parts were made in Aluminium 6061, which has yield strength of 95 MPa. The experiment bulkhead was made out of Aluminium 7075, which has a yield strength of 145 MPa.

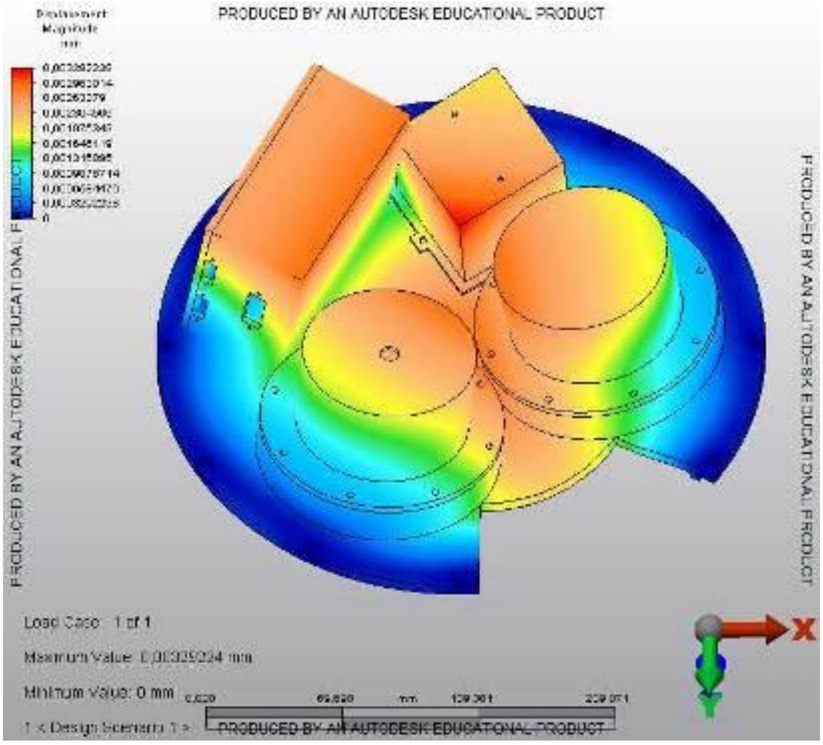


Figure 27 – Displacement due to an acceleration of 20g over the whole payload.

In Figure 28 the von Mises stress results are shown for the simulation of the whole payload. The maximum von Mises stress of 1.28 MPa was found at the screw holes in the experiment bulkhead. Since the stress was small compared to this maximum value in the rest of the payload, only the screw holes in the bulkhead are of interest.

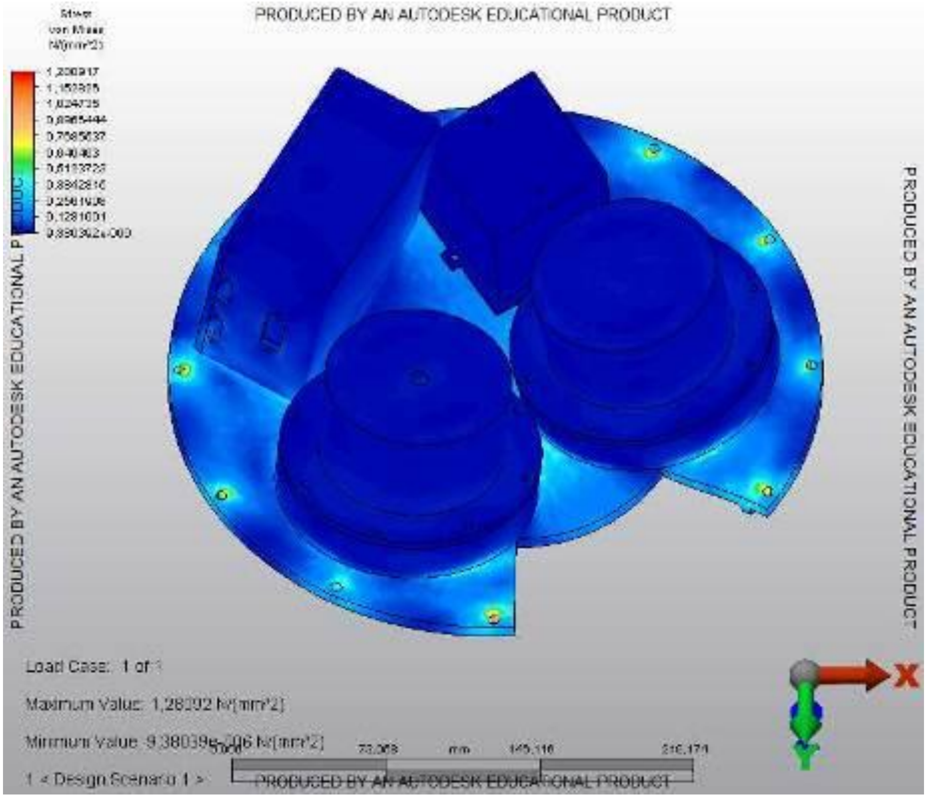


Figure 28 – Image of the von Mises stress distribution for the screw holes attached to the rocket, due to 20g environment.

The von Mises stress of 1.28 MPa was small compared to both the yield strength of Aluminium 6061 and Aluminium 7075. This means that elastic deformation occurs and the structure would return to its original state once the load had been removed, without any permanent deformation. The yield strength of the material around the screw holes was 95 MPa where the maximum stress value was 1.28 MPa which means that the material strength was more than 75 times higher than the applied load, where a common value for a stable structure has the ratio of 2 between material strength and design load.

The inside of the chambers with the perhaps more fragile parts such as the PCB:s can be seen in Figure 29 to have a maximum von Mises stress of about 0.3 MPa. This maximum value poses no threat to the stability of the structure. Similar values, safely below the yield strength of Aluminium 6061, was found for all the other parts of the payload.

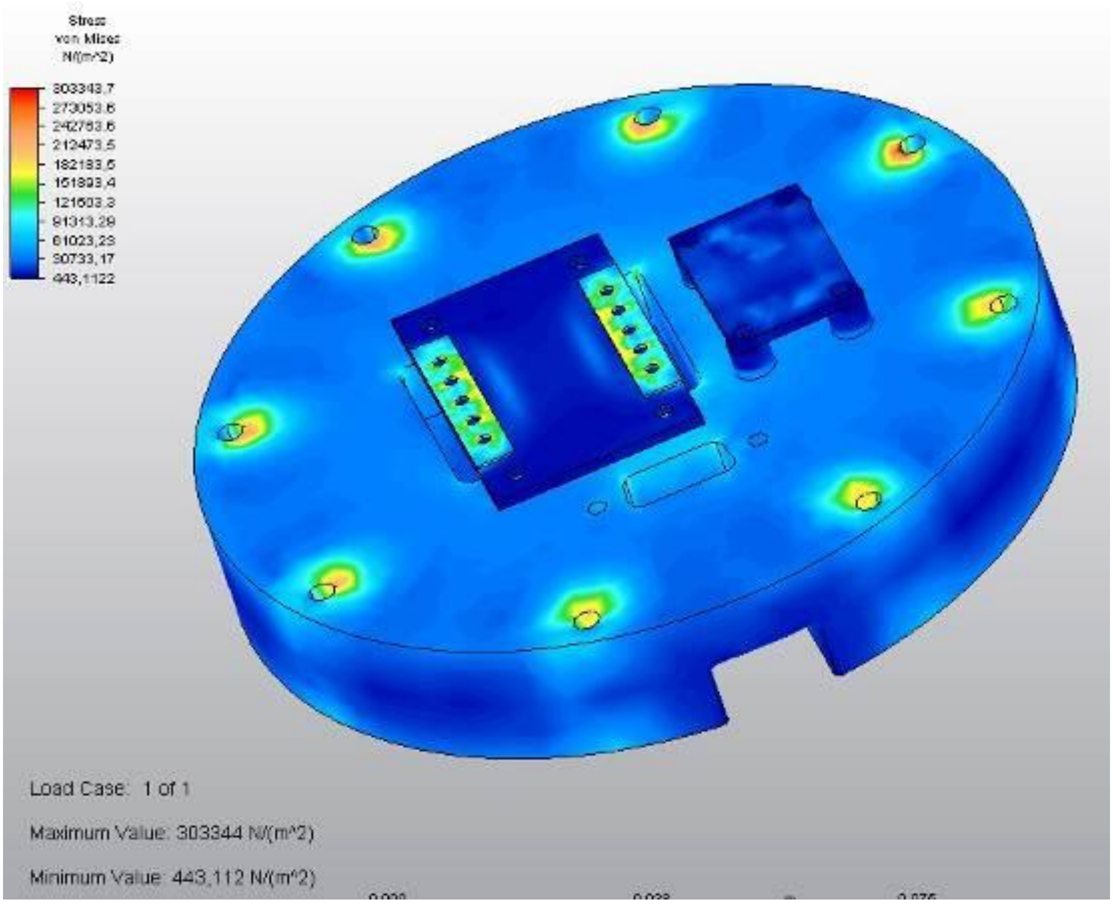


Figure 29 – Image of the von Mises stress distribution for the base and inside of the chambers due to 20g environment.

4.4.4.2 Modal simulation

The modal simulation was used to find the natural frequencies for the whole payload and its different parts. By finding the natural frequencies we could infer if the design was good enough to be tested for vibrational stability. After consulting an expert in structural analysis it was recommended that our lowest natural frequencies must not be found at a frequency lower than 100 Hz. In that case, a re-design might be required.

The first natural frequency for the payload as a whole was found at 504 Hz, which is securely above the 100 Hz recommendation.

Modal simulations for all the separate parts had also been conducted. It was concluded that none of them had a natural frequency that was in the danger zone of the 100 Hz mark, all of them were safely above as can be seen in Figure 31, Figure 32 and Figure 33.

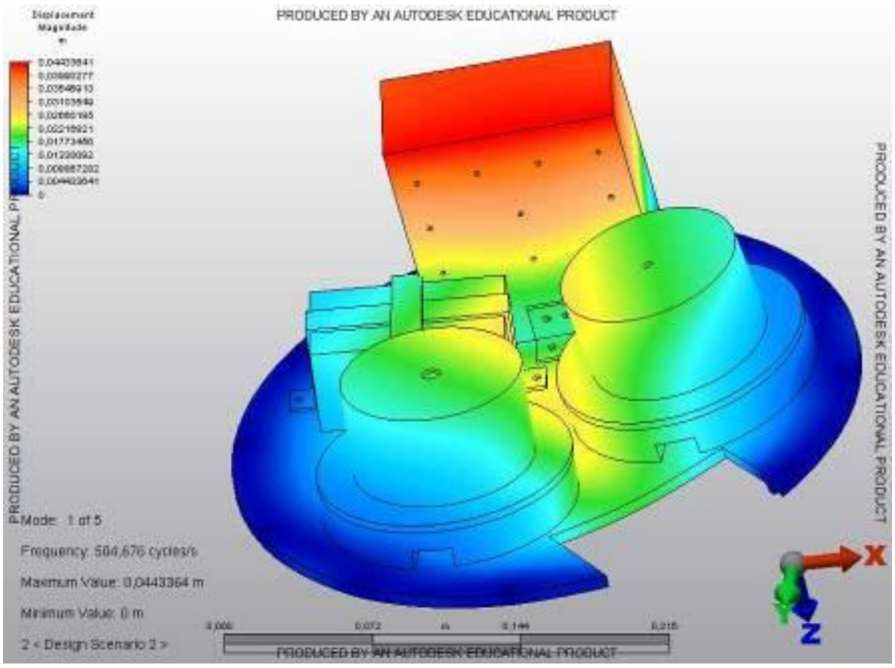


Figure 30 – The displacement at a natural frequency of 504.676 Hz for the whole payload.

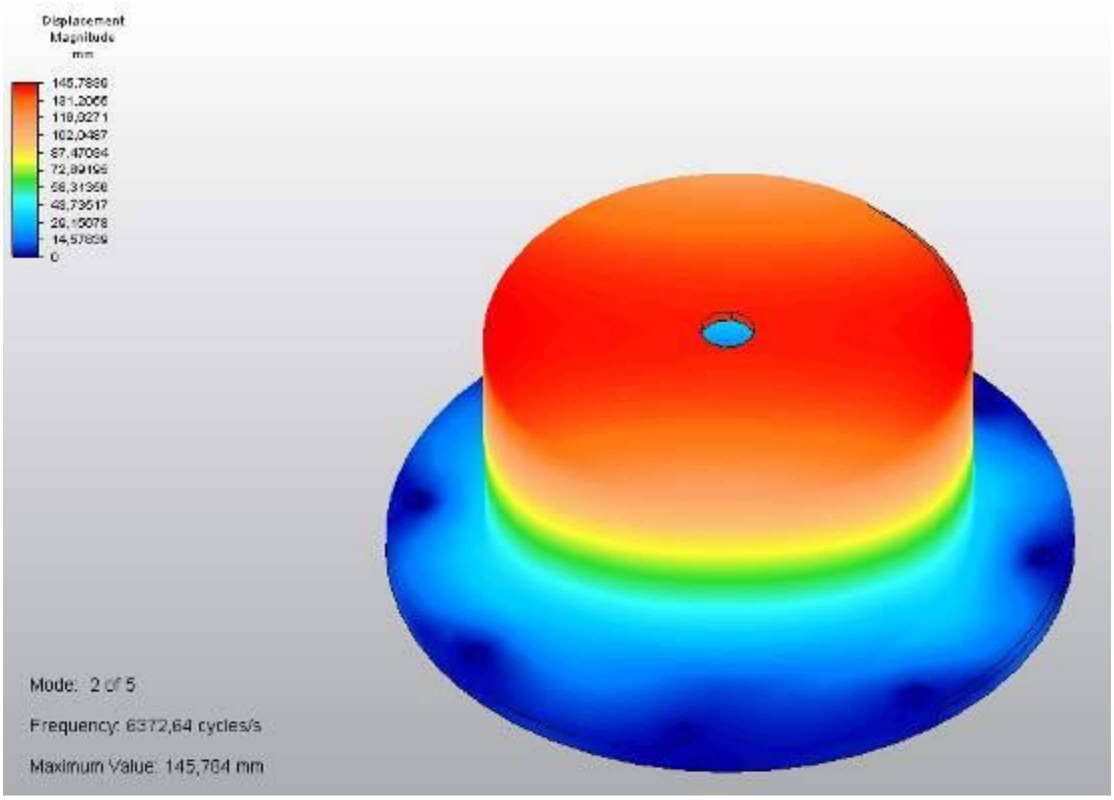


Figure 31 – The displacement at a natural frequency of 6372.64 Hz for the vacuum hat.

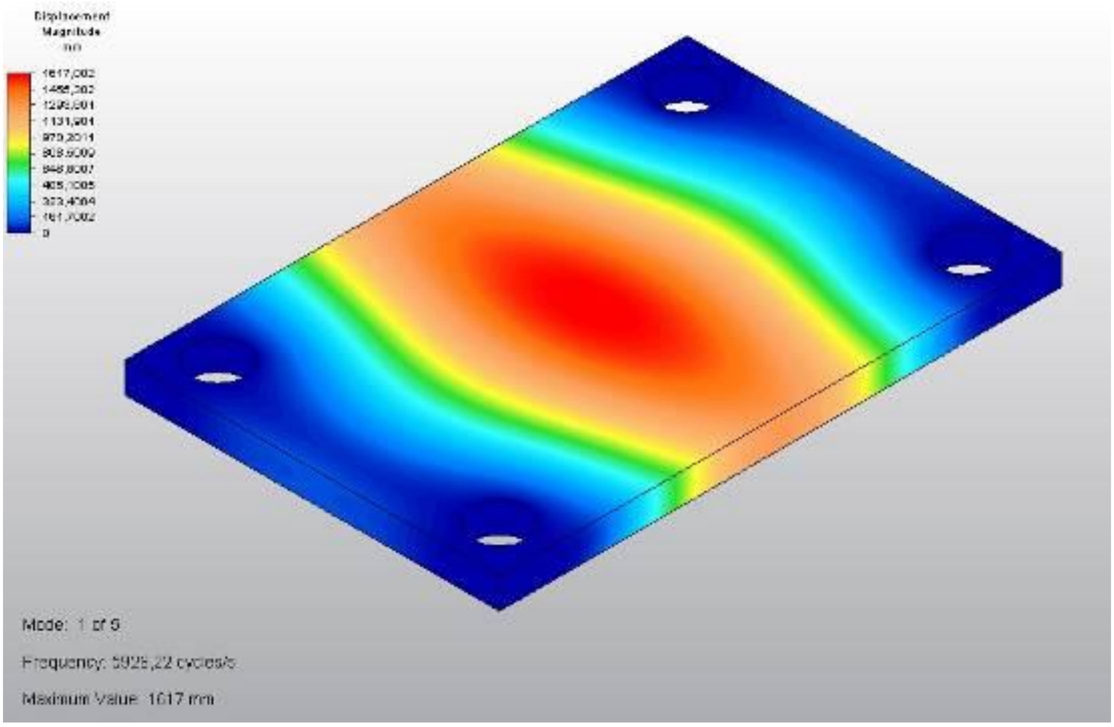


Figure 32 – The displacement at a natural frequency of 5926.22 Hz for a PCB card inside the chambers.

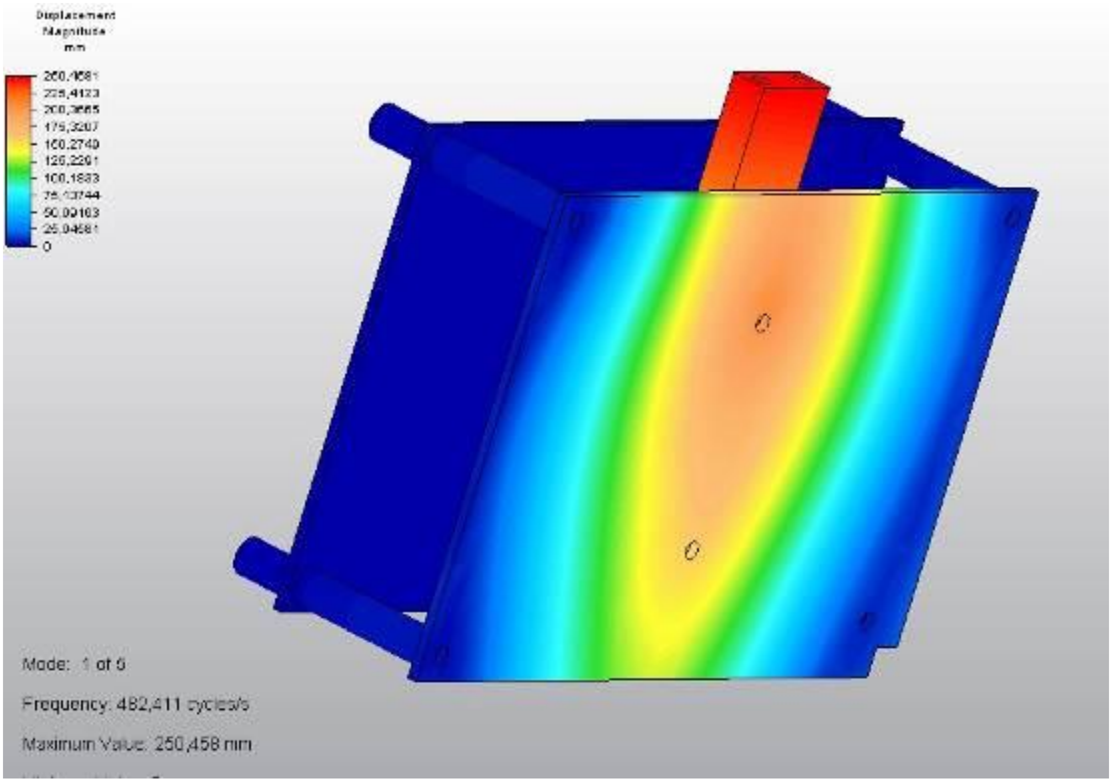


Figure 33 – The displacement at a natural frequency of 482.411 Hz for a PCB card inside the electronics box.

4.4.4.3 Structural displacements simulations

Not only must the structures of the experiment withstand vibrations, but the pressurized chamber would also encounter pressure differences that may deflect the aluminium walls and hence jeopardize the chamber structure. The pressure difference would be of magnitude ~100 kPa when the rocket module was experiencing vacuum like environment during the flight. To evaluate the deflections on the 2 mm thick chamber walls, a static structural simulation in ANSYS 13.0 was performed. A rigid body was assumed and due to the chamber´s symmetries along the longitudinal rotational axis and with respect to a plane that passes through in mid height, only the top half of the chamber was needed to be considered in the simulation. A 90-degree segment of the chamber was used for the analysis. The material for the walls was chosen to an aluminium alloy found in the software´s library and the inner wall pressure was set to 100 kPa. Figure 34 shows the result of the deflection. The conclusion was that the centre of the top part would deflect the most by 77 µm and the side walls would at maximum deflect about 3 µm. Hence the pressure differences was not noticeable going change the chamber structure. However, later tests in a vacuum chamber would show if the aluminium 6065 differs from the alloy used in this analysis.

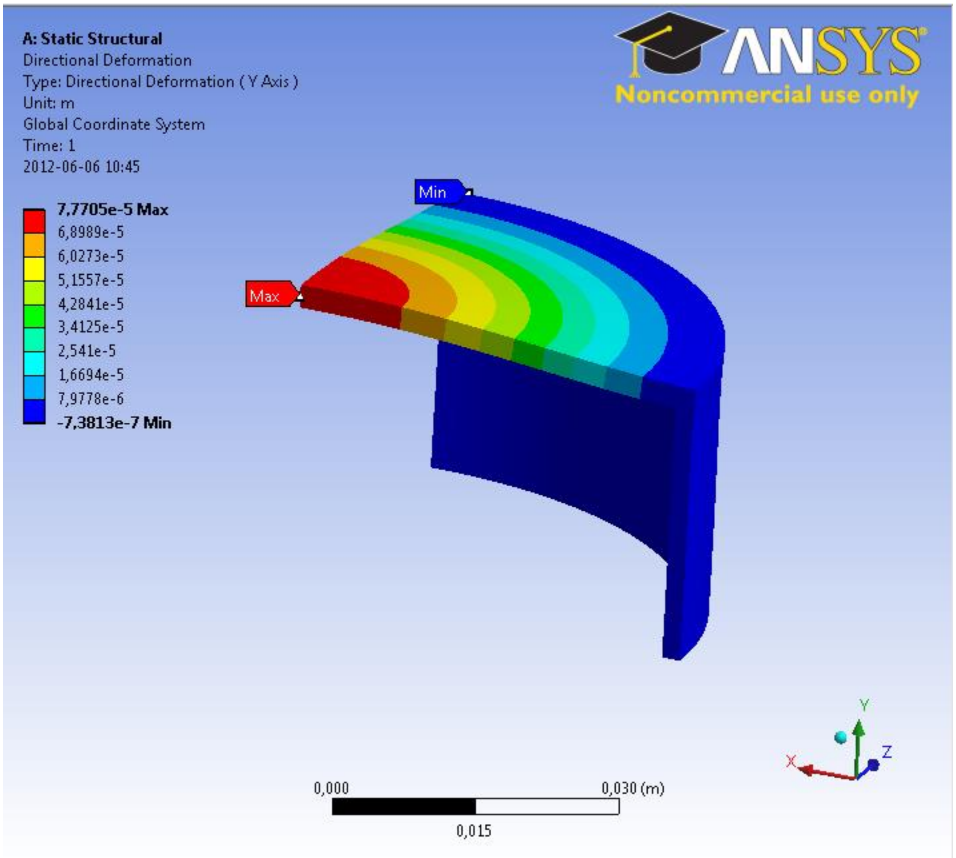


Figure 34 – The displacement of the pressurized chamber walls when experiencing maximum pressure differences.

4.5 Electronics Design

4.5.1 Systems Overview

The main function of the electronics system was to enable data handling in the experiment. There were two main systems which had separate power supplies and were not electrically connected to each other. All interconnections between the systems for communications were done through optocouplers or MOS-transistors. It was crucial that the microcontroller was working correctly and hence it had to have a stable voltage supplied to it. All commands enabling the experiment to function were sent through the microcontroller.

Temperature and pressure sensors were providing data to be stored throughout the flight. It was also of high importance that the resistance wires got a high burst of power during the critical moments of the flight during soldering.

The six resistance wires were powered by two battery packs in the first main system and the rest of the components in the other main system were powered by the RXSM. The input voltage to the components powered by the RXSM were regulated with DC/DC converters and the voltage to the resistance wires were regulated with power resistors.

The main components of the systems were shown in Figure 36 and complete electronics schematics is shown in Figure 37. The main wiring diagram with detailed values and models is also attached in Appendix F .

There are a few things that should be clarified regarding the main wiring diagram. The circuits monitoring the state of the batteries are shown as the ones connected to pin 4 and 5 on the multiplexer. Triple filters are integrated in the main connection to REXUS, the first EMI filter following pin 1 and 9 of the D-SUB 15 are of the Bourne SRF0905 Series Line Filter 251Y and datasheet is attached in Appendix C. This EMI filter is displayed in the schematics as 251Y. The second filter preceding the DC/DC converters contain inductors L1 and L2 with conductors C3 and C7. The third filter is integrated into the DC/DC converters.

4.5.2 Microcontroller System

Atmel328 8-bit was used as microcontroller, shown in Figure 35 - Microcontroller. It operated at 8MHz and has 2 data memories, a 32kB program and 2kB SRAM.

The microcontroller was mounted on the lower main PCB together with the electronics. The microcontroller consumes 9mA at 5V.

An optocoupler was used to receive the lift-off signal (LO) from the RXSM. This signal was at 28 V which would be harmful to the microcontroller and the usage of an optocoupler isolated the microcontroller from the harmful voltage.

MAX488EESA circuit was used to convert RS422 signals into RS232 that the microcontroller was receiving.

Figure 35 - Microcontroller

Table 32 – Description of how the components were connected to microcontroller.

Component	**Signal name**	**Interface**
Temperature sensor 1	Connected to PIN23	Analogue
Temperature sensor 2	Connected to PIN24	Analogue
Chamber 1 voltage	Connected to PIN25	Analogue
Chamber 2 voltage	Connected to PIN26	Analogue
Pressure sensor 1	Connected to PIN27	Analogue
Pressure sensor 2	Connected to PIN28	Analogue
MAX488EESA (EXP-IN/OUT)	Connected to PIN2 - 3	USART
SD card	Connected to PIN11, 17 - 19	SPI
Optocoupler (LO)	Connected to PIN6	Digital
Battery 1 switch	Connected to PIN9	Digital
Battery 2 switch	Connected to PIN10	Digital
Battery 1 voltage	Connected to PIN4	Digital

Battery 2 voltage	Connected to PIN5	Digital

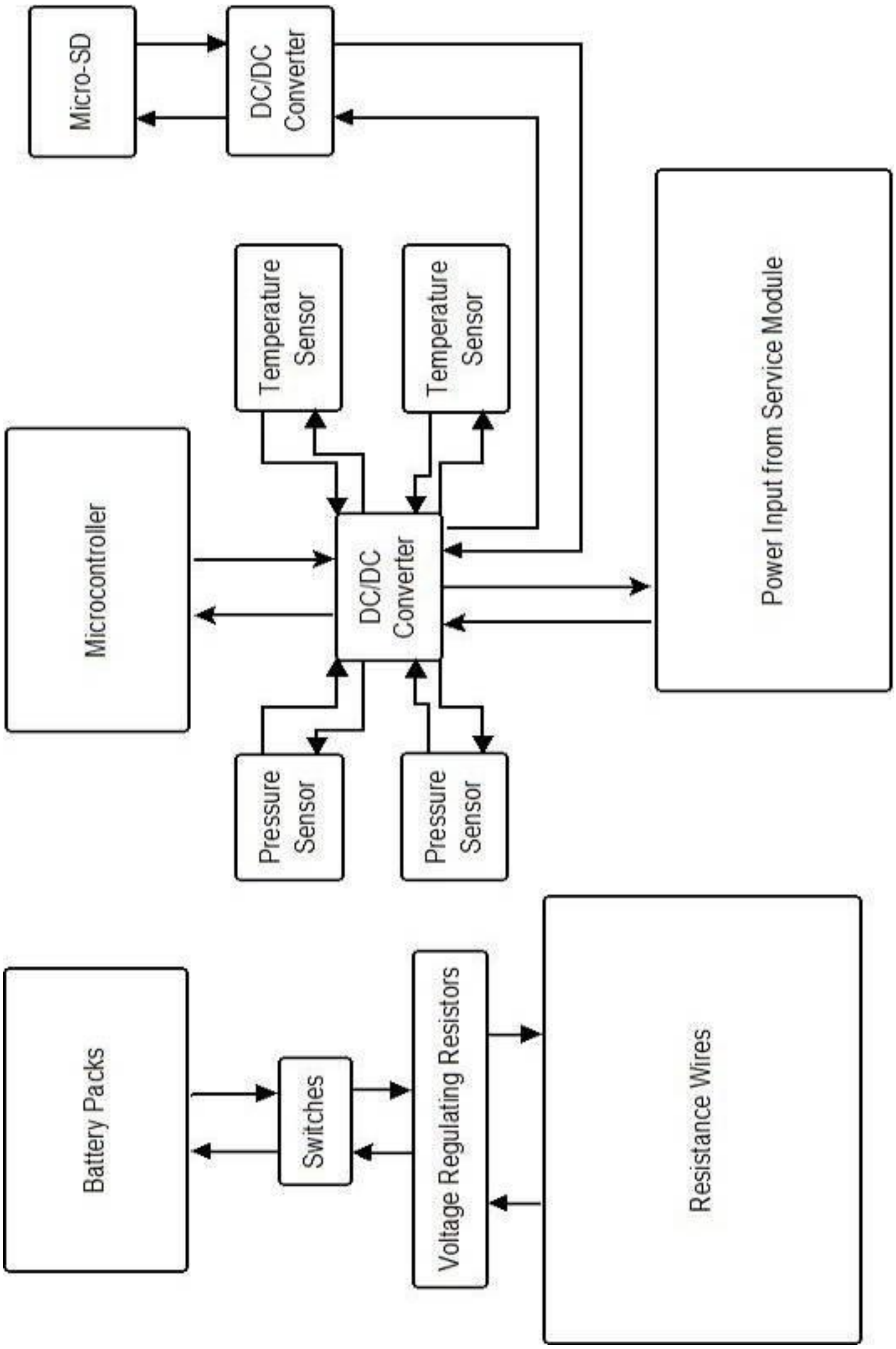


Figure 36 – Electrical design overview.

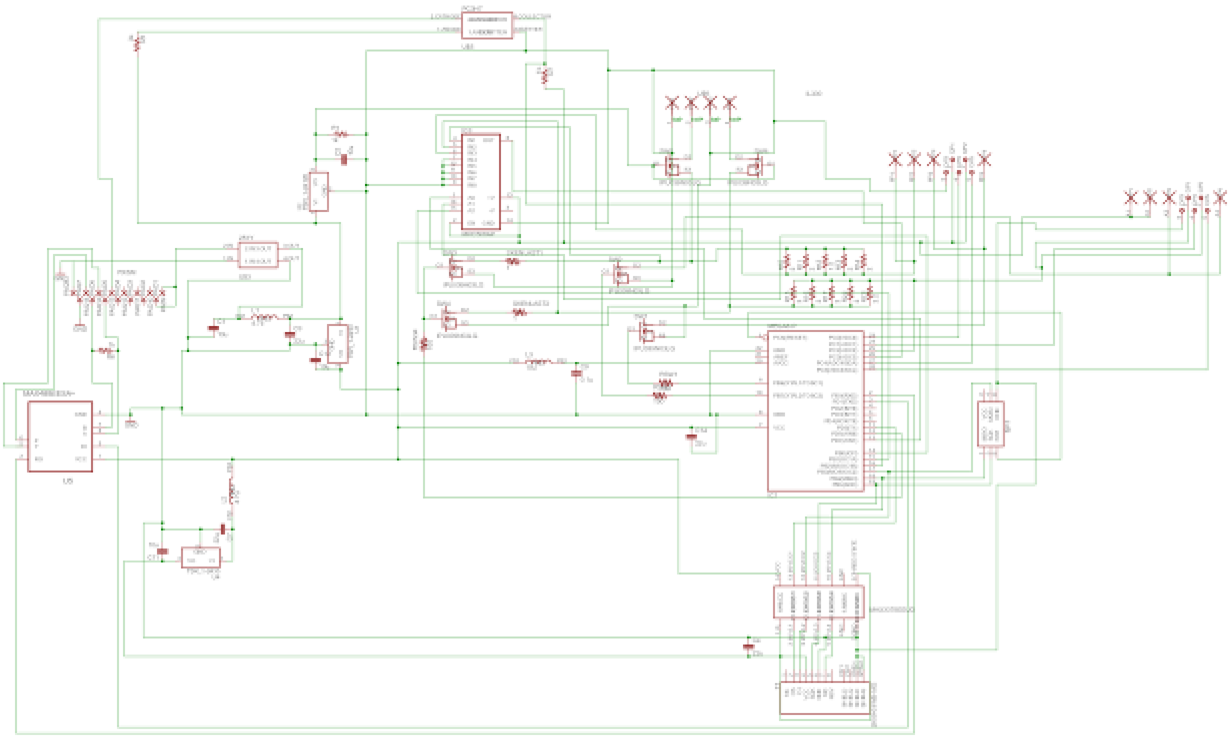


Figure 37 – Electronics schematics. For a more clear view with values and names, see Appendix F.

The microcontroller’s main function, except to sample data from sensors, was to tell when it was time to change to the next phase of the experiment. This was regulated by power switches that either was set to on or off depending on the signal from the microcontroller. For a more detailed description how this was handled by the microcontroller, see chapter 4.7 Ground Support Equipment.

LO, EXP OUT+, EXP OUT-, EXP IN+, EXP IN-, from the RXSM were connected as necessary to the microcontroller.

Table 32 shows how the active components were connected to the microcontroller.

4.5.3 DC/DC Converter

The DC/DC converter used in the power circuits was the TRACO POWER of the TSR 1-24 series. It is a single output converter with a wide voltage input range and a fixed output voltage.

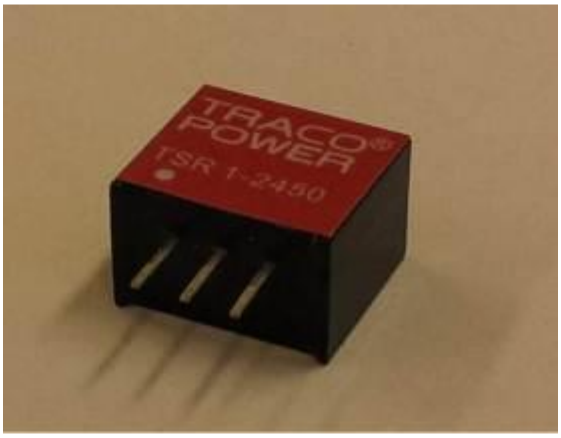


Figure 38 - DC/DC Converter.

It is rated for operation between -40 and 85 degrees centigrade and it has full overload protection. It has a high efficiency of typically 87 %. The reasons for choosing this were the high input voltage span and the good characteristics regarding output current and operating temperature.

The power circuits consisted of an EMI filter, followed by another filter consisting of capacitors and inductors. Then there was a capacitor on the output of the DC/DC converters before the power reached the load.

The application of the power circuit is shown in the Figure 39.

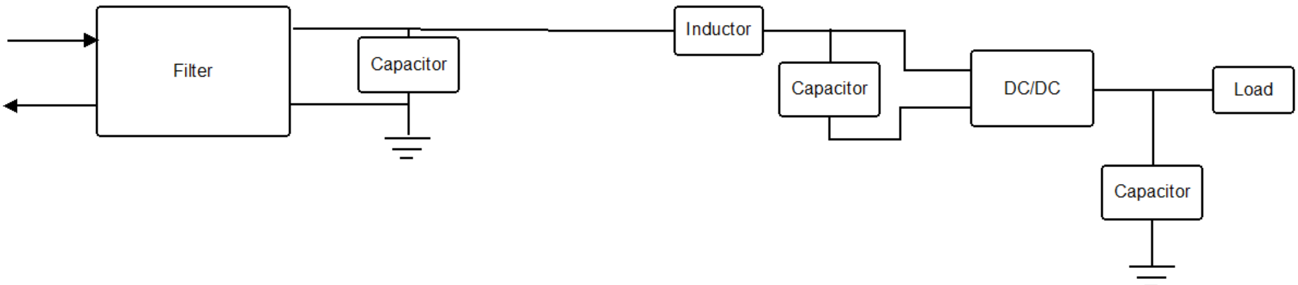


Figure 39 - Power circuit.

4.5.4 Passive Components

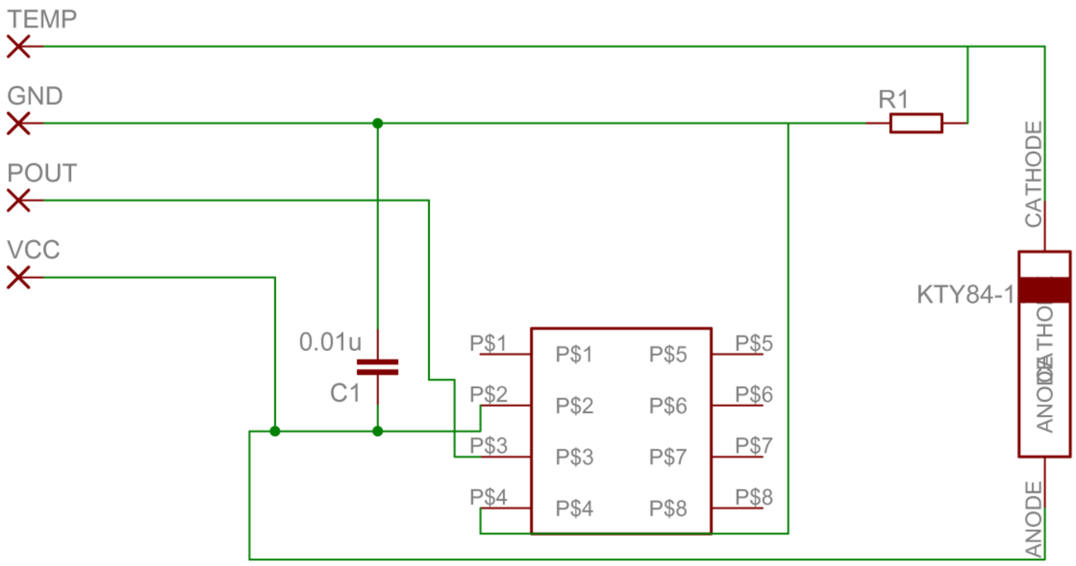


Figure 40 – The chamber circuit.

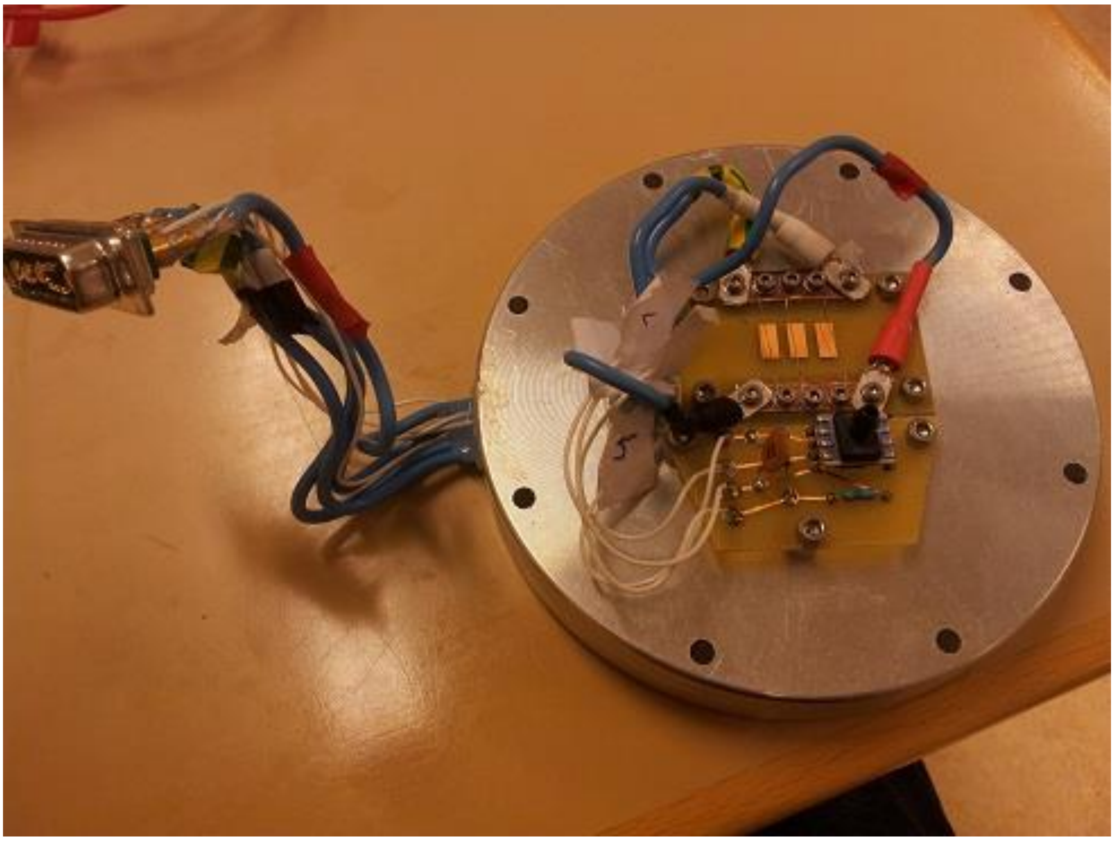


Figure 41 – Sensor PCB attached to chamber base.

Pressure sensors provided data to see that the pressure inside the chambers were within the desired limits. The used pressure sensor was the HSCDANN015PAAA5 and it was supplied by a voltage of 5 V and a current of 10mA. It has an operating temperature between -20 and 85 degrees centigrade and it is temperature compensated. It is a high precision sensor and it operates well both in pressurized environments and in vacuum. The main reason for choosing this was the good measure range.

Figure 42 - Pressure Sensor.

Temperature sensors provided information about the temperature inside the chambers. The used sensor was of the KTY84-1 series with a positive temperature coefficient of resistance. It is suitable for measurements over a temperature range of -40 to 300 degrees centigrade and it has the resistance range of between 950 Ω and 1050 Ω. This sensor has been chosen because it is small and has a good range for measurements.

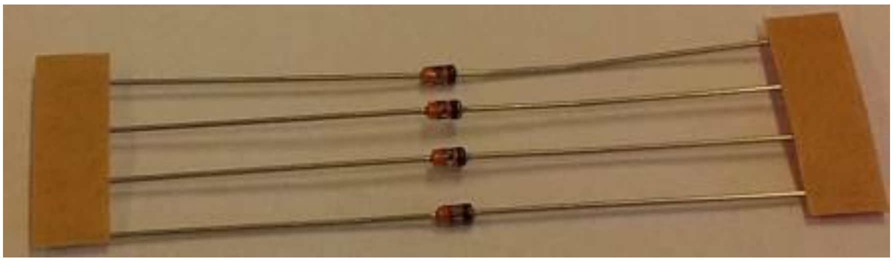


Figure 43 - Temperature Sensor.

Five power resistors in parallel were used to regulate the voltage to each of the chambers. These resistors were of the MCKNP0-series and can dissipate up to 5 W. The total power which needed to be dissipated was 20 W and these resistors have been chosen because it gave us a good safety margin.

4.5.5 Resistance Wires

The used resistance wires were Nichrome wires with a diameter of 0.2 mm. They have similar characteristics of Kanthal wires with a very high temperature sustainability and high yield strength. Testing was done with the 0.2 mm Nichrome wire and with a 0.5 mm Nikrothal wire. The results show that even if the thicker wire has a somewhat higher conductivity, the amount of current per wire needed to reach the ideal temperature is too large to outweigh the advantages. With the 0.2 mm wire the results from numerous testing shows that the wire will reach a temperature of approximately 310 degrees centigrade with a voltage of 1.45 V and a 1.5 A current applied to it. The reasons for choosing these kind of resistance wires is that they reach ideal temperature in seconds, have good conductivity, and cool down to room temperature in seconds. It is also important to point out that the heat dispersion to the surrounding air is very low. One of the testing sessions of the resistance wires can be seen in Figure 45. In the figure the wire held a temperature of 529 degrees centigrade and this temperature were achieved with relatively low power consumption. But it should be noted that the wires did not run that hot during the experiment, since the target temperature was 310 degrees centigrade.

A couple of switches were used to turn on and off the power to the resistance wires and the used switch was an IPU039N03L G MOSFET which has a continuous drain source voltage of 30 V and a current maximum of 50 A. It has an on-state resistance of 3.9 mΩ and it has a low power loss over it. It is fully protected by embedded protection functions. The reasons for choosing it were the very low on-state resistance and the high current maximum of 50 A which fit the experiment and gave a very good safety margin.

Figure 44 - Resistance Wire.

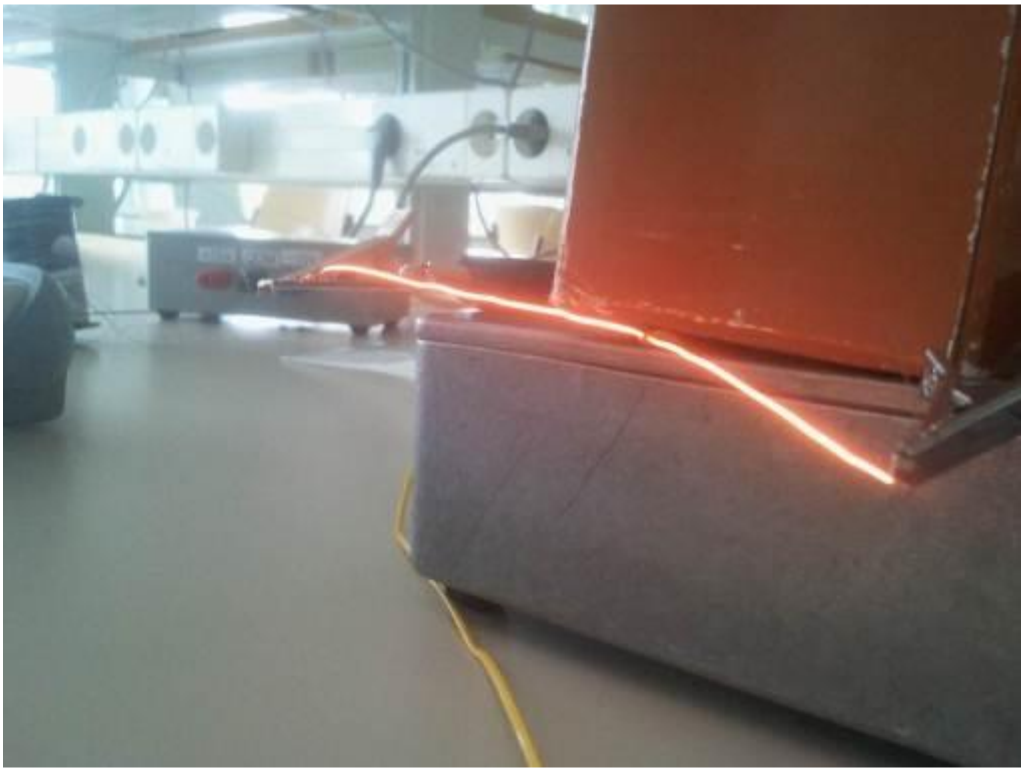


Figure 45 – Testing session of the resistance wires.

4.5.6 Cables and Connectors

The cable used for the system supplied by the RXSM was the ET 2419 which is a PTFE insulation cable, seen in Figure 46. It has a voltage rating of 250 VAC maximum and an operating temperature between -90 and 200 degrees centigrade. The size is AWG 24 and it has an outer diameter of 0.95 mm. It has electrolytic silver plated annealed copper or high strength silver plated copper alloy conductor. The reason for choosing it was the overall good characteristics.

The cable used for the system supplied by the battery pack was the E1219 which is a PTFE insulation cable, seen in Figure 47. It has a voltage rating of 600 VAC maximum and the size is AWG 12. It has an outer diameter of 2.85 mm and otherwise the same characteristics as the ET 2419.

Figure 46 - Cable ET2419.

Figure 47 - Cable E1219.

The connector used in the interface with the RXSM was a D-SUB 15 connector which was chosen because it fits the interface with the service module.

The connectors to the chambers were of a combo model D-SUB 9. The connectors were of the FM9W4S-K series and they were fitted with special high power pins which is able to handle up to 20 A. The D-SUBs can be viewed on the T-Rex racket in Figure 11.

Another hybrid D-SUB 5 was used for the battery connection.

Both the D-SUB 5 and D-SUB 15 connectors were connected to the backside of the electronics box. Limited space maked it impossible to attach the connectors directly on the PCB, so the connectors were spliced to the PCB by cables. The D-SUB 9 connectors for the chambers were be placed on the T-Rex racket outside electronics box. All the hybrid D-SUBs had short hex head jackscrews so that the installing of the connectors would not be a problem regarding the lack of space.

Figure 48 - D-SUB.

4.6 Thermal Design

The temperature range that the resistance wires operated in was 20 to 310 degrees centigrade. The timeline for the heat process can be found in section 6.3. Due to the short heating process the heat production and heat spread was minimal. Figure 49 shows the results of a simulation in Autodesk Simulation Multiphysics 2012 when the resistance wires have been heated from 20 to 310 degrees centigrade during 8 seconds and held at a constant temperature of 310 degrees centigrade for 10 seconds. Since this simulation has been performed on the vacuum chamber, convection was not included. The initial temperature of all parts is 20 degrees centigrade in the simulation according to information from the REXUS manual. Figure 49 show that the rest of the chamber will not increase notable in temperature. The copper plates and experiment PCB will increase in temperature but this is also expected. In Figure 50 the power to resistance wires are off and hence no further warming. It can be seen that the heat has spread in the base, but not to any high temperatures. From this information it could be assumed that the heat transport to the rocket module and other experiments is minimal and negligible. This was further tested during the test phase.

Due to issues with the simulations software, new simulations of the CAD and especially analysis of the heat spread through convection has not been made. Tests have although been made when heating the resistance wires to 310 degrees centigrade in a 100 kPa pressurized room and no noteable heat was detected on sensors held 5 mm from the wires. The heatspread can be assumed to be very low considering the power dissipation of the resistance wires is 15.3 W which would only be powered for 12s.

According to recommendations from IRF the batteries was insulated with ArmaFlex to protect the batteries against possible cold temperatures on the launch pad.

Regarding the cooling after descent when the rocket was exposed to a temperature around 0 degrees Celcius, the experiment was not affected by this. The samples are not affected if their temperature decreases to below zero degrees centigrade.

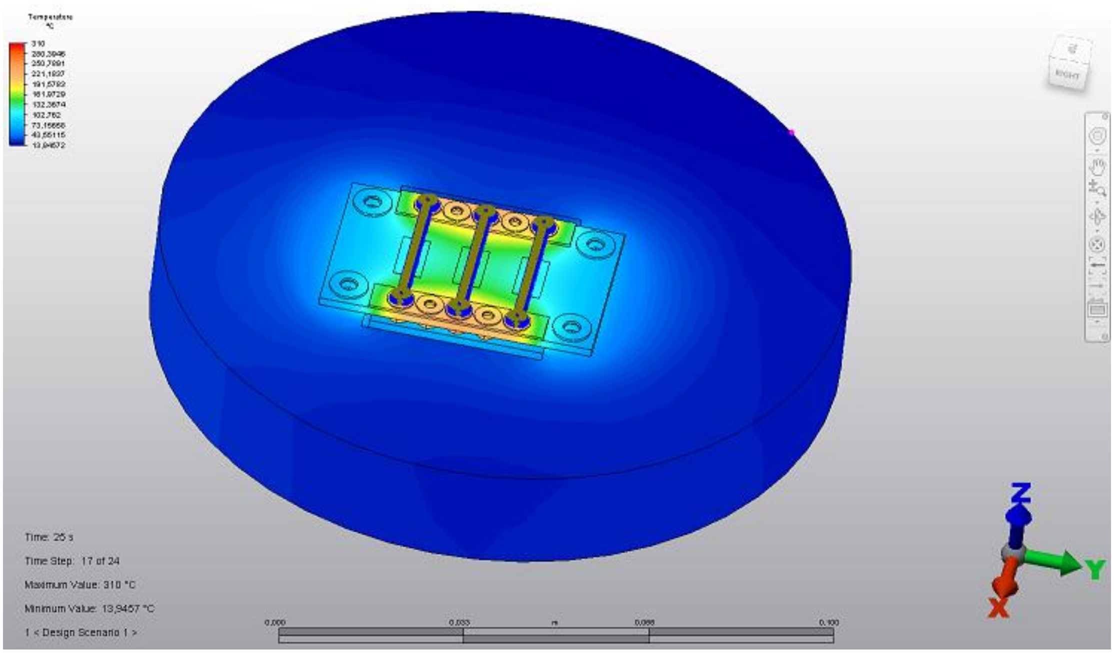


Figure 49 – The heat spread in the chambers after heating the resistance wires to 310 degrees centigrade during 8 seconds and held at a constant temperature of 310 degrees centigrade for 10 seconds.

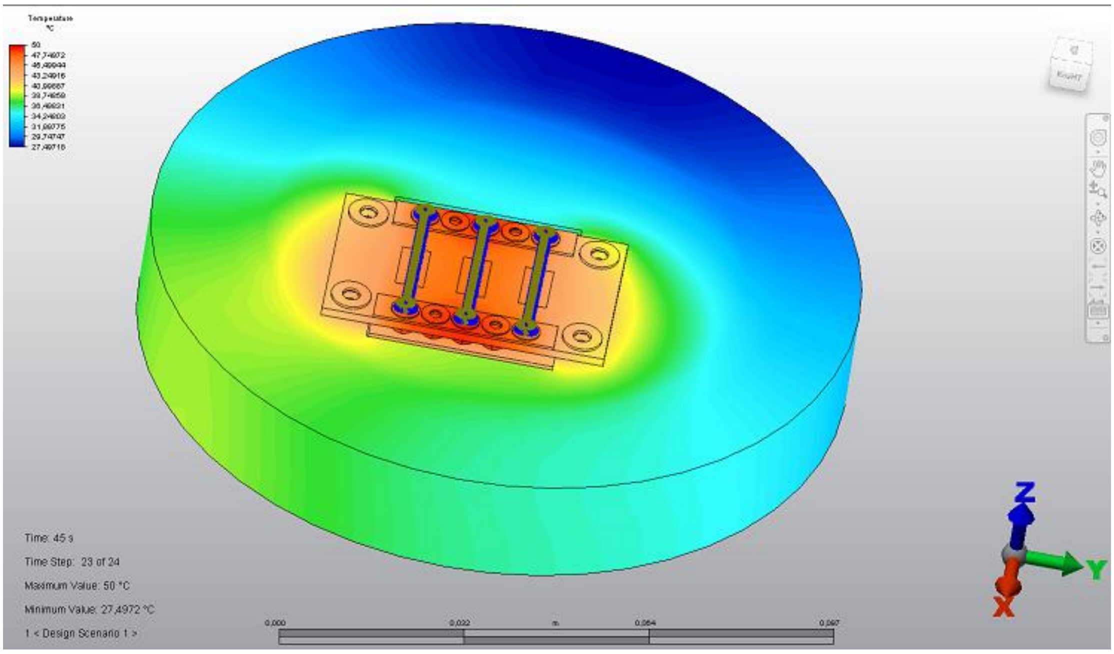


Figure 50 - The heat spread in the chambers shortly after end of heating of the resistance wires.

4.6.1 Thermal Temperature Range Of Components

The operating temperature range of all components of importance are presented in Table 33.

Table 33 – Operating temperature range of components.

Subsystem	Component	Item name	Operating temperature range (degrees centigrade)
Component	Header Board for ATmega328 microcontroller	Arduino UNO R3	-40 to 85
Component	Signal transceiver	MAX488EESA	-40 to 85
Component	Pressure sensor	HSCDANN015PAAA5	-20 to 85
Component	Nichrome wire	Nichrome wire 0.2 mm	-40 to 1000
Component	Temperature sensor	KTY84-150	-40 to 300
Component	Micro SD card	SFSD1024N1BN1TO-I-DF-151	-25 to 85
Component	Level converter bidirectional	MAX3378EEUD	-40 to 85
Power distribution	DC/DC converter	TSR 1-24 series	-40 to 85

Power distribution	Wires	E 1219 and ET 2419	-90 to 200
Power distribution	Battery pack	NHS 4200 SCH	-10 to 55 (in discharge)
Power distribution	D-SUB 15 connector	09 67 015 4715	-55 to 125
Power distribution	Hybrid D-SUBS	FM9W4S-K series	-55 to 130
Power distribution	Filters	SRF0905-251Y	-40 to 105
Power distribution	Optocoupler	PC3H7J00000F	-30 to 100
Power distribution	Switch	IPU039N03L G	-55 to 175
Power distribution	Capacitors	790D-106X0040C2	-55 to 125
Power distribution	Capacitors	T350F226M016AT	-55 to 85
Power distribution	Capacitors	TSL2H-series	-40 to 85
Power distribution	Inductor	HM50-4R7KLF	-55 to 105
Power distribution	Axial metal film resistors	RM0207SFCN-series	-55 to 155
Power distribution	Power resistors	MP915-1.00-1%	-55 to 150

Regarding the temperature range of the battery pack, it should be mentioned that it is the expected temperature range during discharge but it can operate during a wider range from approximately -30 to 80 degrees centigrade.

4.7 Power System

4.7.1 Design

Figure 55 show an overview of the Power Distribution System (PDS). The main function of the PDS was to supply the components of the experiment with the power they needed.

All of the components required an operating voltage that was lower than what was supplied by the RXSM. In the main circuit the input voltage to the components was regulated down to 5 V using a DC/DC converter. Another DC/DC converter was then used to regulate the voltage further down to 3.3 V. This way, both the components powered by 5 V and 3.3 V had a stable voltage input.

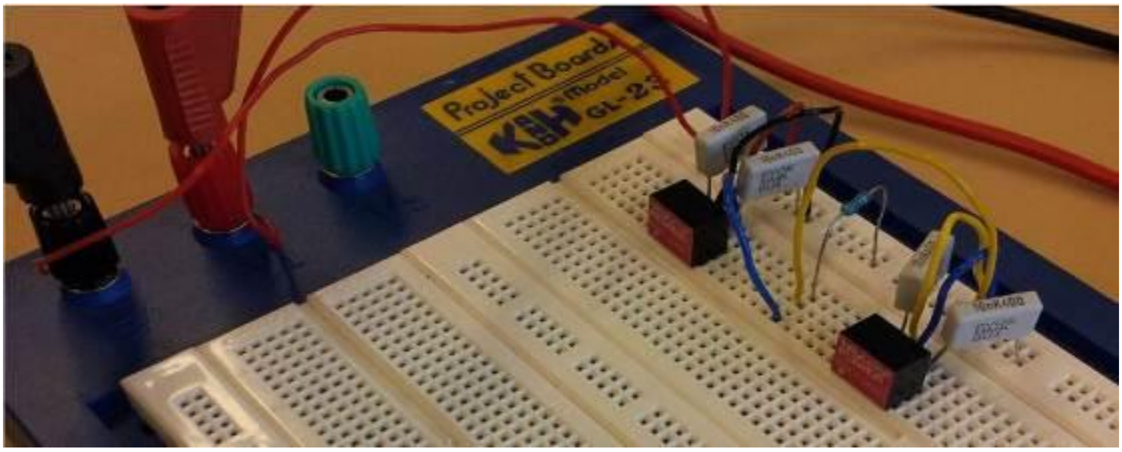


Figure 51 - Breadboarding of DC/DC converters with a few capacitors and a resistor.

All converters in the series of the used DC/DC converter had a high enough guaranteed current output to supply the respective components with a high safety margin for all components powered by the RXSM.

Reaching the ideal temperature of approximately 310 degrees centigrade, the six resistance wires each ideally operated with an input voltage of 1.45 V and a power of 2.2 W. Since there were two sets of three resistance wires in parallel, it would not be enough with the power input from the RXSM to supply them fully. Therefore two battery packs with a individual voltage of 3.6 V in separate circuits were used. The batteries primary purposes were to supply the resistance wires with a burst of power after reaching milligravity and when the soldering is done, the power was switched off.

The cables used in the PDS are PTFE insulation cables, and the rest of the components in the PDS are COTS.

As of writing a full flight version of the entire electrical system have been built, tested and flown with very good results. A backup set of main PCBs were also soldered prior to the launch campaign. The main PCBs with attached cables can be viewed in Figure 52, Figure 53 and Figure 54.

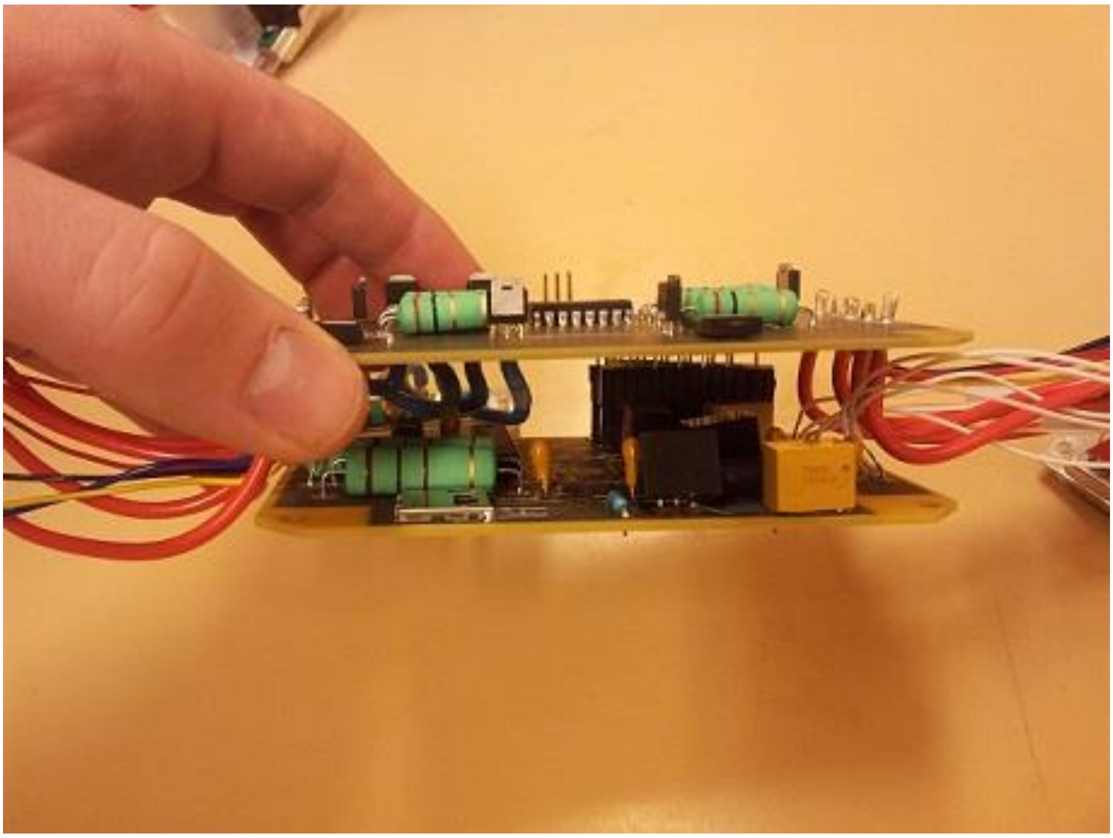


Figure 52 – The main PCBs.

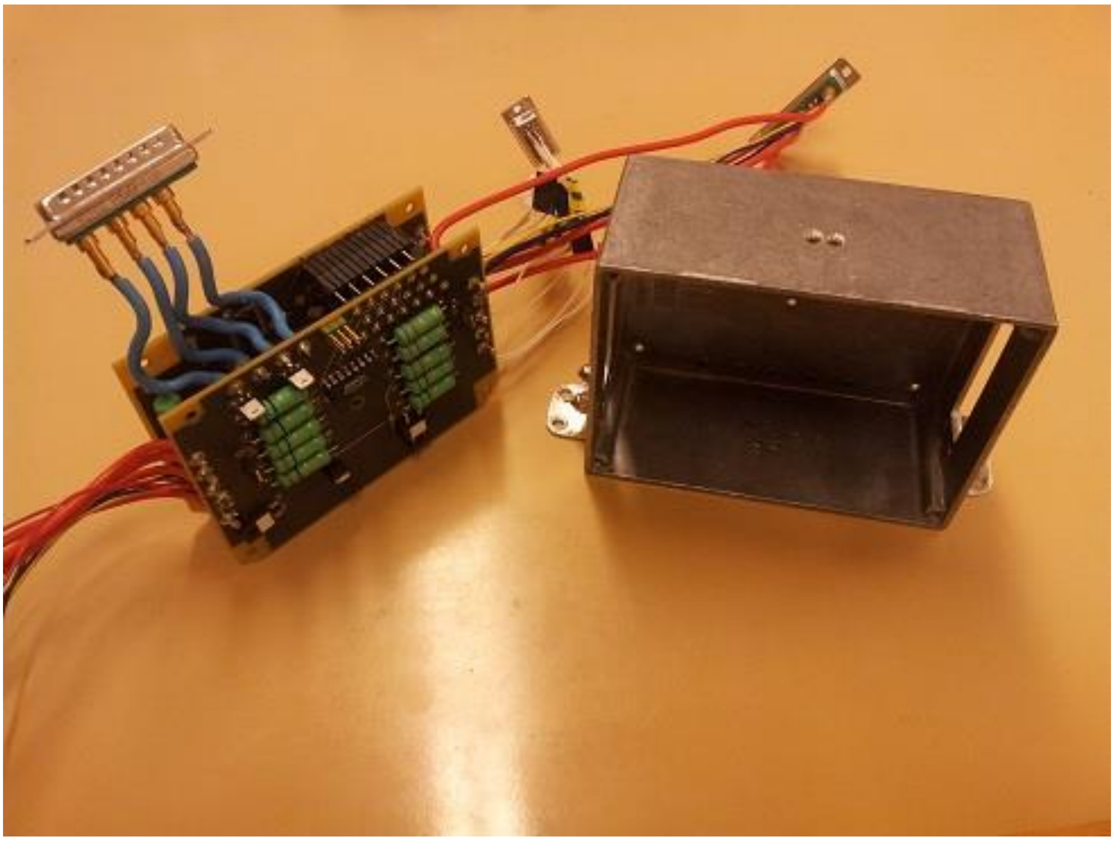


Figure 53 – The main PCBs and the electronics box.

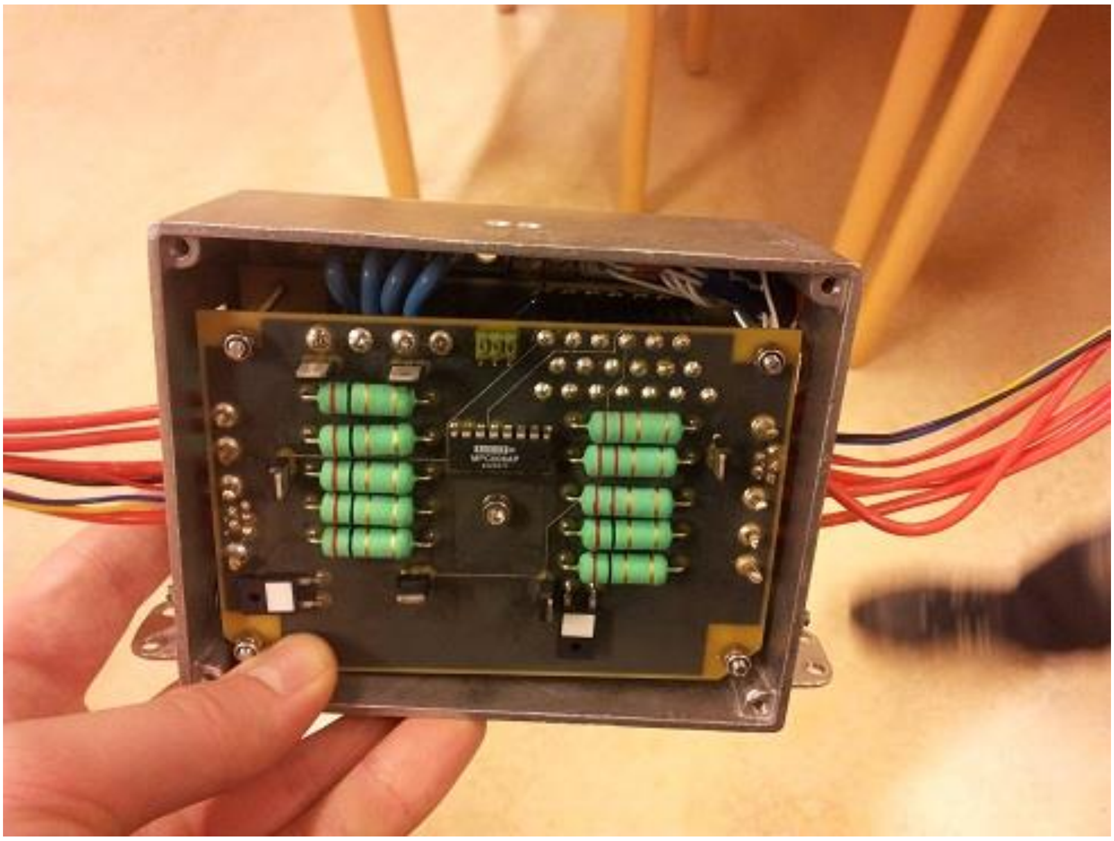


Figure 54 – The main PCBs integrated into the electronics box.

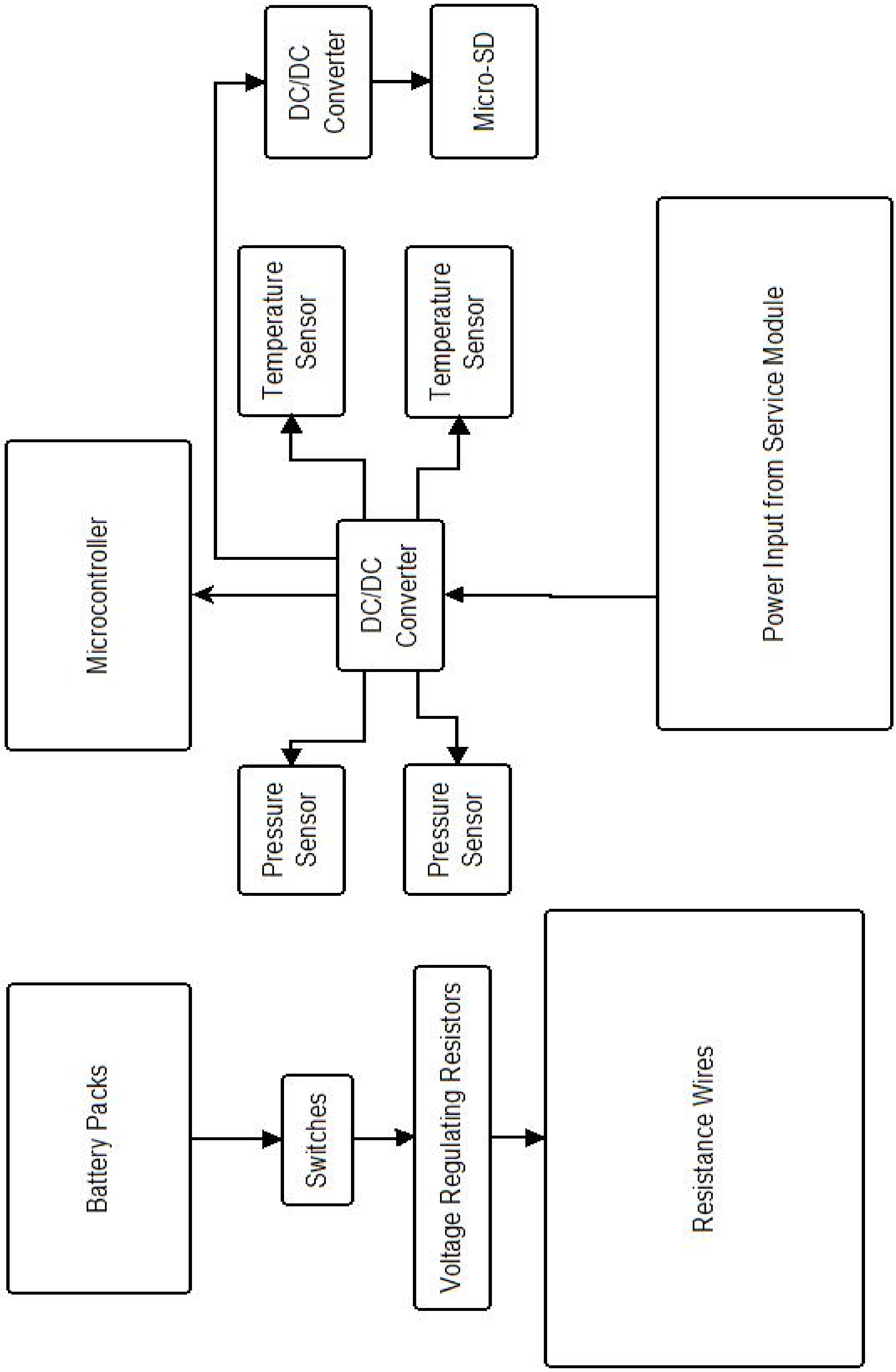


Figure 55 – PDS overview.

4.7.2 Batteries

The batteries were chosen with regard to the following parameters:

- Power demand:
  - They must supply the resistance wires with enough power to reach the required temperature.
- Capacity:
  - High capacity is preferred as the batteries would not have to be charged as often.
- Technology:
  - The batteries must be rechargeable so that they can be tested and reused.
- Operational temperature range:
  - They must be able to operate well in the temperature range that would apply during the experiment.

With this in mind, the battery packs consist of 3 cells each of the following battery:

Table 34 – Information about the batteries.

Battery	SAFT NHS 4200 SCH
Battery type	Ni-MH
Supplier	Celltech
Dimensions	Height: 60 mm Diameter: 22 mm Volume: 22.8 cm^3
Weight	74 g
Reason for choosing	High capacity, rechargeable and good temperature range.

Details are given in datasheet which is given in Appendix C – Additional Technical Information.

Two battery packs were used, each in a separate circuit. This way the wear of each battery pack would not be as great as if one were to power all six resistance wires. This was also a safety measure as the voltage level would have to drop very low for the battery pack not to be able to perform the experiment. This has also been seen to work well with the downscaling means.

The battery packs has a total nominal voltage of 3.6 V and a typical capacity of 4.2 Ah. The maximum continuous discharge current at room temperature is 15 A and during short bursts the allowed discharge current is much higher. Testing and calculations of the power supplied to the six resistance wires show that maximum 5 A per battery pack are drawn at the same time during approximately 15 seconds, resulting in a good safety margin.

Protective electronics are to some extent integrated into the battery packs which protects against short circuits and temperature overloads. Six battery packs in total was purchased, so in case of battery pack failure at last bench test, the battery pack would have been replaced swift and easy.

Since using the battery packs at all after final assembly and before reaching milligravity will ruin the samples, no power was to be drawn from the battery pack during this period of time. It was then the common understanding after feedback from several experts, that charging of the battery pack after final assembly would not be needed. This thesis has also as of writing been thoroughly tested, and it has worked well during integration week, bench test and the launch itself. That is, neither a charging circuit nor an external charger/umbilical was used.

Since the total capacity of the battery pack after full charging is approximately 4.2 Ah, the only threat of complete discharge is exposure of very cold weather during a long period of time, which was avoided.

With this in mind, it should once again be clarified that no means of charging was used after final assembly, that is, neither a charging circuit nor an external charger/umbilical was used. A couple of circuits monitoring the state of the batteries was integrated into the experiment to make sure the battery packs had enough power

To make sure that the power from the batteries to the resistance wires could not be switched on accidentally, a couple of active high switches were used to switch on the power to the resistance wires. As all power to the experiments was cut off during radio silence, no power could be fed to the switch, providing a safety interlock. The switching procedure including the software part had been tested thoroughly to make sure the power to the resistance wires could not accidently be switched on when the subsystem powered by the RXSM was powered on.

The power from the battery packs to the resistance wires was regulated with a number of power resistors in parallel.

4.7.3 Power Budget

To determine the necessary capacity of the batteries and the input from the RXSM, the power consumption needed to be calculated. In

Table 35 all major power consuming components are displayed.

Table 35 – Power budget.

Subsystem	**Component**	**Quantity**	**Operating voltage**	**Maximum current**	**Power consumption**
Powered by the RXSM:					
Component	Microcontroller	1	5 V	40 mA	0.20 W
Component	Pressure sensor	2	5 V	10 mA	0.10 W
Component	Temperature sensor	2	5 V	5 mA	0.05 W
Power distribution	DC/DC converter Sensors	3	23 V	4.5 mA	0.30 W
Total (from RXSM)				0.088 A	0.65 W
Powered by the batteries:					
Component	Resistance wires	6	1.45 V	1.5 A	13.05 W
Total (from batteries)				9 A	13.05 W
Total				9.088 A	13.7 W

Comments regarding the power budget:

The table describe when all components are running at maximum power. All components did not run at maximum power at the same time through the whole flight since the components powered by the battery pack only was powered during a short time. But the PDS was designed to be able to supply all the components with a very good safety margin.

The resistance wires which were the major power consumers were powered separately by the battery packs.

When milligravity was obtained, power to the resistance wires from the battery packs was switched on. The resistance wires run for approximately 15 seconds, reaching the desired temperature in approximately 10 seconds, and then the power was switched off after the soldering was done. After this point in time, there was not any power delivered from the battery packs resulting in significantly lower total power consumption.

The total value of 14 W was the peak value and was only drawn for approximately 15 seconds in the beginning of the time in milligravity. Before and after that the power consumption was significantly lower as shown in Figure 56. The average power consumption was approximately 0.89 W as shown in 6.1.3 Electrical interfaces.

The peak value of approximately 14 W may seem as much but keep in mind that six resistance wires were powered at the same time during a very short period of time and these were all powered by the battery packs in separate circuits so no power was taken from the RXSM for this part.

As seen in

Table 35, the components powered by the RXSM had a total power consumption of 0.55 W which was well below our given quota.

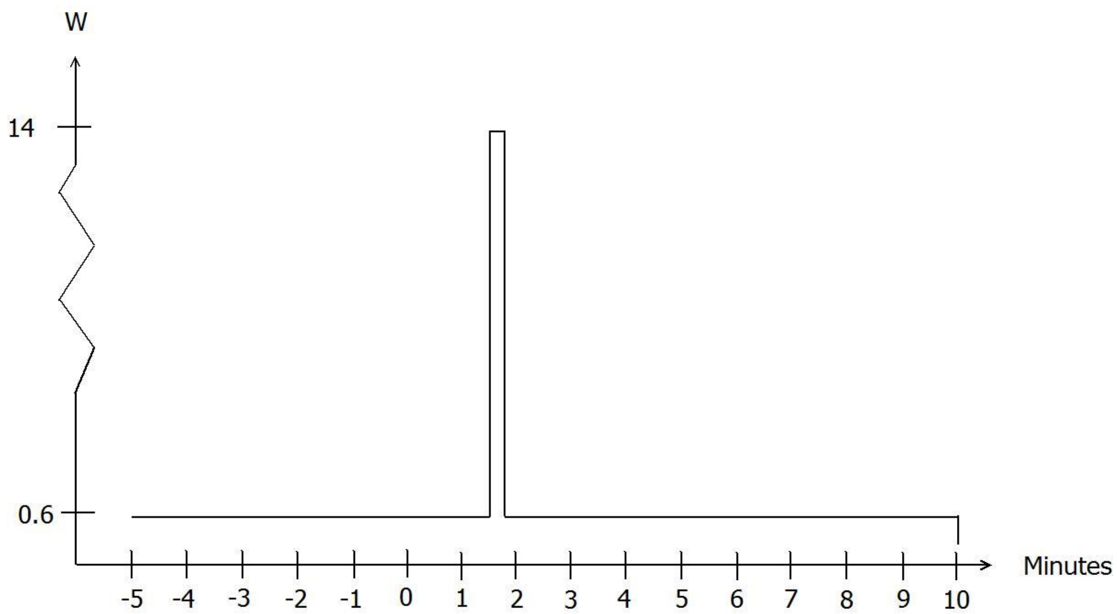


Figure 56 – Power consumption over time.

The resistance wires along with its switch and the power resistors were supplied by the 4.2 Ah battery pack. Testing has revealed that the experiment can run about 100 times before need to recharge the batteries, indicating a very good safety margin.

4.8 Software Design

The SOLAR project was using the ATmega328 microcontroller, which was responsible for experiment operation, timeline, data handling, and telemetry. During flight, experiment data was collected and stored on-board, and for redundancy a downlink to transmit data to the ground station was also used. Temperature and pressure was collected during the whole flight from analogue components, and communication with the service system was through RS-422. A ground station was used for data backup and data visualization, providing a real-time view of the progress of the experiment.

4.8.1 Languages and development environments

The IDE used was Atmel studio 6.0 which can be found at http://wwwatmel.com/Microsite/atmel_studio6/default.aspx. The programmer used was the AVRISP mkII. TortoiseSVN was used for source control and keeping track of changes, this SVN is located at Google Code at the following web address: http://code.google.com/p/solar-rexus/

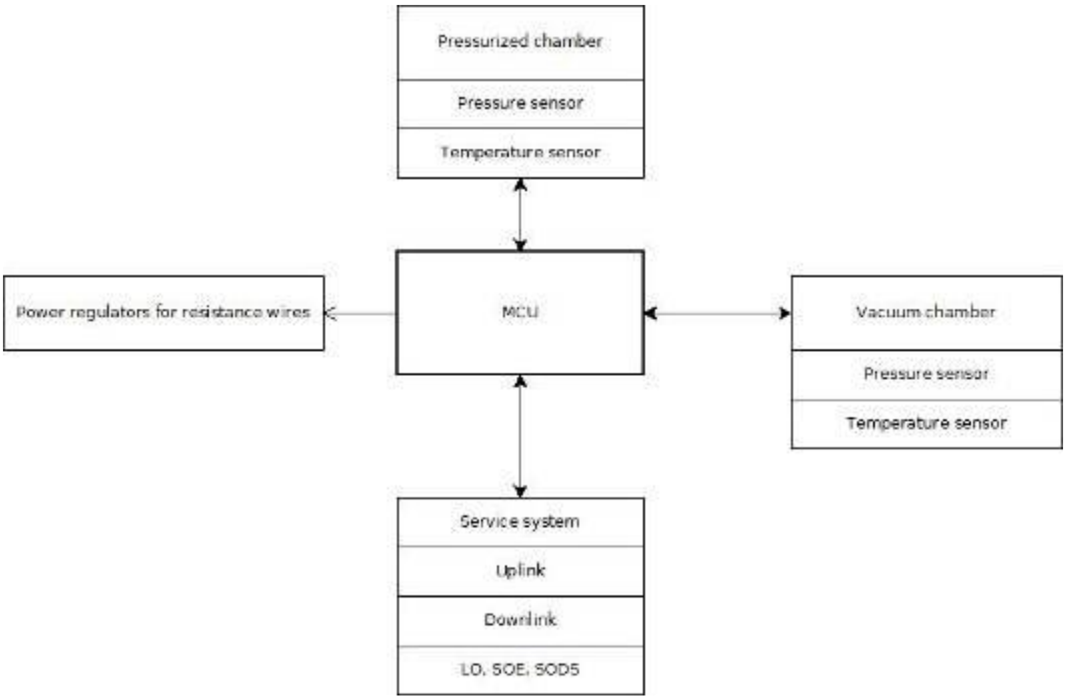


Figure 57 – Top down structure.

4.8.2 Automation

The system was automated through the use of a timeline which decided which stage the microcontroller was currently in and triggered events at certain timestamps. This timeline was started by the LO signal. This timeline governed all aspects of the experiment after lift-off since no uplink was used.

4.8.3 Start-up procedure

At start-up the system initiated a system check procedure to ensure all components and data transfer was active and working. It then listened for incoming commands coming through the service module, continuously checked for LO signal, and sent MESSAGE_OK, or a relevant MESSAGE_ERROR to ground station. During the preflight stage, the battery voltage was transmitted at 10 minute intervals. The analogue components was tested by verifying a signal was received at all the input pins, the digital components was verified by sending commands to them or reading commands received from them. A timer was started at system power on to provide timestamps for all pre-launch actions.During this stage we could send a MESSAGE_ARM command which would decide if the heating stage would melt our samples, this was for testing.

4.8.4 Stages

Table 36 describes the software stages the microprocessor used to execute the experiment. Exactly how this was carried out is described in 4.8.8 Software flow.

Table 36 – Software stages.

ID	Stage	Start time	Description
1	Arming	<T-600s	Experiment completely shut down.
2	Pre-flight	T-600s	Experiment start-up procedure as described in Start-up procedure 4.8.3. Household data was from hereon sampleded and transferred via downlink to the SGS as well as to the micro SD card until stated otherwise.
3	Ascent	T=0s	The microprocessor's timer was synched with the LO.
4	Heating	T+90s	A signal was sent to activate the resistance wires that melted the soldering samples. This stage would not execute unless an ARM command had been received during pre-launch phase.
5	Melting	T+103s	The resistance wires were still kept on while the samples were melted.
6	Cooling	T+105s	A signal was sent to deactivate the resistance wires after the samples had melted.
7	Descent	T+150s	Data was sampled and transferred via downlink as long as contact could be established with the SGS. Data was sampled and stored on the micro SD card until payload impact.
8	Post-flight	>T+540s	Experiment completely shut down.
9	Emergency	-	Handles emergencies that may have arised during experiment.

4.8.5 Emergency

In case of software crash, the internal watchdog timer countdown would have been used to force a restart/interrupt of the system when the timer reached zero. To ensure that the microcontroller knowed which stage was active when it was interrupted, all stage changes were saved as a log on the on-board memory card which should be accessed immediately after restart. No experiment data would have been erased or overwritten during this countermeasure.

4.8.6 On-board data logging

On-board data logging was done to a 1GB micro SD. Sensor data, timer values, household data and emergency backup logging was stored on the card.

4.8.7 Telemetry

All sensor and timer data was transmitted to the ground station every 100 milliseconds. As for uplink telemetry, there was a status check for sensors, timers and a manually forced interrupt to ensure the safety of the experiment.

Table 37 - Downlink messages

Name	ID	Bytes	Function
MESSAGE_OK	1	8	Continiously sent during pre-launch phase to signal experiment functionality.
MESSAGE_ERROR	2	9	Sent after system startup if an error was encountered.
MESSAGE_DATA	4	20	Signals packet contains experiment data. Temperature, pressure and household data.
MESSAGE_EVENT	8	9	Signals packet contains information about an experiment event, e.g. SD card data successfully joined,
MESSAGE_STAGE	16	9	Signals packet contains information about stage changes

Table 38 - Uplink messages

Name	ID	Bytes	Function
MESSAGE_ARM	1	6	Arms the experiment so it starts after LO has been recieved.
MESSAGE_DEARM	2	6	De-arms the experiment.
MESSAGE_CLEARSD	8	6	Sends clear SD card to experiment.
MESSAGE_CLEARAVRSD	16	6	Sends clear SD card and reset AVR to experiment.
MESSAGE_RESETAVR	32	6	Sends reset AVR to experiment.

4.8.7.1 Checksum

To check for accidentally corrupted data streams in the downlink the Fletcher-16 algorithm was applied. This is a simple checksum formula used widely for error checking and is comparable to CRC algorithms. It was mainly chosen because of its simplicity, thus increasing the performance of the software code. It will detect all single-bit error and only allow a small fraction of about 0.001538 data error to go undetected. The two 8-bit bytes checksums generated by the Fletcher-16 was attached to the transmitted data sent to the SGS, where it was compared.

4.8.7.2 Bandwidth

The sum of sensors multiplied by their input/output bit in addition to the timer values and the telemetry checksum, gave the approximate bandwidth needed for downlink telemetry.

Every package contained a 1 byte ID to determine what type of message that was transmitted.

Then 1 byte which which specified the length of the data.

Three bytes which held the timestamp.

Since two temperature sensors were used to measure the temperature at a frequency of 10 Hz with a resolution of 2bytes, the amount of input/output bytes was 2x2 bytes = 4 bytes

Two other temperature readings were made from the resistance wires from both chambers. These were also 2 bytes each.

This also applied on the pressure sensors, thus the amount was 2×2bytes = 4 bytes.

Storage of the timer data was ten values every second, where each value was 2 Bytes.

As previously mentioned the checksum was sent with each data package with a byte size of 2 byte.

The total amount of bits transferred every second, and bandwidth needed:

10×(1+1+3+4+4+4+2) ~ 190 bytes/second.

A summary of the experiment downlink is shown in Table 39.

Table 39 – Summary of the bit rate.

	Total number of bytes	Frequency	Bit rate
ID	1	10 Hz	80 bps
Length	1	10 Hz	80 bps
Storage timer	3	10 Hz	240 bps
Temperature reading	8	10 Hz	640 bps
Pressure reading	4	10 Hz	320 bps
Checksum	2	10 Hz	160 bps
Total	19	10 Hz	1520 bps

4.8.8 Software flow

The microprocessor was using a certain software flow to switch and keep track of the software stages, see Figure 58. It was regulated through the time impulses given by the RXSM and synched with an internal timer. At experiment start up, the microprocessor was starting the first timer, the pre-launch timer, so all pre-launch actions got a time tag. The sampling of household data began as soon as the microprocessor was finished with the start up of the system.

When LO was activated, a second timer, the post-launch timer, started with the main purpose to indicate stage shifts and to tag household data after lift-off. LO also stoped the pre-launch timer meaning the last time tag received from it was T=0sec. At specific predefined times the post-launch timer indicated a stage shift and commands were carried out to the affected components by the microcontroller.

Apart from the active commands given through the system flow, there was also a main loop for sample and store data, see Figure 59. This includes temperature, pressure, and timer data which was sampled in a loop that operated at a 10Hz frequency. In each of the chambers, the mean temperature of the three resistance wires was calculated by measuring the resistance of the circuit. After the data was stored it was also transmitted to the ground station via downlink. The main loop was embedded in the software flow as can be seen in Figure 58.

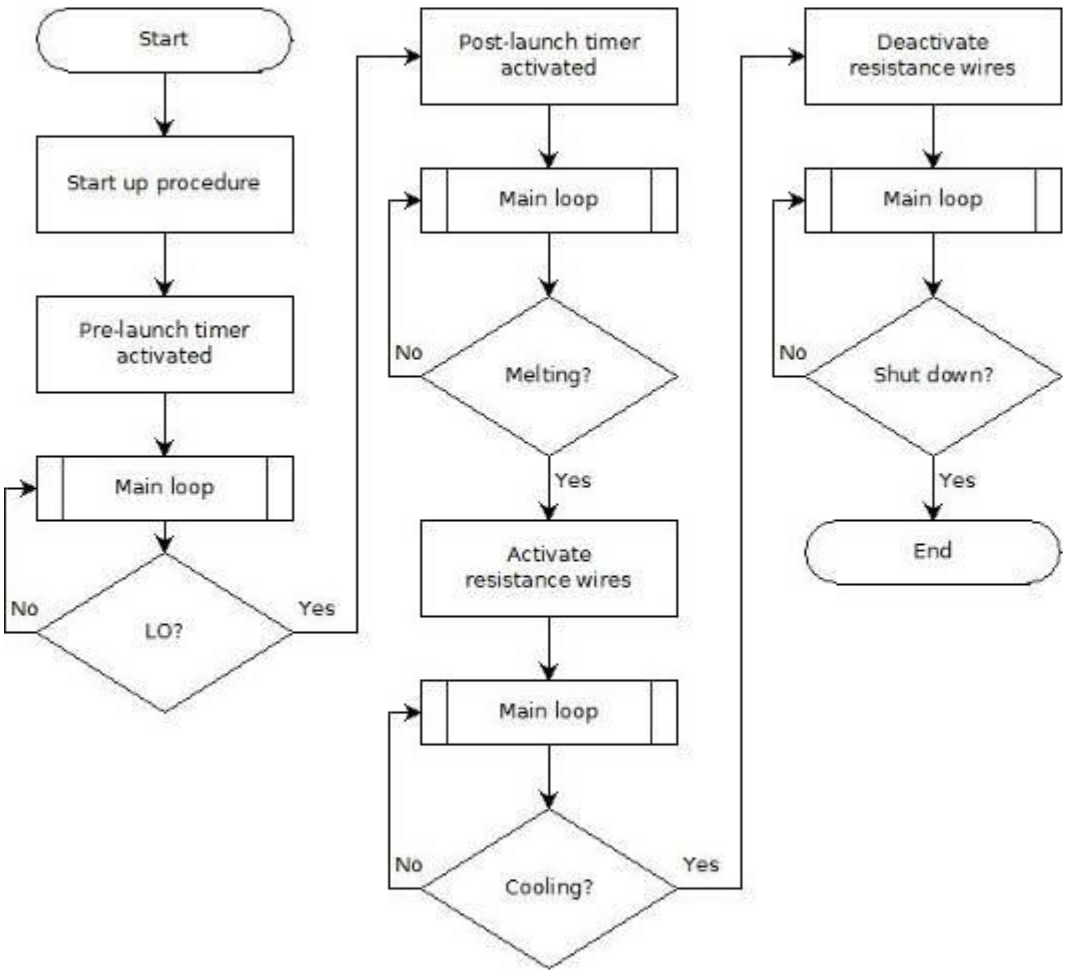


Figure 58 – Software flowchart.

4.9 Ground Support Equipment

The SGS consisted of a computer which was connected to the Esrange Ground Station (EGS) via an asynchronous serial link. It processed the telemetry data that was received at the EGS, and then visualized it on a monitor. The ground station handled all the interaction with the experiment through which we could arm/de-arm the experiment before launch and see the state of the experiment.

4.9.1 Language and development environment

The ground station was written in visual basic using visual studio, therefore only Windows was supported. The main development platform was Windows

7 SP1. The SVN used to backup the source code is available at the same web address as the MCU code: http://code.google.com/p/solar-rexus/

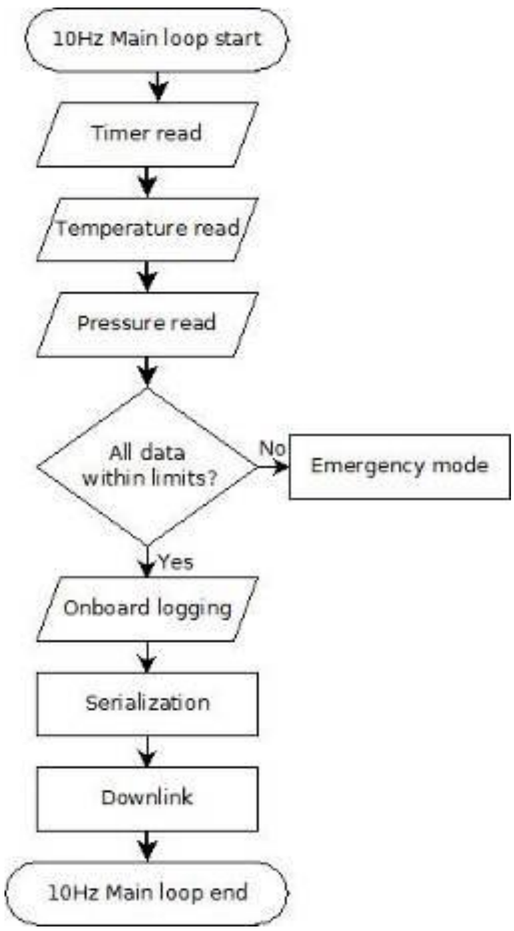


Figure 59 – Software main loop.

4.9.2 Visualization of data

The SGS featured a total of six charts - two for the pressure sensors, two for the temperature sensors, and two for the resistance wires. The charts were updated as soon as new data was received and could be viewed in different time-spans. It also featured a table with all collected household data.

4.9.3 Storage

All data received was stored on the ground stations hard drive with relevant timestamps. The data was stored as RAW data, the exact same way as it was received.

5 EXPERIMENT VERIFICATION AND TESTING

This chapter contains information on verification and testing for the project. The objective of this chapter is to verify that the experiment meets the requirements set in chapter 2.

5.1 Verification Matrix

This section will comprise a set of tables describing how to verify that all of the requirements have been fulfilled. Table 40 contains abbreviations for the different methods of verification.

Table 40 – Methods of verification.

T	Testing
I	Inspection
A	Analysis/similarity
R	Review-of-design

Testing and inspection are self-explanatory, whereof analysis/similarity and review-of-design need a more elaborate explanation. Verification by Analysis refers to verify through using computer modelling, whereas similarity refer to a component that has already been used successfully in a similar function. Verification by review-of-design uses design documents to show if the experiment would perform as expected.

5.1.1 Mechanics Verification Table

Table 41 – Mechanics verification table.

ID	Requirement text	Verification	Status	Test number
M.F.1	The solder shall reach a solid state before T+150s.	R, T	Done	IST.1
M.F.2	The vacuum chamber shall have a pressure close to the outside environment.	R, T	Done	OST.2

M.F.3	The solder sample shall have a well-defined melting point.	R	Done	
M.P.1	The experiment shall be able to work in an environment of -10 to +45 degrees centigrade.	R, T	Done	OST.3
M.P.2	The solder sample shall reach a temperature below +183 degrees centigrade before T+150s.	R, T	Done	IST.1
M.P.3	The pressure in the vacuum chamber shall not have a difference greater than +/-5 % from the outside environment when soldering.	R, T	Done	OST.2
M.P.4	The solder sample shall have a melting point of 183 +/- 1 degrees centigrade.	R, T	Done	IST.1
M.D.1	The whole experiment shall withstand an acceleration of 20 g.	R, A	Done	
M.D.2	The whole experiment shall be able to hold against vibrations of 12.7 G_{rms}.	R, T	Done	OST. 1
M.D.3	The weight of the experiment with experimental module shall not exceed 10 kg.	R, A, T	Done	OST.5
M.D.4	The experiment shall not produce a heat transfer to adjacent experiment of more than 10 degrees centigrade.	R, A,	Done	
M.D.5	The resistance wire shall be in contact with the solder sample during flight.	R, T	Done	OST. 1
M.D.6	The pressurized chamber shall be able to hold the pressure that is present at launch site with a maximum change of +/-10 kPa during the soldering.	R, T	Done	OST.2

M.D.7	The experiment shall be resistant against thermal changes.	R, A	Done	

5.1.2 Electronics Verification Table

Table 42 – Electronics verification table.

ID	Requirement text	Verification	Status	Test number
E.F.1	There shall be a downlink from the experiment to the EGS.	R	Done	
E.F.2	There shall be an on-board data storage for the gathered data on the experiment.	R	Done	
E.F.3	The experiment shall measure the temperature inside each of the chambers.	R,T	Done	CPS.7
E.F.4	The experiment shall measure the pressure inside each of the chambers.	R,T	Done	CPS.3
E.F.5	The battery pack shall be able to operate in the temperature profile inside the REXUS rocket.	R,T	Done	OST.3
E.F.6	The PDS shall provide accurate power to all subsystems.	R,T	Done	PDS.1
E.F.7	The battery pack shall supply the resistance wires with enough power to reach the required temperature.	R,T	Done	PDS.3
E.F.8	The power distribution system shall comprise a safety system enabling shut down of experiment on request.	R,T	Done	PDS.4

E.P.1	The on-board data storage shall have a memory capacity of 1GB.	R	Done	
E.P.2	The temperature measurement inside each chamber shall be possible between -40 and +300 degrees centigrade.	R,T	Done	CPS.7
E.P.3	The temperature measurement inside each chamber shall be made with an accuracy of +/- 5 degrees centigrade.	R,T	Done	CPS.7
E.P.4	The pressure measurement inside each chamber shall be possible between 0 and 110 kPa.	R,T	Done	CPS.3
E.P.5	The pressure measurement inside each chamber shall be made with an accuracy of +/- 3 kPa.	R,T	Done	CPS.3
E.P.6	The battery pack shall be able to operate within a temperature range of -30 to +85 degrees centigrade.	R,T	Done	OST.3
E.P.7	The resistance wires shall operate within a range of +300 to +320 degrees centigrade while the samples are melted.	R,T	Done	CPS.6
E.P.8	The power circuits shall regulate the voltage to the level required by each component.	R,T	Done	PDS.6
E.P.9	The battery packs shall be able to provide the resistance wires with a steady current of a total 11 A during the soldering process.	R,T	Done	PDS.3

E.P.10	If no power is received from the service module, the active high switch for the battery pack/resistance wires system shall remain open.	R,T	Done	PDS.4
E.D.1	All components shall be selected to withstand vibrations of 12.7 G_{rms}.	R,A,T	Done	OST.1
E.D.2	All components shall be selected to fit into the mechanics design dimensions.	R,T	Done	CPS.5
E.D.3	All components shall be selected to operate well within the expected limit with regard to safety margin and derating.	R,T	Done	CPS.4
E.D.4	All components shall be selected to operate within the expected temperature range with a safety margin.	R,T	Done	OST.3
E.D.5	The connector to the pressurized chamber shall be airtight.	R,T	Done	OST.1
E.D.6	The batteries shall be qualified for use on a REXUS rocket.	R	Done	
E.D.7	The battery pack shall be easily accessible and rechargeable.	R,T	Done	CPS.5 PDS.2
E.D.8	All communication between the two main systems shall be isolated through MOS-transistors.	R	Done	
E.D.9	The resistance wires shall be able to melt the soldering samples.	R,T	Done	CPS.8
E.O.1	The battery pack shall be switchable.	R,T	Done	PDS.5

5.1.3 Software Verification Table

Table 43 – Software Verification table.

ID	Requirement text	Verification	Status	Test number
S.F.1	The SGS shall be able to display information received from the experiment.	R, T	Done	SGS.1
S.F.2	The microcontroller shall collect, decode and store data received on a memory card.	R, T	Done	OBDH.1
S.F.3	The microcontroller shall transmit data to the RXSM.	R, A, T	Done	OBDH.2
S.F.4	The experiment shall measure the mean temperature of the resistance wires in each chamber.	A, T	Done	OBDH.3
S.F.5	The experiment shall measure the pressure in each chamber.	R.T	Done	OBDH.3
S.P.1	The SGS shall be able to update the charts at the rate it is transmitted from the EGS.	R, A, T	Done	SGS.1
S.P.2	The microcontroller shall collect, decode and store data at a rate of 10 Hz.	R, T	Done	OBDH.1
S.P.3	The microcontroller shall transmit downlink data at a rate of 10 Hz.	R, T	Done	OBDH.1
S.P.4	The mean temperature measurement of the resistance wires in each chamber shall be possible up to +400 degrees centigrade.	R, T	Done	OBDH.3
S.P.5	The mean temperature measurement	A, T	Done	OBDH.3

	of the resistance wires in each chamber shall be made with an accuracy of +/- 10 degrees centigrade.			
S.P.6	The telecommunication link shall have a data rate of minimum 2kbps.	R, A	Done	SGS.1
S.P.7	The pressure measurement inside each chamber shall be possible between 0 and 200 kPa.	R, T	Done	OBDH.3
S.P.8	The pressure measurement inside each chamber shall be made with an accuracy of +/-3 kPa.	A, T	Done	OBDH.3
S.D.1	The system shall utilize a timeline to determine which stage it is in.	R, T	Done	OBDH.1
S.D.2	The SGS shall be able to receive information from the experiment through the EGS.	R, T	Done	SGS.1
S.O.1	The ECS shall handle experiment control failures safely.	R, T	Done	OBDH.4
S.O.2	The ECS shall be able to operate autonomously.	R, T	Done	OBDH.4

5.2 Test Plan

5.2.1 Mechanics Test Plan

Test number	OST.1
Test type	Vibration
Test facility	SRT
Tested item	Chambers, electronics box and battery pack
Test level/procedure	Acceptance test.

and duration	This test was done in two steps. 1. The structures of the experiment were put on a shaker and vibrated according to directives from the REXUS manual. 2. The whole experiment with all components installed was put on a shaker which vibrated according to directives from the REXUS manual Before the test the resistance wires were inspected so that they were in contact with the solder samples. An inspection after the test was also be done. Duration of shake test, 5min.
Test campaign duration	7 days
Verifies	M.D.2, M.D.5

Test number	OST.2
Test type	Vacuum & performance
Test facility	IRF
Tested item	Chambers
Test level/procedure and duration	Verification test. The experiment were executed in a vacuum chamber where the solder was melted and returned to a solid state on a set amount of time. M.F.2 The data were analysed to see if the pressure in the chamber followed the pressure in the vacuum chamber. An acceptance test was also done on the pressurized chamber to see how long it would hold its initial pressure with a change of ± 10 kPa when it was put in a vacuum chamber.

Test campaign duration	7 days
Verifies	M.F.2, M.P.3, M.D.6, E.D.5

Test number	OST.3
Test type	Thermal
Test facility	SRT
Tested item	Whole experiment
Test level/procedure and duration	Acceptance test. The experiment was tested in a freezer and in an oven. The experiment was in the freezer for 2 hours at -10 degrees centigrade and 30 minutes in the oven at 45 degrees centigrade. During this time, measurements were taken on the experiment to see how it reacted to the different environments. The data registered from the heat sensors was analysed after the test.
Test campaign duration	7 days
Verifies	M.P.1

Test number	OST.5
Test type	Weight
Test facility	SRT
Tested item	Whole experiment without bulkhead module

Test level/procedure and duration	Acceptance test. Once all the parts of the experiment are put together it will be weighed. 10 min.
Test campaign duration	1 day
Verifies	M.D.3, E.D.2

Test number	IST.1
Test type	Performance
Test facility	SRT
Tested item	Solder sample
Test level/procedure and duration	Verification test. Under controlled and monitored conditions the solder sample will be heated to 183 degrees centigrade. 5min
Test campaign duration	1 day
Verifies	M.F.1, M.P.2, M.P.4

5.2.2 Electronics Test plan

Test number	CPS.3
Test type	Operational
Test facility	IRF
Tested item	Pressure sensors

Test level/procedure and duration	Verification test. The sensors shall be placed in a pressure chamber for 30 min and verified to operate.
Test campaign duration	1 day
Verifies	E.F.4, E.P.4, E.P.5

Test number	CPS.4
Test type	Operational
Test facility	SRT
Tested item	All electronics except batteries
Test level/procedure and duration	Verification test. Test items shall be tested on a bread board to ensure that they withstand the expected current and voltage with a margin for 30 min. 8h.
Test campaign duration	1 day
Verifies	E.D.3

Test number	PDS.1
Test type	Operational
Test facility	SRT
Tested item	Power distribution system

Test level/procedure and duration	Verification test. The PDS shall be connected on a bread board and measurements of current and voltage shall be made for all subsystems. 5h.
Test campaign duration	1 day
Verifies	E.F.7

Test number	CPS.5
Test type	Functional
Test facility	SRT
Tested item	All electronics
Test level/procedure and duration	Verification test. The entire system shall be placed in the dedicated area and easy access for specific components shall be verified. 5h.
Test campaign duration	1 day
Verifies	E.D.7

Test number	CPS.6
Test type	Operational
Test facility	SRT
Tested item	Resistance wires

Test level/procedure and duration	Verification Test. The resistance wires shall be heated up and the incoming voltage and current shall be calibrated to a specific temperature. 5h.
Test campaign duration	2 days
Verifies	E.P.7

Test number	PDS.2
Test type	Functional
Test facility	SRT
Tested item	Battery pack
Test level/procedure and duration	Verification Test. The battery pack shall be discharged to a predefined level and recharged for verification. 20h.
Test campaign duration	3 days
Verifies	E.D.9

Test number	PDS.3
Test type	Performance
Test facility	SRT

Tested item	Battery pack
Test level/procedure and duration	Verification Test. The resistance wires shall be supplied with power from the battery pack and verified to achieve the required temperature. 5h.
Test campaign duration	2 days
Verifies	E.F.8, E.P.9

Test number	CPS.7
Test type	Performance
Test facility	SRT
Tested item	Temperature sensors
Test level/procedure *and duration	Verification Test. Day 1: Test items shall be placed in a high temperature chamber and verified to a calibration sensor Day 2: Test items shall be placed in a low temperature chamber and verified to a calibration sensor
Test campaign duration	2 days
Verifies	E.F.3, E.P.2, E.P.3

Test number	PDS.4

Test type	Operational
Test facility	SRT
Tested item	Safety switches
Test level/procedure and duration	Verification Test. The safety system shall be connected on a breadboard and verified to shut down on request from the microcontroller. 10h.
Test campaign duration	2 days
Verifies	E.P.10

Test number	PDS.5
Test type	Operational
Test facility	SRT
Tested item	Charging circuit
Test level/procedure and duration	Verification test. The battery pack shall be connected on a bread board and be verified to switch on and off as requested. 10h.

Test campaign duration	2 days
Verifies	E.O.1

Test number	PDS.6
Test type	Operational
Test facility	SRT
Tested item	Power circuits
Test level/procedure and duration	Verification Test. The power circuits shall be connected on a breadboard where input and output voltage will be measured and verified. 10h.
Test campaign duration	2 days
Verifies	E.P.8

Test number	CPS.8
Test type	Operational
Test facility	SRT
Tested item	Resistance wires
Test level/procedure and duration	Verification Test.

	The resistance wires shall be provided with accurate power and verified to melt a sample of solder. 5h.
Test campaign duration	1 day
Verifies	E.F.6

5.2.3 Software Test Plan

Test number	SGS.1
Test type	Performance
Test facility	SRT
Tested item	ECS and SGS software
Test level/procedure and duration	Acceptance Test. Repeated testing for reliability. Checking compatibility with EGS for transfer data from downlink. Approximately 5 hours.
Test campaign duration	1 day
Verifies	S.F.1, S.P.1, S.D.2

Test number	OBDH.1
Test type	Functional
Test facility	SRT
Tested item	Microcontroller, ECS software

Test level/procedure and duration	Verification Test Run the MCU and observe the UART output through the GROUND STATION. Connect the SD card to a computer and check the data.
Test campaign duration	3 days
Verifies	S.F.2, S.P.2, S.P.3, S.D.1

Test number	OBDH.2
Test type	Functional
Test facility	SRT
Tested item	UART
Test level/procedure and duration	Verification Test. Making sure UART works as intended with a minimum of packet errors, and being able to detect and discard packets with CRC errors.
Test campaign duration	3 days
Verifies	S.F.3

Test number	OBDH.3
Test type	Functional
Test facility	SRT
Tested item	Sensors, ECS software

Test level/procedure and duration	Verification Test Making sure sensors work as instended and measure the correct values.
Test campaign duration	3 days
Verifies	S.F.4, S.P.4, S.P.5, S.F.5, S.P.7 S.P.8

Test number	OBDH.4
Test type	Functional
Test facility	SRT
Tested item	ECS software
Test level/procedure and duration	Verification Test
Test campaign duration	3 days
Verifies	S.O.1, S.O.2

5.3 Test Results

A table showing the current status of tests, if they are passed or not with remarks can be seen in Table 44.

Table 44 – Summary of test results.

Test Number	Test type	Test Level	Status	Pass/Fail	Remarks
OST.1	Vibration	Acceptance	Complete	Pass	

OST.2	Vacuum & Performance	Verification	Complete	Pass	Leakage of air will start to occur in the pressurized chamber when the outside environment is under (what could be measured) 20 kPa.
OST.3	Thermal	Acceptance	Complete	Pass	
OST.4	Thermal	Acceptance	Test removed		Because of the small heat dissipation from the resistance wires and the large structures that surrounds it, no heat spread will occur and therefore this test was removed.
OST.5	Weight	Acceptance	Complete	Pass	
IST.1	Performance	Verification	Complete	Pass	
CPS.1	Vibration	Acceptance	Test removed		OST.1 verifies instead
CPS.2	Thermal	Acceptance	Test removed		OST.3 verifies instead
CPS.3	Operational	Verification	Complete	Pass	
CPS.4	Operational	Verification	Complete	Pass	

PDS.1	Operational	Verification	Complete	Pass	
CPS.5	Functional	Verification	Complete	Pass	
CPS.6	Functional	Verification	Complete	Pass	
PDS.2	Functional	Verification	Complete	Pass	
PDS.3	Performance	Verification	Complete	Pass	
CPS.7	Performance	Verification	Complete	Pass	
CPS.8	Operational	Verification	Complete	Pass	
PDS.4	Operational	Verification	Complete	Pass	
PDS.5	Operational	Verification	Complete	Pass	
PDS.6	Operational	Verification	Complete	Pass	
SGS.1	Performance	Acceptance	Complete	Pass	
OBDH.1	Functional	Verification	Complete	Pass	
OBDH.2	Functional	Verification	Complete	Pass	
OBDH.3	Functional	Verification	Complete	Pass	
OBDH.4	Functional	Verification	Complete	Pass	

6 LAUNCH CAMPAIGN PREPARATION

6.1 Input for the Campaign / Flight Requirement Plans

6.1.1 Dimensions and mass

Table 45 shows the calculated dimensions and mass of the experiment, including the protection caps, the bulkhead and the 120 mm rocket module i.e all parts seen in Figure 60 - Figure 62. It also shows the centre of gravity and the moment of inertia.

Table 45 - Experiment summary table

Experiment mass [kg]	7.75
Experiment dimensions (rxh) [m]	0.156x0.105
Experiment footprint area (on bulkhead) [m^2]	0.0378
Experiment volume [m^3]	0.00283
Experiment centre of gravity position (x, y, z) [mm]	(-30.320, -5.091, -1.338)
Experiment moment of inertia (I_x, I_y, I_z) [$kg \cdot m^2$]	(0.145, 0.0939, 0.0868)

Regarding the experiment dimensions, the radius is the radius of the bulkhead and the height is the distance between the lowest part of the bulkhead and the top of the electronics box. The footprint area is the total footprint area for all experiment parts attached to the bulkhead.

A clarification of the centre of gravity position can be seen in Figure 60 - Figure 62.

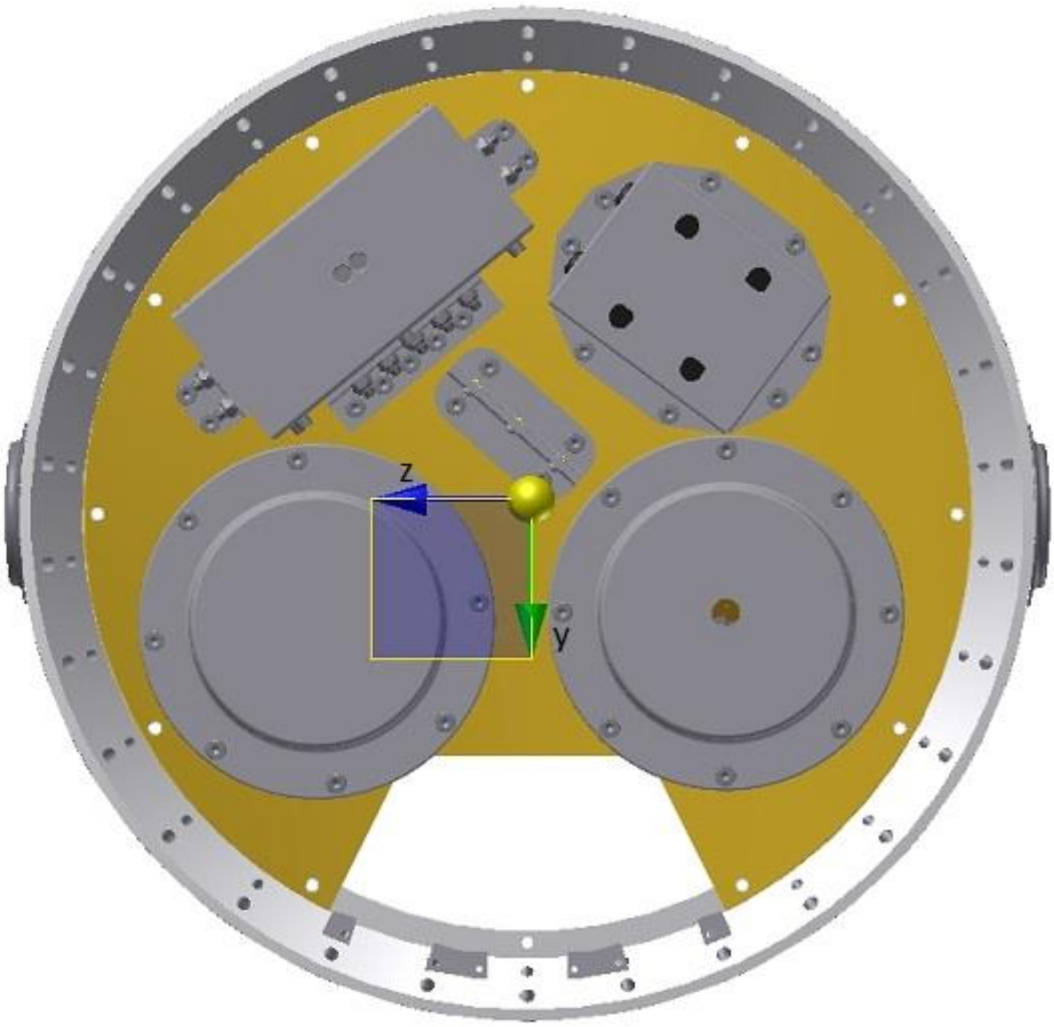


Figure 60 - Centre of gravity position in z and y-direction.

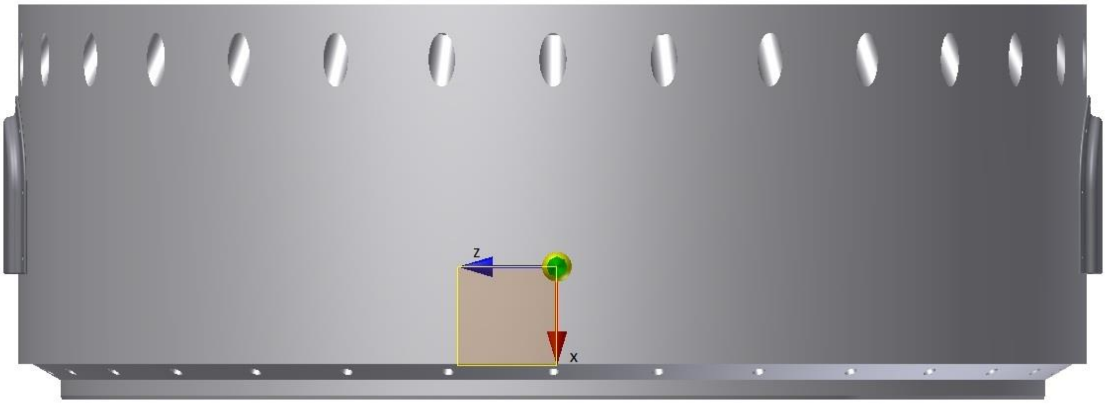


Figure 61 - Centre of gravity position in z and x-direction

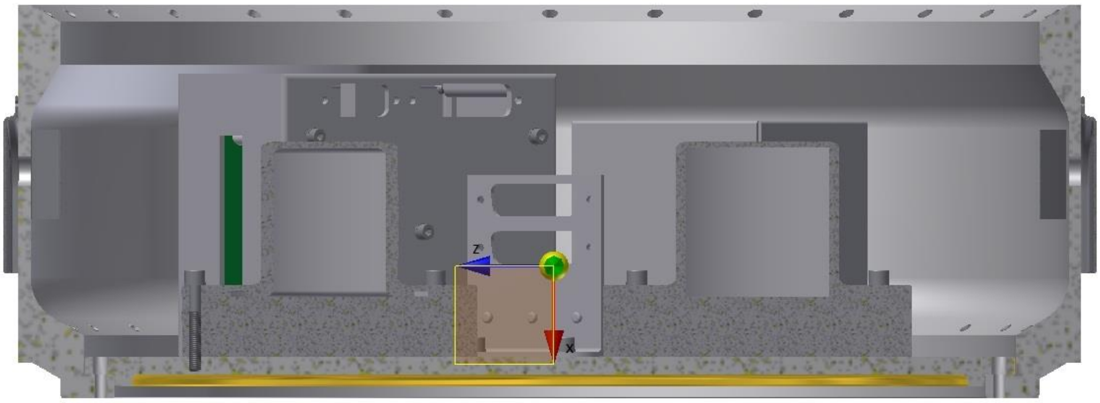


Figure 62 -. Centre of gravity position in z and x-direction with section view.

6.1.2 Safety risks

Risks during experiment transport to the launch site:

- None

Risks during experiment unpacking, assembly and mounting:

- Risk of NiMH battery explosion during charging.
- Slight shock hazard from electrical components.
- Risk of burn injuries when handling the resistance wires during the assembly.

Risk during flight and recovery:

- Risk of acid burns due to NiMH battery breaking during the impact.
- Slight shock hazard from the NiMH battery if the active high switch has failed to shut down the power system.

6.1.3 Electrical interfaces

Table 46 - Electrical interfaces applicable on REXUS.

REXUS Electrical Interfaces		
Service module interface required? Yes		
	Number of service module interfaces:	1
	TV channel required? If yes, when is it required:	No -
Up-/Downlink (RS-422) required? Downlink – Yes, Uplink – Only before launch		

	Data rate - downlink:	2kbit/s
	Data rate – uplink	20 byte package (maximum)
Power system: Service module power required? Yes		
	Peak power consumption:	14 W
	Average power consumption:	0.89 W
	Total power consumption after lift-off (until T+600s)	0.22 Wh
	Power ON	600s before lift-off
	Power OFF	540s after lift-off
	Battery recharging through service module:	No
Experiment signals: Signals from service module required? Yes		
	LO:	Yes
	SOE:	No
	SODS:	No

6.1.4 Launch Site Requirements

A dedicated space for the charging of batteries was needed due to the potential risks of failure during charging.

Workspace and dedicated power outlets were needed for assembly and testing of the experiment.

Access to a basic tool set at Esrange was favourable but not necessary. Other tools that were crucial and necessary were brought with the team.

A table with two chairs were required for the SGS. Connection to the EGS and a power supply were also to be available.

In order to avoid complete discharge of the batteries and be able to estimate the power needed to melt the samples, heating of the experiment module in case of very cold weather was required and preferred in the greatest possible extent, but in the end not needed.

6.2 Preparation and Test Activities at Esrange

A series of checklists were used to make sure all procedures were done as planned. The lists included procedures for pre-flight, in flight, post-flight and emergencies.

6.2.1 Mechanics checklist

Before the flight, the experiment was inspected and prepared, according to the checklists below.

A vacuum test was executed on the pressurized chamber close up to the launch campaign which ensured its performance.

Launch campaign checks

Activity	Responsible team member	When/duration
Inspection of the payload's structures and parts	Johanna Åstrand	29 April 30 min
Inventory of the payload structures and parts	Johan Strandgren	29 April 45 min
Inventory list of tools	Adrian Lindqvist	29 April 45 min
Inspection of new screws, washers, nuts and spacers to use during flight	Johan Strandgren	29 April 45 min
Inspection of extra screws, washers, nuts and spacers in case of damage or loss	Johan Strandgren	29 April 45 min
Inventory list for spare parts and consumables	Sara Widbom	29 April 45 min

Pre-flight checks

Activity	Responsible team member	When/duration
Pre-flight final assembly of payload before flight	Adrian Lindqvist Johan Strandgren	6 May 2 hours

Note: The Loctite needed to harden for about 24 h before launch for maximum effect.

Post-flight checks

Activity	Responsible team member	When/duration
Post-flight disassembly of the experiment from the bulkhead	Johan Strandgren	7 May 45 min
Post-flight inspection of the payload's structures and parts	Johanna Åstrand	7 May 30 min
Post-flight inspection of the soldering and storing the samples	Adrian Lindqvist	7 May 45 min
Post-flight inventory of the payload structures and parts	Johan Strandgren	7 May 1 hour
Post-flight inventory list of tools	Adrian Lindqvist	7 May 1 hour
Post-flight inventory list for spare parts and consumables	Sara Widbom	7 May 1 hour

The time it took to swap samples in one chamber in case of a wet test was about 15 minutes as was proven by procedure [G.M.3].

6.2.2 Electronics checklist

To bring to the launch

See [G.E.CL.16]

Before the flight, the experiment was inspected and prepared, according to the checklists below.

Launch campaign checks

Activity	Responsible team member	When/duration
Verify that all needed items are brought	Emil	Day 1/ 30min
Inspect and qualify all wiring	Björn	Day 1/ 10min

after transport to Esrange		
Inspect and qualify all connectors after transport to Esrange	Björn	Day 1/ 10min
Inspect and qualify main PCBs after transport to Esrange	Emil	Day 1/ 15min
Recharge batteries (make sure they are fully charged)	Björn	Regular checks
Functional test on main PCBs	Björn	Day 2/1 hour
Inspection of solder station	Emil	Day 2/15 min
"Safety interlock" (make sure the experiment can be turned off)	Emil	Day 2/ 30 min
Test batteries	Björn	Day 2/ 30min
Test system	Emil	Day 2/ 1 hour

Pre-flight checks

These activities were done before the experiment module were mounted in the rocket.

Activity	Responsible team member	When (duration)
Inspect and qualify all wiring	Jens Kanje Nordberg	3/5 – (10min)
Inspect and qualify all connectors	Björn Sjödahl	3/5 – (10min)
Inspect and qualify main PCBs	Emil Vincent	3/5 – (15min)
Recharge batteries (make sure they are fully charged)	Björn Sjödahl	3/5 – (10min)
Connect batteries	Emil Vincent	

In flight

Activity	Responsible team member
Emergency procedures might have to be started during flight, in terms of preparing staff and rocket technicians.	Anneli Prenta

After the flight, the experiment was recovered, reviewed and analyzed for results and possible damages.

Post-flight

Activity	Responsible team member	When (duration)
Recover the experiment	-	7/5
Detach electronics	Jens Kanje Nordberg	7/5
Review and analyze damage to equipment	Björn Sjödahl	7/5
Analyze voltage of battery pack, and values received from telemetry to make sure everything went as planned	Björn Sjödahl	7/5

Emergency/Failure

Activity	Responsible team member
Samples melts before flight	Emil Vincent
Battery discharges	Björn Sjödahl
Electrical failure – no experiment start	Emil Vincent

6.2.3 Software checklist

Activity	Responsible team member	When/duration
[G.S.CL.1] Item list	Hamoon Shahbazi	Before launch campaign

Procedures

Activity	Responsible team member	When/duration
[G.S.1] Experiment Test	Robert Lindberg	Launch campaign
[G.S.2] Pre flight setup	Björn Paulström	Pre flight
[G.S.3] Computer crash	Björn Paulström	During flight
[G.S.4] Post flight procedure	Hamoon Shahbazi	Post flight

6.3 Timeline for countdown and flight

After the initial start-up procedure was completed, data sampling started and went on until the experiment was shut down. All times are described in Table 47.

Table 47 – Timeline.

ID	Stage	Start time	Duration (s)	Approx. alt. (km)	Remark
1	Arming	<T-600s	-	0	Experiment completely shut down.
2	Pre-flight	T-600s	600	0	Experiment start-up procedure and data sampling started.
3	Ascent	T=0s	90	0 - 75	-
4	Heating	T+90s	13	75 - 77	The resistance wires were activated. This stage would not have been executed unless an ARM command had been received during pre-launch phase.
5	Melting	T+103s	2	77 - 78	The resistance wires reached the desired temperature for melting.
6	Cooling	T+105s	45	78 - 85	The resistance wires were deactivated and the cooling process started.
7	Descent	T+150s	250	85 - 0	-
8	Post-flight	>T+540s	-	0	Experiment was completely shut down.
9	Emergency	---			May have been activated anytime if necessary.

6.4 Post Flight Activities

When the experiment was retrieved after the flight, the PCB-cards with the solder samples were extracted. The samples were then brought to the University of Oulu in Finland where an X-ray scanner was used.

After retrieval the experiment was brought to a clean working area. The hats were dismounted, followed by the PCB holding the soldering samples. The screws holding the resistance wires were then loosened and the wires untwisted from the samples. The solder was now left connected only to the component pin. A visual inspection was done and documented to see any structural flaws of the surface of the solder. The samples were then marked by putting a piece of coloured tape at the end of the component pin. When the inspection and marking were done, the samples were put into a closable box covered with foam to avoid any physical damage during transportation. For further details regarding the evaluation of the samples please see Chapter 7.

7 DATA ANALYSIS PLAN

7.1 Data Analysis Plan

The data analysis plan describes the approach for analysing data post flight.

Planned activities	When	Where
X-ray inspection of the solder joints	Finished, May 2012	University of Oulu, Finland
Physical inspection of payload	After payload retrieval, Finished, May 2012	Kiruna, Sweden
Sensor data analysis (pressure, temperature)	Finished, May 2012	Kiruna, Sweden
Result comparison with prior experiments SoRGE and CLEAR	Finished, May/June 2012	Kiruna, Sweden

Conducting an X-ray inspection of the solder joints has resulted in data of void fractions and inspection of the quality of the joints. This information can be seen in 7.3 Results and has been used in comparisons with other studies on the same topic.

When the payload was retrieved, a thorough physical investigation of the payload took place. The main objective of this investigation was to confirm that all parts of the payload were still intact, indicating that the hardware part of the experiment functioned as it was supposed to.

With the data from the sensors placed in the two chambers of the experiment, information regarding the pressure and temperature levels has shown that the experiment operated successfully during the flight. This data can be compared to the results from the X-ray inspection to give an idea of the effect of pressure and temperature on the quality of the solder joints.

A comparison of the SOLAR experiment results and the NASA projects SoRGE and CLEAR has partly resulted in some initial conclusions about the validity of the method used in the SOLAR project for soldering. A comparison between the void fractions of the corresponding solder sample in each chamber has been done to reach a concusion wether the thesis about better samples in vacuum was correct.

The x-ray scanner is a Feinfocus FXS-160.23 and scans in two dimensions.

From the scanner, images like Figure 63 were acquired. From the figure a void count was found using the software Image-J. The software counted the pixels containing voids and the pixels of “pure” soldering iron by looking at different shades of grey.

By dividing the number of void pixels with the number of pixels in total, a number describing the quality of the solder joint was found.

R= void fraction in solder

P_{voids}= Number of pixels containing voids

P_{total}= Number of pixels in total in solder

$$R = \frac{P_{voids}}{P_{total}} \quad (1)$$

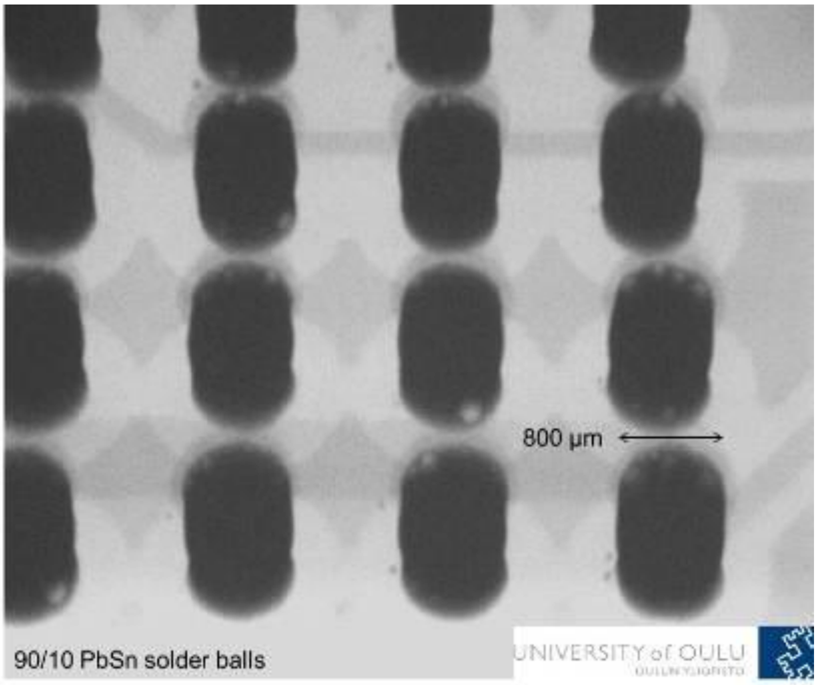


Figure 63 – Figure illustrating an image from the x-ray scanner that is intended to use.

This method was used for each soldering sample in each chamber. The number R was then used to compare the different soldering methods to determine how the proposed solution affected the soldering process. Each sample was expected to contain approximatley 42.41 mg solder which allows the scanner to perform accurate images.

7.2 Launch Campaign

In the launch preparations at ESRANGE the checklists and procedures worked well. There where certain issues with the interface between the OBDH and groundstation. The problem eventually was concluded to be a driver for the UART to serial converter. A procedure was set up to face this problem as well as a backup converter.

The launch campaign can be considered successful. The experiment worked as expected considering melting of all six samples and accurate data recordings from all sensors. The only non nominal occurance was loss of downlink from the rocket after ca T+400s which happened due to the rocket loosing altitude more rapidly than expected when the deployment of the main parachute malfunctioned.

Surprisingly the pressure in the pressurized chamber maintained at a steady level and increased ca 5% from the pressure at ground level. This pressure was expected to drop a maximum of 10% but due to a good sealing and heating from the friction between the air and the rocket skin the pressure increased which can be regarded as having a positive impact on the data due to a larger pressure difference between the chambers.

7.3 Results

Retrieving the samples post flight, the specimens were subjected to a visual inspection which confirmed that none of the samples were damaged at impact and that all the solder had been melted in flight. They were then taken to the Kemi-Tornio University of Applied Science to be analysed with microscope and X-ray scans. Microscopic images were only taken for sample 2 in each test scenario. The resulting images can be seen in Figure 64. To investigate the voids X-ray scans were done individually for each of the twelve samples. The internal images produced could then be used to estimate the void population.

In order to calculate the void fraction in each specimen the software ImageJ was used to determine for each pixel if it belongs to a void or not. This is then compared to the total area of the void which finally yields an estimate of the void to solder ratio. The result can be seen in Table 48.

Table 48 - Void to solder ratio

Sample ID	**1**	**2**	**3**	Average
1G, 1 Bar	3.2%	2.4%	0.9%	2.2%
1G, 5µ Bar	3.6%	0%	0.3%	1.3%
mG, 1 Bar	0.9%	4.6%	0.2%	1.9%
mG, 10µ Bar	16.4%	4.8%	11.9%	11.0%

Please see 8.2Appendix I for more detailed reagarding the results.

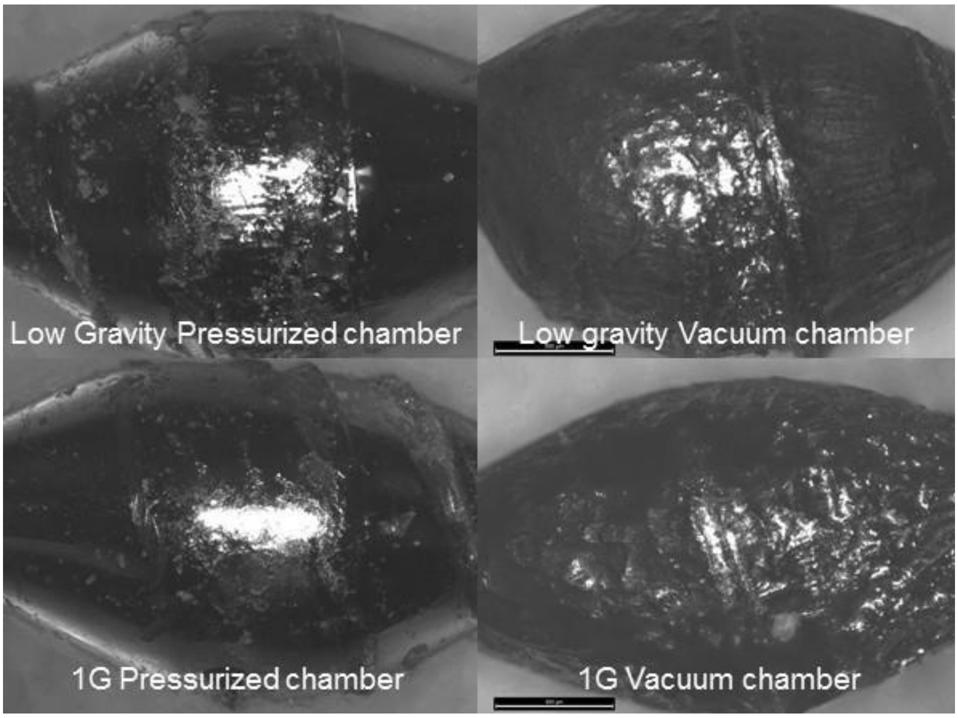


Figure 64 - Microscope Images of selcted samples

7.4 Discussion and Conclusions

7.4.1 Evaluation of the Electrical System

Microcontroller System

The main function of the electronics system was to enable data handling in the experiment and the heart of the experiment and data handling is the microcontroller. The chosen Atmel328 8-bit performed well and was easy to handle. We could have had use for a few more analogue input pins, but this was easily solved by using a simple multiplexer which also worked well and never gave rise to any problems. However, early in the testing period it was discovered that there could be current leakage from one nearby pin to another resulting in, for example, that we could not have LO connected to the pin besides the voltage supply pin. This was solved by some careful planning of the pin configuration.

Voltage Regulation

The 28 V from the RXSM was regulated to defined levels by the power circuits containing the DC/DC converters from TRACO POWER and filters. These configurations worked very well as we never detected any power drops, current spikes or irregularities in the power supply of the components. The DC/DC converters was very easy and handy to use, and most of all very reliable. A potential fault however is that the body of the component is very large compared to the pin size, making it quite unstable on the PCB after soldering. We solved this by fastening the components to the PCB using silicon based glue.

RXSM Interface and Data Related Components

Not much to evaluate in this part other than that basic predefined components were used and that they performed as expected. We never experienced any loss of signals and we had sufficient filters and safety components for our experiment to never be a danger to the RXSM. If any problems would have been experienced then a source of error could have been that the data related components were all surface mounted which made it harder to make good hand soldering. Also to solder signal cables to D-subs with solder cups always makes for a potential error source as a cable or solder joint can break under too much stress.

Data Storage

The data storage with the Micro-SD card was the big problem child in the later part of the project. Already in the design part there were problems with finding information about implementation and connections regarding SD card, power supply, MAX3378 and microcontroller. The next problem was the soldering. The MAX3378 is a surface mounted component with very small pins tightly together. We had to ask for professional help to make the circuit work and conduct as supposed to. After that the data storage circuit worked as it was supposed to, but the problems continued with software issues. In the end at the launch everything worked very well, and we got all the data stored on the Micro-SD as well as received by downlink. In retrospect we would have wanted a lot more information about implementation.

Sensors

The temperature sensors performed very well throughout the whole project, and we are satisfied with the results presented after the flight. They were very basic and simple to use which was a major benefit and relief in the beginning of the project when we were struggling with many other things. The only less good thing about it was that the temperature range in the readout table was a bit too big, resulting in some extra calibrations to make sure you know the right temperature at the specific resistance.

The pressure sensors had to be changed a number of times until we found a sensor that could operate in those specific pressures and that was not too expensive. The sensor we ended up with was very good, and we are very satisfied with the results during the launch.

The sensor PCBs in the chambers were handmade and soldered by ourselves resulting in a less than professional look but the functionality was indisputable as we never had any loss of data during testing and flight due to faulty sensor PCBs.

Switches

We used a total of 6 switches in the experiment. Two were used for ensuring the experiment were completely dead when no power from the RXSM was received. Two were used for the battery voltage level monitoring system and the last two were used to switch the power on to the resistance wires. We are very satisfied with the operation of the chosen switch. The high performance level ensured that there were no significant power losses and that they were very reliable. This was also the simplest possible solution, making it perfect for our design.

Downscaling Resistors

Also in the case of downscaling the voltage from the battery packs to the resistance wires we went for the simplest solution using 5 resistors in parallel for each chamber. The good thing about this design is that we had no possible single-point failures, if one resistor would have broken, the resistance wires would still have received a current. However in this case that current would not have been the right level, that is the temperature in the resistance wires might have been too high, destroying the samples. To prevent this power resistors with high maximum effect were chosen. This of course meant they took up quite some space on the main PCB, but it also made them robust.

In the early testing stage we had some problems with the power resistors running hot and thereby unnecessary power losses to heat. This was also solved by using resistors with high maximum effect and using more resistors in parallel. 5 resistors in parallel turned out to be the perfect number. After seeing differences in melting time of vacuum soldering and pressurized soldering we chose to use a higher downscaling level for the vacuum chamber, resulting an all samples melting at approximately the same time. After visual inspection and inspection of data after flight we can confirm that this seems to be the case. So we are overall very satisfied with the operation of the downscaling resistors.

In retrospect the downscaling could have been solved with shifting regulators and PWM modulation but at the time of design our knowledge of how to pull this off was simply not enough.

Resistance Wires

We have been very satisfied with the NiChrome wires that we used throughout the project. They were very cheap, very strong and were able to withstand very high temperatures. Most of all we were able to reach a specific temperature and keep it there by applying a specific voltage. The ability to spread heat by conduction was also vital for our project. The extremely fast heating and cooling is in itself very impressive.

Throughout the design phase it took a lot of time to reach the perfect layout, length of wires and voltage level required to reach the predetermined temperature. But since this was achieved the results has been better than expected as there always are some variables. Since all samples melted during flight and were visually good, the resistance wires certainly did a good job and we are very satisfied with this simple and reliable solution.

Main PCBs

Two six layer PCBs were used in the electronics box. We designed them with different applications on the different layers, that is, ground layer, analogue layer, 5 V layer etc. The connections between the main PCBs were then made by pin and socket headers. There were a lot of problems with this at first before we found pin and socket headers of good quality that did not have a too loose fit, that is that we did not get signal losses. But after this was achieved we never had any problems with the connection between the PCBs other than they were a bit tricky to pull apart at the disassembly of the electronics box.

Another problem that we had and a minor setback was that we trusted to much in the auto-routing function in the PCB design program resulting in the first set of PCBs being faulty. This was quite easily repaired but as we did not dare to fly PCBs with too many modifications we ordered new PCBs that worked very well and became our flight version.

One thing that in retrospect was not so good regarding design was all the splicing of cables directly onto the PCBs. We did not have any choice because of lack of space, and in retrospect it worked well. But at the assembly and disassembly of the electronics box we had to be pretty rough with the cables to get the PCBs into place resulting in great stress on the solder joints and cable ends. Nothing ever broke because the solder joints of the large cables were very robust but you all the same got the feeling every time you were bending and pulling a cable attached to the PCB that this is not good. We would definitely have wanted a better solution for this if we had the possibility, but as it were now it worked quite nice, and we actually had redundancy of an extra power cable to the resistance wire because we knew the risk.

Cables and Connectors

The cables used for data were just ordinary signal cables. They performed as expected, and thereby there is no need of evaluating them further than that. The PTFE insulation cable used for the powering of the resistance wires and connection to the battery pack had a size of AWG 12 which is coarser than we needed but we did not want any power losses due to heating or any risk of failure due to power overload. The big gauge also contributed to a high stiffness in the cables which is good because they did not move around as much during launch, creating less stress on the solder joints. Overall we are very satisfied with the operation of all the cabling. No cabling had sustained any damage after flight as well.

In the case of RXSM interface a common D-sub 15 was used but the rest of the D-subs were of a hybrid type with usual signal pins as well as with substantial high power pins that could operate up to 20 A. In the end we were not anywhere near these limits but it was better to be safe. This was hybrid D-subs that we could create ourselves very easy and cheap in relation the finished versions on the market.

All D-subs in the experiment performed as expected and we are fully satisfied with the result.

Battery Packs

We ended up using two Ni-MH packs each containing 3 cells with a nominal voltage of 3.6 V and a typical capacity of 4.2 Ah. This turned out to be a bit overkill as we could have run the experiment a couple of hundred times and still have enough power to run it again. But we do not see this as a bad thing as this way we ensured that the battery packs would not have discharged too much even if it had been colder outside. And we actually almost never had to charge the packs which of course is a benefit. At post flight review of data we could see that the battery packs were still almost fully charged which must be a good rating. We are very satisfied with the performance of the battery packs and consider the money spent on them as some of the most well spent in the project.

General Conclusions

Already at integration week and at bench test we got the feeling that we had built a very solid and robust electrical system that always seemed to work regardless of shaking, travels, impacts and necessary roughness at assembly. At post flight we can only confirm that we were totally right. Not only did the system work exactly as we wanted it to (even better in some instances) during flight, it also survived a crash at 32 m/s, continued recording data, and after recovery and disassemble we plugged it in and it still worked perfectly. Our general perception in the electronics group is that we did certainly not build the most good looking electrical system, but we did build the best working and most reliable system.

7.4.2 Evaluation of the Mechanical System

Chambers

The design of the chambers was decided early in the project design phase. The design was simple and easy to manufacture. From simulations, and later on tests and launch, the chambers were proven to be robust and tolerant to the impact with the ground after descend. What could have been improved was the mass of each base of the chambers. They were practically solid which could have been hollowed out enough to keep its stability. It was also discussed if the hat of the vacuum chamber was necessary, and it was decided to keep it due to how the impact would affect the samples. According to the results of the launch, it might have been possible to remove the hat and achieve the same result. The attachments of the two PCB's on the base worked very good and experienced no problems.

O-ring and silicone insulation

To seal the gap between the base and the hat for the pressurized chamber an o-ring was used. This solution was easy to work with during tests and the campaign and it worked well.

The silicon insulation was used to seal the space between the cables going into the pressurized chamber through the cable-track in the base. When using this solution it is hard to know if there are any cracks in the silicon insulation, even after a thorough inspection one could not be entirely sure about how good the sealing was but during the campaign there were no problems with the insulation, this meant that we had to use a lot more silicon that maybe was necessary.

During the campaign the pressure in the chamber stayed in the approved values, so the insulation for the chamber worked as intended.

Soldering method

From a design point of view the soldering method used was very simple, and thus we chose that method. The method is easy to prepare and control, which gave constant results during tests and launch. Scientifically speaking the method could have been improved to resemble a real soldering process. This would require more time and probably more sponsors, but the method would be more accurate compared to a soldering process done on Earth. This is something that would be interesting to look further into in the future.

Battery housing

The functions of the battery housing were to keep the batteries in place and keep them inside their temperature range. No major problems occurred with the housing and it was an easy part to work with during the campaign and it functioned as it should. In the end the housing was just needed to keep the batteries in place during the launch, this could have easily been made by using a couple of brackets to reduce weight and costs.

Electronics box

The electronics box was the part that we had to compromise most with. The chambers size was determined at a very early stage and the size of the batteries and housing could not be modified. This led to the fact that we had to customize the size of the box to the size left on the bulkhead. This size limitation and the requirements in strength and stability made it to a tricky but still a fully functional part of the experiment. A COTS box was chosen that could fit on the bulkhead. To gain as much space as possible we manufactured our own angle braces for the attachment and the size of the PCBs was designed to precisely fit the box. From the chambers, battery housing and the RXSM we had four D-SUB contacts that we had to lead through the box. This was solved with extra holes in the side walls and the D-SUB holder, which worked as a hub for the electronics outside the electronics box.

The equal size of the PCBs and the electronics box and the high walls needed on the electronics box in order to separate the cards made the assembly of the box very tricky. At the beginning the solution felt disproportionate and the fact that we had to disassemble and assemble the box quite fast in case of component failures seemed nearly impossible. But with training we became faster and found better solutions and clever workarounds. For example we replaced the initial stabilization rod below the upper PCB with an ordinary spacer. At the end, both the disassembly and assembly went quite fast without any problems.

What we could have done better would be to start with the design of the electronics box at an earlier stage. As it were, we let the other parts determine its size which clearly was not the best way to do it. The side holes for the D-SUB cable fed out to the D-SUB holder could most likely have been enlarged which would have eased the assembly since the cables were very stiff, but due to lack of time we did not have the chance to enlarge them and still prove the strength. Perhaps it would have even been possible to extend those holes up to the edge of the box, which would have simplified the assembly considerably. Another approach could have been to manufacture an electronics box all by our own to gain ever more space, but due to our inexperience we felt more confident using and modifying a COTS box. A possible design would have been something similar, but instead of attaching the cards and contacts on the bottom of the box and then fasten the lid, it would probably have been much easier to attach everything on a lid-shaped structure and then fasten the protecting box structure, i.e. performing the assembly in the reverse order.

Overall we are satisfied with the design, since we had room for all cables and components, could assemble it in a not too long time and because it did its job very well.

Tests

The tests that were made on the system were, a vacuum test to try the pressurised chamber, thermal test to see how well the batteries would hold up against the cold and a vibration test to try the structural strength of the experiment. Each of these tests gave good results and proved to be very accurate to the real launch. The pressure inside the pressurised chamber proved to be even better during the launch than the tests we made; it resulted in an increase in pressure which probably was due to heating from the resistance wires.

Due to the warm weather during May there were no problem with the batteries discharging and all the structures were proven to be intact even though there was a rough impact for the rocket when it landed.

7.4.3 Evaluation of the Software

On-board Data Handling

The first plan when deciding which MCU to use was to buy a complete header board to save time. This idea was discarded in favour of integrate a microcontroller onto the main PCB. This gave us more flexibility to adapt the system for our needs and it also reduced the space required for the electronics. The software used was developed by the MCU manufacturer which made it smooth to work with.

The SD-card turned out to be the main issue with the system due to its complexity. By using standard libraries it was possible to create a working system without having to code everything from scratch.

The emergency backup system was dependent on the SD-card and we therefore also experienced some problems when implementing that system. Since the system was more of a precaution than a necessity and the launch went as expected, in the end it was not needed. One bug was found post launch which meant that if the system had been restarted after lift off, the experiment would have been reset to unarmed.

Ground Station

The groundstation initially had some problems communicating with the experiment due to lots of checksum errors, this was later solved which greatly eased the development of the software for the experiment since we would get feedback of what we just implemented was working.

The groundstation contained a bug which was discovered and fixed two days before launch. The buffer for holding recieved data never cleared itself when recieving trash data before launch, which eventually led to a buffer overflow.

The main issue with the groundstation was always the communication with the experiment, especially sending commands. This was mostly solved after a rewrite of the recieve code on the MCU.

7.5 Lessons Learned

7.5.1 Electronics group

The project has been very educational, not only in the field of science and technology but also about project management and documentation. All of us can are proud and happy about their contribution and participation leading to a successful result. We knew that we would need to put down a lot of hours in the project but we were maybe not fully prepared for the challenge. In the beginning we had to make re-designs every other day, and we were failing more often than not. But we overcame problems by troubleshooting and discussing solutions and after a rough start we really think that we learned a lot when it comes to team work and project work. We found a working system for how to communicate within the group by having weekly meetings, both with the entire group but also with just the group leaders. We also learned the very important reason for having a thorough time plan. So despite the problems in the beginning, we managed to design and build a working system which we think is the result of hard work and tons of learning throughout the project.

It has been extremely fun, and sometimes very hard work and not as motivating but throughout both good and bad at has always been very educational. We have learned a lot about the full circle of a space related project, and more specifically for the electronics group about electronics and design of PCBs. We have learned how to choose components that will be able to operate in space and how to correctly solder for space application. Through mistakes made we have also learned how to make repairs on existing PCBs. To be able to meet and work with experts in the field has also been a very good experience and can hopefully lead to collaborations in the future.

Practically we have learned that it is easier to use through hole packages for components with regard to the soldering process. We have learned quite well how to use the program Eagle to design schematics and then PCBs but we have also learned to always double check everything that a programs auto function does for you, it can save you a lot of money.

A thing that we definitely have learned is that if your university does not have experience of having students involved in REXUS then you have to push them to agree to rules and guidelines at an early stage. For us this unfortunately did not work well at all. We had great problems reaching our funds and to get access to labs and equipment based on the responsible people at the university not understanding the process of a REXUS campaign. So we have learned that it is not worth spending time and energy on arguing, move on to the next person that can help you instead.

7.5.2 Mechanical group

With our participation in REXUS we have gained great experience in many different and important areas. The most valuable experience have been to work in a large group with several documentation and deadlines which we are sure of that we will continue to do in the future as well and to design and build an own experiment totally from scratch. Besides from working with groups of people and documentation we have had a lot of practical experience and hands on testing and manufacturing, learning how to use CAD programs to create a model of the experiment, do a lot of different analyzes like FEM and modal. Another valuable experience has been to work close to companies for consultancy regarding design, materials etc, giving us a broader perspective of what is a good solution.

For us in the mechanics, to build parts of the experiment have improved our understanding of the progress, difficulties and problems that are most likely to occur during a problem like this, cause some things are easy to depict and draw on paper or in a CAD program but problems may occur at the smallest thing. An important lesson that we all will take with us is probably that it is important to try and make a quick prototype to see what is flawed and need improvement, because one does not simply produce a perfect result on the first try.

7.5.3 Software group

Since most of the group had little or no experience in programing this has been a great opportunity to get some knowledge in the area. Most of the code has been developed by getting inspiration from other projects found on the internet, but of course adapted to our own needs. Our lack of knowledge was the main reason why we experienced so much trouble with the implementation of the SD-card. This resulted in some corrupt and even destroyed SD-cards, but in the end we learned by our mistakes and developed a working system.

Of course we had our share of bugs and in the future we will start with a more structured system already at the beginning. Since the SD-card so much time the experiment had been sent away before the emergency system was fully developed, and therefore we could not do a full test. These tests may have prevented the arm/disarm bug described in 7.4.3 Evaluation of the Software.

Initial development on the MCU was slow since it was hard to test if it was working, having access to a groundstation earlier which we could communicate through would have eased the development alot.

8 ABBREVIATIONS AND REFERENCES

8.1 Abbreviations

This section contains a list of all abbreviations used in the document.

A/D	Analogue/Digital
ADC	Analogue/Digital Converter
AIT	Assembly, Integration and Test
ASAP	as soon as possible
AWG	American Wire Gauge
BEXUS	Balloon-borne Experiments for University Students
BO	Bonn, DLR, German Space Agency
BR	Bremen, DLR Institute of Space Systems
CDR	Critical Design Review
COG	Centre of gravity
COTS	Components Of The Shelf
CPS	Component
CRP	Campaign Requirement Plan
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EAT	Experiment Acceptance Test
EAR	Experiment Acceptance Review
ECS	Experiment Control System
ECTS	European Credit Transfer System
EGS	Esrange Ground Station
EIT	Electrical Interface Test
EL	Electronics
EPM	Esrange Project Manager
ESA	European Space Agency
ESRANGE	Esrange Space Centre
ESTEC	European Space Research and Technology Centre, ESA (NL)
ESW	Experiment Selection Workshop
FAR	Flight Acceptance Review
FST	Flight Simulation Test
FRP	Flight Requirement Plan
FRR	Flight Readiness Review
GCC	Gnu Compiler Collection
GSE	Ground Support Equipment
HK	House Keeping
H/W	Hardware

ICD	Interface Control Document
IDE	Integrated Development Environment
I/F	Interface
IPR	Interim Progress Review
IRF	Swedish Institute of Space Physics
IST	Inner structure
kbps	Kilobits per second
LED	Light Emitting Diode
LO	Lift-off
LT	Local Time
LTU	Luleå University of Technology
LOS	Line of sight
Mbps	Megabits per second
MCU	Microcontroller
MFH	Mission Flight Handbook
MORABA	Mobile Raketen Basis (DLR, EuroLaunch)
OBDH	Onboard data handling
OP	Oberpfaffenhofen, DLR Center
OpenOCD	Open On-chip Debugger
ORG	Organization
OST	Outer structure
PCB	Printed Circuit Board (electronic card)
PD	Power Distribution
PDB	Power Distribution (subgroup)
PDS	Power Distribution System
PDR	Preliminary Design Review
PST	Payload System Test
PTFE	Polytetrafluoro Ethylene
REXUS	Rocket-borne Experiments for University Students
RXSM	Rexus Service Module
SD	Secure Digital
SED	Student Experiment Documentation
SGS	SOLAR Ground Station
SKF	Svenska KullagerFabriken
SNSB	Swedish National Space Board
SODS	Start Of Data Storage
SOE	Start Of Experiment
SOLAR	Soldering Alloys in Reduced gravity

SRT	Department of Computer Science, Electrical and Space Engineering
STW	Student Training Week
SVN	Subversion
SW	Software
S/W	Software
T	Time before and after launch noted with + or -
TBC	To be confirmed
TBD	To be determined
TBO	To be ordered
UART	Universal Asynchronous Receiver/Transmitter
WBS	Work Breakdown Structure

8.2 References

(Books, Paper, Proceedings)

[1] EuroLaunch: **REXUS User Manual** (2011)

[2] European Cooperation for Space Standardization ECSS: Space Project Management, **Project Planning and Implementation**, ECSS-M-ST-10C Rev.1, 6 March 2009

[3] SSC Esrange: **Esrange Safety Manual**, EU A00-E538 , 20 March 2006

[4] European Cooperation for Space Standardization ECSS: Space Engineering, **Technical Requirements Specification**, ECSS-E-ST-10-06C, 6 March 2009

[5] European Cooperation for Space Standardization ECSS, Space Project Management, **Risk Management**, ECSS-M-ST-80C, 31 July 2008

[6] European Cooperation for Space Standardization ECSS: Space Engineering, **Verification**, ECSS-E-ST-10-02C, 6 March 2009

[7] Project Management Institute, **Practice Standard for Work Breakdown Structures – second Edition**, Project Management Institute, Pennsylvania, USA, 2006

[8] European Preferred Parts List, Issue: 19, 14 December 2011

[9] NASA: **Soldering in a Reduced Gravity Environment (SoRGE)**, January 2012

[10] NASA: **New Methods for Repairing Space Equipment Enhance Astronaut Safety**, Retrieved April 28 2012 from http://microgravity.grc.nasa.gov/print/clear_prt.htm

Appendix A – EXPERIMENT REVIEWS

Preliminary Design Review - PDR

Date: Wed 29 Feb, 2012

Location: Esrange, Kiruna, Sweden

Participants: Anders Svedevall

Björn Paulström

Adrian Lindqvist

Martin Eriksson

Björn Sjödahl

Robert Lindberg

Main recommendations:

The review board called for a more concise description of the experiment procedure. Brass or Teflon coated railings actuated by a linear actuator or a stepped motor were recommended instead of the spring/roller bearing set-up. Also more simulations in form of FE, modal, and thermal analysis were requested. Some concerns were raised regarding the safety of the argon gas cartridge and the effect consumption of the heating elements. Finally it was pointed out that the soldering temperature for the samples already should have been tested and therefore this should be done as soon as possible.

The official Experiment Preliminary Design Review report is attached.

Critical Design Review - CDR

Date: Wed 4 July, 2012

Location: DLR, Oberpfaffenhofen, Germany

Participants: Anders Svedevall

Björn Paulström

Emil Vincent

Maja Nylén

Main recommendations:

The review board thought the mechanics design and the organisation, project planning & outreach parts had well improved since the PDR. However, a more continuous update of the website and overall outreach was requested. Concerns were raised regarding the accessibility to the D-SUB connector after assembly and the dangers of charging the batteries at the last bench test. Most prominen recommendation was for the experiment design to be tested in reduced pressure to ensure the concept of heating wires for solder works at all in reduced pressure.

The official Critical Preliminary Design Review report is attached.

Integration Progress Review - IPR

Date: Thu 27 September, 2012

Location: IRV, Kiruna, Sweden

Participants: Anders Svedevall
SOLAR Team

Main recommendations:

The overview presentation was good and the review board were pleased that the team had solved previous issues from the CDR comments. There were some problems with the UART communication which should be addressed as soon as possible. An implementation of an arm signal or similar is also of vital importance during flight testing. To further improve the scientific result, a solder preparation process should be documented. Lastly the on-board data handling should be finalized so that all subsystems can go into a testing phase.

The official Integration Progress Review report is attached.

Appendix B – OUTREACH AND MEDIA COVERAGE

Listed below are Project SOLAR´s media coverage and outreach actions so far:

- Project SOLAR has created an official homepage accessible at:
  http://solar.rymdteknik.com/

- Project SOLAR has created a blog accessible at:
  http://solar-rexus.blogspot.com

- Project SOLAR has an official Facebook page accessible at:
  http://www.facebook.com/#!/pages/Project-SOLAR/151880708257109

- Project SOLAR is active on Twitter at:
  https://twitter.com/SOLARrexus

- An article regarding the Master Programme in Space Engineering at Luleå University of Technology mentioning Project SOLAR has been published in Blekinge läns tidning (publish date: 2011-12-27)
  accessible at the homepage of Project SOLAR:
  http://solar.rymdteknik.com/?page_id=52

- An article about Project SOLAR has been published at the front page of Luleå University of Technology´s website (publish date: 2012-01-26) accessible at:
  http://www.ltu.se/ltu/media/Studentforslag-far-testas-skarpt-i-rymden-1.88148

- An article about Project SOLAR has been published by Piteå-Tidningen (Publish date: 2012-01-26) accessible at:
  http://www.pitea-tidningen.se/nyheter/telegram/artikel.aspx?ArticleId=6676480

- An article about Project SOLAR has been published by Norrländska Socialdemokraten (NSD) (Publish date: 2012-01-27) accessible at:
  http://www.nsd.se/nyheter/artikel.aspx?ArticleId=6679154

- A blog post about Project SOLAR has been published at the blog of Rymdkanalen (Publish date: 2012-02-17) accessible at:
  http://www.rymdkanalen.se/blogg/2012/2/tva-svenska-studentexperiment-utvalda-for-rexus-1314

- An article about Project SOLAR has been published by Ny Teknik (Publish date: 2012-02-29) accessible at:
  http://www.nyteknik.se/nyheter/fordon_motor/rymden/article3418635.ece

- Article about project SOLAR published in *Norran*, 2012-09-21 accessible at: http://solar.rymdteknik.com/wp-content/uploads/2012/01/viewer.png

- A blog post about Project SOLAR has been published at the blog of Rymdkanalen (Publish date: 2012-09-25) accessible at: http://www.rymdkanalen.se/blogg/2012/9/experiment-pa-rexusbexus

Appendix C – ADDITIONAL TECHNICAL INFORMATION

[C1] Pressure sensor – XFHMC-200KPGR(H)

[C2] Temperature sensor - KTY84-150

[C3] Microcontroller - STM32-H107 development board

[C5] Battery - VHT CS 3200

[C6] Switch - IPU039N03L

[C7] Loctite 270 - 270 10 ML

[C8] Silicone Adhesive – TSE397

[C10] PC3H7 Series Optocoupler

[C12] DC/DC Converter Series TSR 1-24

[C13] Tranciever MAX1487-MAX491

[C14] SRF0905 Series Line Filter 251Y

[C15] Level Converter MAX3372E-MAX3393E

[C25] Power resistor MCKNP05SJ012JAA9

C[26] Soldering wire, hazards

Appendix D – FINANCES

[D1] SOLAR Budget v 3.0

[D2] Component List v 3.0

Appendix E – WORK BREAKDOWN STRUCTURE/GANTT

[E1.W] WBS Electronics

[E1.G] Gantt Chart Electronics

[E2.W] WBS Software

[E2.G] Gantt Chart Software

[E3.W] WBS Mechanics

[E3.G] Gantt Chart Mechanics

Appendix F – DRAWINGS

[F1] Main wiring diagram

[F2] drawing_chamber base_v2

[F3] drawing_vacuum hat_v2

[F4] drawing_pressurized hat_v2

[F5] drawing_electronic pcb_v3

[F6] drawing_electronic box_v3

[F7] drawing_bulkhead_dlr_SOLAR

[F8] drawing_battery case_v3

[F9] drawing_copper plate_v2

Appendix G - PROCEDURES AND CHECKLISTS

[G.S.1] Experiment Test

[G.S.2] Pre flight setup

[G.S.3] Computer crash

[G.S.4] Post flight procedure

[G.E.1]samples_preparation

[G.M.1]solering_pcb_preparation

[G.M.2] Assembly of bulk head

[G.M.3] Procedure_soldering PCBswop

[G.M.4]Copper plates_manuf

[G.M.5]sensor_pcb_preparation

[G.M.6]Battery insulation and assembly

[G.M.7] Assembly of the vacuum chamber

[G.M.8] Assembly of the pressurized chamber

[G.M.9] Assembly of a complete soldering PCB with all fixings

[G.M.10]Attachment of electronic contacts

[G.M.11] Procedure_assembly electronicsbox

Checklists

[G.S.CL.1] Item list

[G.E.CL.1]Launch campaign recharging of batteries

[G.E.CL.2]Launch campaign functional test on main PCBs

[G.E.CL.3]Launch campaign inspection of solder station

[G.E.CL.4]Launch campaign Safety interlock

[G.E.CL.5]Launch campaign Test batteries

[G.E.CL.6]Launch campaign Test system

[G.E.CL.7]Pre-flight inspection and qualification of all wiring

[G.E.CL.8]Pre-flight inspection and qualification of all connectors

[G.E.CL.9]Pre-flight inspection and qualification of main PCBs

[G.E.CL.10]Pre-flight Connect batteries

[G.E.CL.11]Post flight Detach electronics

[G.E.CL.12]Post flight Review and analyse damage of equipment

[G.E.CL.13]Post flight Analyse voltage of battery pack

[G.E.CL.14]Emergencyfailure Samples melts before flight

[G.E.CL.15]Emergencyfailure Battery discharges

[G.E.CL.16]To bring to launch campaign

[G.E.CL.17]Contents of box of components

[G.E.CL.18]To bring to the launch from LTU equipment

[G.M.CL.1]Pre-flight inspection of the payload's structures and parts

[G.M.CL.2] Pre-flight inspection of the payloadads structures and parts

[G.M.CL.3] Pre-flight inventory list of tools

[G.M.CL.4] Pre-flight inspection of new screws, washers, nuts and spacers to use during flight

[G.M.CL.5] Pre-flight inspection of extra screws, washers, nuts and spacers in case of damage or loss

[G.M.CL.6] Pre-flight inspection of spare parts and consumables

[G.M.CL.8] Pre-flight final assembly of payload before flight

[G.M.CL.9] Post-flight disassembly of the experiment from the bulkhead

[G.M.CL.10]Post-flight inspection of the payload's structures and parts

[G.M.CL.11] Post-flight inspection of the soldering and storing the samples

[G.M.CL.12] Post-flight inspection of the payload structures and parts

[G.M.CL.13] Post-flight inventory list of tools

[G.M.CL.14] Post-flight inspection of spare parts and consumables

Appendix H – TEST

[H.OST1](step1)2012-10-16

[H.OST1](step2)2012-10-16

[H.OST2]2012-10-16

[H.OST2]2012-10-27

[H.OST2]2012-11-19

[H.OST5]2012-11-17

[H.CPS3]2012-11-08

[H.CPS4]2012-09-22

[H.CPS5]20012-11-10

[H.CPS6]2012-04-23

[H.CPS7]2012-09-18

[H.CPS8]2012-04-24

[H.OBDH1]2012-08-20

[H.OBDH1_Complementary]2013-02-11

[H.OBDH2]2012-09-28

[H.OBDH3]2012-10-02

[H.OBDH4]2013-02-05

[H.SGS1]2013-04-13

[H.PDS1]2012-09-15

[H.PDS2]2012-09-19

[H.PDS3]2012-08-29

[H.PDS4]2012-09-18

[H.PDS5]2012-09-14

[H.PDS6]2012-09-15

Appendix I – RESULT

[I1] – solar_pac__svedevall_2013-07-15

APPENDIX A

Experiment Reviews

REXUS/BEXUS

Experiment Preliminary Design Review

Flight:	REXUS 14		
Payload Manager:	Mikael Inga		
Experiment:	SOLAR		
Location:	Esrange, Kiruna, Sweden	**Date:**	Wed 29 Feb, 2012

1. Review Board members

Hans Henriksson	SSC Esrange
Mikael Inga	SSC Solna
Mark Fittock	DLR Bremen
Martin Siegl	DLR Bremen
Nils Hoegr	DLR MORABA
Markus Pinzer	DLR MORABA
Koen de Beule	ESA Technical Directorate (Chair)
Natacha Callens	ESA Education Office
Paul Stevens	ESA Education Office (Minutes)

2. Experiment Team members

Anders Svedevall
Björn Paulström
Adrian Lindqvist
Martin Eriksson
Björn Sjödahl
Robert Lindberg

3. General Comments

- SED
    - The document was generally well presented and formatted, however it was noted that the SED was light on technical detail; most notably in the Mechanical, Electrical and Thermal design chapters.
    - The experiment description was unclear, and the SED would have benefited from a more concise explanation of the operational procedure. The slide in your presentation, outlining the step-by-step procedure, provided clarity on this issue and would have been a welcome addition to the SED.
    - Any additional material or information referenced within the main body of the SED, should be included in the Appendices of the document.
    - Chapters 6 and 7 will require elaboration prior to submission of SED v1-2.

- Presentation
    - The presentation was generally well delivered, with good timing. It was clear and concise, and clarified several sections of the SED, most notably the experiment procedure.
    - The team engaged well with their audience, although it was noted that the time allocated to each speaker could have been more evenly distributed.

4. Panel Comments and Recommendations

- Requirements and constraints (SED chapter 2)
  - The requirements need further elaboration in general, especially with regard to the design and operational requirements.
  - Please take care when defining your requirements, as some classifications were redundant and confusing. When defining performance requirements, please quantify them and provide values where necessary.

- Mechanics (SED chapter 4.2.1 & 4.4)
  - **It is strongly recommended that the solder initiation system design is revised. A sample plate actuated by a linear actuator or stepper motor, guided by Brass or Teflon coated rails would be more preferable to the current spring actuated/roller bearing set-up. This approach would provide a more controllable and stable platform on which to conduct soldering, and would allow the heating elements to be statically fixed, reducing the overall complexity of the solder chambers.**
  - **It is recommended that FE and Modal analyses be performed on the structural elements of the updated experiment design. A dynamic system such as this may be sensitive to the acceleration, impact and vibration loads of the REXUS flight, so please perform these analyses as soon as possible, as it may present a requirement to further modify the design.**
  - Please provide further information on the pressure levels within the Argon canister. It is recommended that you ensure any surrounding sensors or electrical systems are robust enough to handle a pressure leakage. Test this extensively.
  - Please define the required vacuum level in non-pressurised chamber. You should pay close attention to how these vacuum levels will be maintained during flight, especially considering the cable feed-through.
  - Please define camera placements as soon as possible. Where view ports are to be used, it is recommended that you use Polycarbonate.

- Electronics and data management (SED chapter 4.2.2, 4.2.3, 4.5 & 4.7)
  - **Please elaborate on electrical interface definitions as soon as possible, and include detailed electrical schematics incorporating your updated design, in the next version of the SED.**
  - Please ensure that the Argon delivery valve cannot be prematurely activated during preparation and testing. It is recommended that safe plugs be used for this function.
  - Please pay close attention to the battery charging procedure, and incorporate easy accessibility into your design for late access purposes.
  - Please pay due attention to your battery selection. Make sure they are safe to use in the REXUS thermal/vacuum environment. It is also recommended that you familiarise yourselves with the international battery transport regulations well in advance of experiment delivery to Esrange.
  - **It is recommended that you fix your heating element design as soon as possible. How many heating elements do you require? How much power do they consume? When will they require power? All of these questions will drive your design.**
  - It is recommended that you fix your power requirements as soon as possible. Power budget will need to be fixed and elaborated once the experiment design has been updated.
  - **It was noted that the soldering temperature outlined in your requirements was 380°C. For space applications, the required soldering temperature is 308°C. When soldering at too high a temperature there is a risk of sticking, crystallisation and the formation of irregularities within the solder.**
  - **You will be required to prove that the independent soldering iron/battery system, can be isolated and shut down on request i.e. a safety interlock; especially when radio silence is required. Please test this thoroughly.**
  - The panel felt that the cables and connectors analysis described on page 62 of the SED was very good.

- Thermal (SED chapter 4.2.4 & 4.6)
  - **The thermal analysis section of the SED will need to be elaborated for the next version of**

the SED, including preliminary calculations.
  - It is recommended that you provide a table outlining the thermal ranges of individual components.

- Software (SED chapter 4.8)
  - The software system will need to defined from the top down. Please give a detailed overview of how the system will work, clearly defining which systems will have to communicate and when. The use of software flow diagrams was good in the SED. These will have to be updated and elaborated to include design updates.
  - Software should be developed so that data cannot be corrupted in the event of glitches, power cycling or hard cuts.
  - Please define any back up procedures and protocols, in case of faulty signals etc.
  - Please provide definitions for any specific software terms or acronyms used in the SED, e.g. OPENOcd.
  - There was no mention of source control from the ground in the SED. Please include this in the next version SED.
  - Please define which type of controllers will be used in the next version SED.
  - Experiment start-up procedures will have to be defined in detail.
  - Please be careful with your use of definitions, e.g. bits, bits/s etc.
  - Please specify which bandwidths you plan to use.
  - Please allow plenty of time for testing and development. Most problems stem from under developed software, so don't underestimate the amount of time and effort required for development and de-bugging.

- Verification and testing (SED chapter 5)
  - It is recommended that you group the verification matrix sections as in the requirements, to allow cross-referencing.
  - Please allow plenty of time for testing, especially considering the complexity of the experiment.
  - **The optimum soldering temperature for the samples in their specific environments should have been defined and tested by now. It is strongly recommended you do so as soon as possible, as this is a design driver.**
  - **Please test the Argon delivery valves' ability to withstand the REXUS vibration profiles. Ensure that they can't prematurely open under vibration loads.**

- Safety and risk analysis (SED chapter 3.4)
  - The FLM prefix used in the risk register is not defined prior to use. Please provide definitions of any abbreviations used.
  - It is recommended that you incorporate project planning risks into your risk register; including loss of personnel through illness, injury or withdrawal. Manufacturing and integration risks should also be included, such as damage to critical components, late delivery of materials etc. Please give as much thought as possible to all risks.
  - Please be careful with risk classification e.g. severity and likelihood. Try not to under or overestimate risks, and only include those risks that you cannot reasonably control.
  - **It is strongly recommended that you consult with the PoleCATS Team, regarding Argon venting during flight. Determine how much gas will be vented, when it will be vented and discuss any possible implications on their experiment.**

- Launch and operations (SED chapter 6)
  - Chapter 6 of the SED will have to be elaborated prior to submission of SED v1-2.

- Organisation, project planning & outreach (SED chapters 3.1, 3.2 & 3.3)
  - Please provide a more detailed version of the WBS, including individual tasks and team member delegation.
  - It is recommended that the Gantt chart/project schedule be further elaborated.
  - It is recommended that the budget is included in Word format within document. If the budget is too complex, then please provide a basic overview in the main body of text and include the complete budget in an appendix.

- The panel acknowledges that your team is well supported by your university.
- The outreach conducted to date has been very good. The panel was very impressed by your efforts and encourage you to keep it up.

- Others
    - The PCB you have selected for the experiment is fine.
    - If you decide to implement an opaque chamber design, it is recommended that you use Polycarbonate. This material is shatter resistant, strong, and has very good thermal and optical properties.

5. Internal Panel Discussion

- Summary of main actions for the experiment team
    - It is strongly recommended that you fix the design requirements and constraints as soon as possible. Particular attention needs to be paid to the mechanical design, software design and implementation, materials selection, operational procedures, and heating element/power supply requirements.
    - Review and address all discrepancy items and inconsistencies listed within this report, prior to submission of SED v1-2.

- PDR Result: pass / conditional pass / not passed

    PDR Not Passed – Please re-submit the v1 SED, within one month of receipt of this PDR Report.

- Next SED version due
    - SED v1-2

REXUS
Experiment Critical Design Review

Flight:	**REXUS 14**		
Payload Manager:	Mark Fittock,		
Experiment:	SOLAR		
Location:	DLR, Oberpfaffenhofen, Germany	**Date:**	04/07/2012

1. Review Board members

Mark Fittock	DLR Bremen
Martin Siegl	DLR Bremen
Andreas Stamminger	DLR MORABA
Tobias Ruhe	DLR MORABA
Nils Hoeger	DLR MORABA
Frank Hassenpflug	DLR MORABA
Markus Pinzer	DLR MORABA
Natacha Callens	ESA Education
Alex Kinnaird	ESA Education – minutes
Koen DeBeule	ESA Technical directorate (not in attendance)
Mikael Inga	SSC Solna - chair
Jianning Li	SSC Solna

2. Experiment Team members

Anders Svedevall	Luleå University of Technology
Maja Nylén	Luleå University of Technology
Björn Paulström	Luleå University of Technology
Emil Vincent	Luleå University of Technology

3. General Comments

- Presentation
    - There was a lack of introduction/objectives for the presentation.
    - Overall it was very clear, well done.

- SED
    - It was felt there could be some development of the objectives in section 1.2 of the document.
    - Please update the preface.
    - Please update the references section.
    - Please update the appendices (include the full PDR and CDR reports in appendix A).
    - Please include high quality schematics (increase DPI), particularly for complex electrical schematics.
    - Be careful with continuity throughout the document, there are some contradictory points from previous designs.
    - You use the old Eurolaunch logo on some pages, be sure to update this throughout the document.

- Be careful when referring to ground station or computer, in general be clear and consistent with definitions throughout the document.
- Re-consider the distribution of information between the team members section and the manpower section (read carefully what is required in the SED guidelines).
- Be careful and consistent with the units throughout the document (bar vs. 1 atm).

4. Panel Comments and Recommendations

- Requirements and constraints (SED chapter 2)
  - Please reconsider the classification of requirements (thermal design is not a functional requirement).
  - Be clear whether in MD.1 you mean gravitational or acceleration force.

- Mechanics (SED chapter 4.2.1 & 4.4)
  - Overall this section was very good with good progression from PDR.
  - You should try and include the manufacturing drawings.
  - On Page 55 you mention the old electronics box dimensions – ensure this is updated and be consistent throughout the document with design changes.
  - Consider access for screw driver/connection to the D-SUB connector after assembly. You're current design makes this quite hard.
  - There is a lack of drawings for the electronics box mounting.
  - It seems possible to have a single piece electronics box with no additional parts for mounting, please consider this design option.
  - Consider the assembly procedure in general when you're designing.
  - It's difficult to tell the dimensions of the base of the boxes. There's a possibility it has been oversized and may not fit.
  - Battery box: consider the use of more (possibly smaller) screws at the extremities.
  - **Implement helicoils, washers and Loctite in the bulkhead: make this consistent throughout the SED document.**

- Electronics and data management (SED chapter 4.2.2, 4.2.3, 4.5 & 4.7)
  - Your battery charging concept is not clear, make it clear in the document whether you require battery charging through the service module.
  - **Be aware of the dangers of charging the batteries at the last bench test and possible discharge, strongly consider including a way to monitor the state of the batteries.**
  - Provide values in the schematics for components.
  - **Filtering is not integrated in the main connection to REXUS, please include this.**
  - Look back over the PCB schematics, there is at least one floating node.
  - Look into the details of the microcontroller specifically with respect to drift in communication time/speed.
  - Be careful with your choice of MOSFET, be sure you are confident with this one.
  - Please show the filter type on the schematics.
  - Be careful with crossing wires or three way connections in schematics.

- Thermal (SED chapter 4.2.4 & 4.6)
  - Please include thermal temperature range of components.
  - Be sure to choose the perforated version of the MLI to allow for gas expulsion.

- Software (SED chapter 4.8)
  - It's not clear why you need the SOE signal, make this clear.
  - You should make it clear in the documentation how you move between your defined software stages.
  - Be careful with final power cut for data writing to the SD card and how this might affect the data stored.
  - Your data packet seems an odd size, consider use of bytes not bits.

- Verification and testing (SED chapter 5)
  - Some points are doubtful for example NB 4 mass could also be analysis.
  - Page 101, SD3 is currently verified by analysis this should be by review or test
  - Overall there has been considerable improvement from PDR, but you should keep

checking the verification method.
- **You should test as close to flight functionality as possible (with burning the solder)**.

- Safety and risk analysis (SED chapter 3.4)
  - You should include the pressure vessel issues here, this should be tested to the recommended SSC pressure difference (possibly 1.6x delta pressure – check with the organisers).
  - Your risk analysis is well updated although the risk matrix should not change, numbers should not disappear if you a delete a risk (due to a design change) then it should be marked as 'risk deleted'.

- Launch and operations (SED chapter 6)
  - Please include bulkhead and module in your mass and comment that are included.
  - Include and update the schedule for preparation activities, including outlining those people responsible.
  - Consider including pressure and temperature in the launch timeline, as it's important for your experiment.

- Organisation, project planning & outreach (SED chapters 3.1, 3.2 & 3.3)
  - Well improved since PDR.
  - Please update your website, especially the events calendar.
  - Add more pictures to the gallery for the STW, PDR, CDR and/or work.
  - Update your media outreach, you currently have nothing after 19th of February.
  - Be careful with the typos on the blog.
  - Try to increase the 'likes' on your Facebook.

- Others
  - **You should test the experiment design in a reduced pressure test to ensure the concept of heating wires for solder works at all in reduced pressure.**

<u>5. Internal Panel Discussion</u>

- Summary of main actions for the experiment team:
  - Consider the additional points for mechanical design optimisation.
  - Implement the required changes to the electrical design.
  - Clarify the software design.
  - **Test your experiment in the reduced pressure environment to prove the concept.**

- CDR Result: conditional pass
  - Based on the above comments the panel recommends a resubmission to address all the points outlined in this report. Be sure to review the guidelines and template to bring your entire document to CDR standard and include ALL the necessary information.

- Next SED version due
  - **Version 2-1** is due on the **2nd of August,** this should address all the above points.
  - **Version 3-0** will then be due around the **27th of July** (TBC).

REVIEW

Flight: RX-13

Payload Manager: Mikael Inga

Experiment: SOLAR

Review location: IRV, Kiruna, Sweden

Date: 05Sep2012

Review Panel

Mikael Inga – SSC

Alex Kinnaird - ESA

Experiment Team members

Anders Svedevall

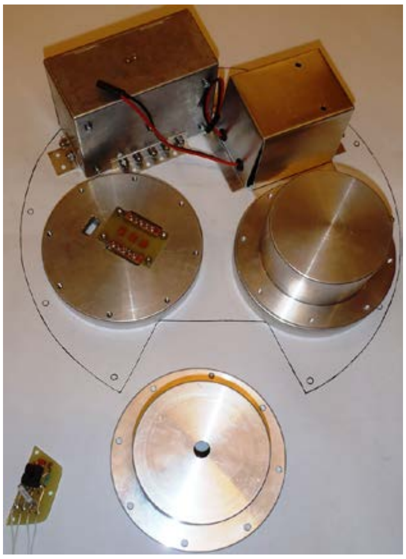
SOLAR Team

Expert support:

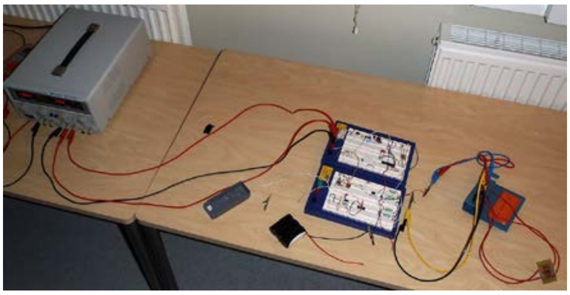
Esa Vuorinen

Kjell Lundin

PICTURES



SOLAR Components



Bench Test

GENERAL COMMENTS

- The team is very large and well turned out for the review. The overview presentation was good and took on-board a lot of the comments from the CDR.
- Hardware was well laid out for inspection.

PANEL COMMENTS AND RECOMMENDATIONS

Science

- **Procedures are needed for the preparation of soldering samples.**
  - This needs to be the result of thorough practice and testing to determine the best verifiable method for preparing the samples. The result (method) including the time and tools required should be added to the SED.

Requirements and constraints (SED chapter 2)

- No comments.

Mechanics (SED chapter 4.2.1 & 4.4)

- The majority of mechanical components have been manufactured.
- The team still have some questions around the placement of their units on the bulkhead.
- The team still have some questions about the placement of the d-sub connectors.
- The team would like their bulkhead ASAP as they require it for the full systems vibration test, which they believe can be done in house with a new test adapter.
  - Eurolaunch expected delivery for the bulkhead is mid-November.
- Vacuum/leakage test still required for the sealed chamber.

Electronics and data management (SED chapter 4.2.2, 4.2.3, 4.5 & 4.7)

- Electronics design is frozen and tested on breadboard.
- PCB will be manufactured in beginning of October.
- **Problems with communication hardware (UART).**

Thermal (SED chapter 4.2.4 & 4.6)

- Thermal insulation of test chambers not necessary.
  - This removes previous issues related to MLI.

Software (SED chapter 4.8)

- **On-board data handling software still to be developed.**

Verification and testing (SED chapter 5)

- Melting of solder tested in vacuum.

- **More melting test to be done, and procedures how to prepare samples to be produced.**

Safety and risk analysis (SED chapter 3.4)

- Qualification of pressurized test chamber still to be done.

Launch and operations (SED chapter 6)

- **The team were made aware of the possibility of full flight tests (where the LO signal is given), and the need to stop the melting process initiation in this case.**
    - **They should consider the use of an arm-command for this.**
- **In case of a full flight test where the samples are melted then the team should document and time the process for refurbishment of their experiment unit.**
- The team should also have prepared samples ready to speed up the process of refurbishment.

Organisation, project planning & outreach (SED chapters 3.1, 3.2 & 3.3)

- ~5000 SEK (~600 EUR) deficit in the budget
    - Team say this is under control and new sponsor is all but finalised.
- The team have more Facebook likes than any other current REXUS team and are very active with their outreach.

SED

- The SED is of record length. The organisers are to discuss how to reduce the document in size.
    - For the short term the team should deliver two documents, one with the appendices (complete) and one with the main document and index of the appendices (for email distribution and printing).

End-to-end Test

- No End-to-end test performed, only test of melting samples was done.

Others

- The team has some questions around shipment for their batteries.
- The team are still having difficulty receiving emails from the rexus-bexus account (particularly for group emails when the solar email address is in the BCC field).
    - Suggested solution is to CC in Anders’ private email as well.

FINAL REMARKS

Summary of major actions for the experiment team

- **Solve communication problem (UART)**

- **Finalize on-board data handling.**
- **Finalise solder preparation process.**
- **Implement arm signal or similar for flight testing.**
- Finalize and go into testing phase

IPR Result: pass / conditional pass / fail

- Conditional Pass.

Next SED version due

- 22Oct2012

Summary of actions for EuroLaunch

- Provide shipment information.
- Provide test/launch dates.

REVIEW

Flight: RX-13

Experiment: SOLAR

Review location: IRV, Kiruna, Sweden

Date: 19Nov2012

Review Panel

Mikael Inga – SSC

Alex Kinnaird - ESA

Experiment Team members

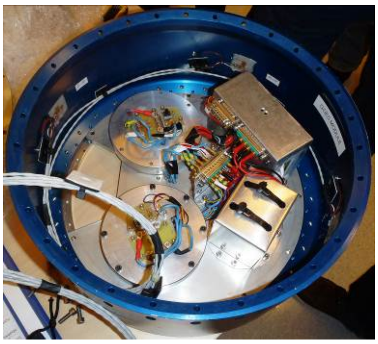
Anders Svedevall	Adrian Lindqvist
Hamoon Shahbazi	Robert Lindberg
Jens Kanje	Emil Vincent
Björn Sjödahl	Anneli Prenta
Johanna Åstrand	Maja Nylén
Sara Widbom	Johan Strandgren

Supporting professors

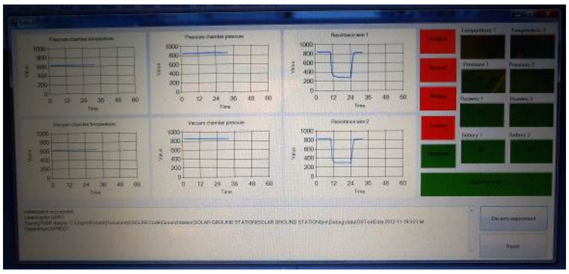
Thomas Kuhn	Kjell Lundin

PICTURES

SOLAR Flight Simulation



SOLAR with Module



Ground Support Software

GENERAL COMMENTS

- The experiment is almost finished, just requiring minor tweaks
- The overview presentation was very useful and clearly addressed points raised at the EAR.

PANEL COMMENTS AND RECOMMENDATIONS

Science

- The team are confident the experiment will meet the scientific objectives.

Requirements and constraints (SED chapter 2)

- Inconsistencies outlined at the IPR were removed.
- Requirements were further refined to fit with the flight model.

Mechanics (SED chapter 4.2.1 & 4.4)

- The team has practiced and devised a procedure for changing the solder samples – this process take 15 minutes per chamber
- The team has qualified the pressurised chamber, but believes there is some leakage through the silicon sealant (within tolerance). This issue is also possibly temperature related (manipulation of the cables following heating of the sealant maybe caused the leakage).
  - **The team will investigate and possible improve this sealant**
- The vibration testing is complete.
- A fit check was performed with the former GGES module and it was shown to fit, the module will be refurbished and provided to the team ASAP.
- The team will add venting holes to their module once delivered.
- The team have received and integrated with their flight bulkhead.
- The reported experiment mass (sans module) is 4.237kg.

Electronics and data management (SED chapter 4.2.2, 4.2.3, 4.5 & 4.7)

- The full flight model has been manufactured and tested.

- The team plan to continue to improve the chapter 6 (campaign operations) test procedures for electronics.
- **The team will provide a complete back up set of PCBs for use in refurbishment is needed.**
- **The team must change RXSM Connector (D-Sub 15) from female to male.**
- The team does not currently have a way of verifying battery charge, they intended on using a temperature probe.
  - **The team should implement a fixed sensor with connection on the battery box for verifying battery temperature/charge status, or an alternative should be found**
- Cables without shrink tube (at connector) have to be modified, and connections in general should be ‘cleaned up’ to ensure safety under the launch vibration environment.
- **The team should investigate the integrated safety circuit in the batteries and consider implement their own safety methods such a software watchdog or fuse.**
- **The team also need to look at cable routing from the electronics box to the cable feed through hole and possible use/placement of constraints.**

Thermal (SED chapter 4.2.4 & 4.6)

- No comments.

Software (SED chapter 4.8)

- The UART problem from IPR has been solved.
- An Arm-command has been implemented to allow for full flight with LO without melting the samples.
- The team will continue to test the software for bugs.
- A battery check is currently implement every 10 minutes.
- Ground station now allows visualisation of data and is fully integrated with the UART.
- **The onboard data storage needs to completed and tested.**
- The team needs to consider emergency modes and whether they are needed.
- Cpu Start-up in arm/disarm mode has to be decided (in case of failure).
- The ground station should be updated to scientific values, or at least to know the specifications in engineering values – this processing should be done on ground.

Verification and testing (SED chapter 5)

- Tests OBDH.1 and OBDH.4 (requiring onboard data storage) need to be completed.

Safety and risk analysis (SED chapter 3.4)

- Datasheet for the soldering material should be added for ground safety.
- The team should read the Esrange safety manual and be sure they are 100% compliment with all aspects.
- The pressurised chamber may also be a risk – Eurolaunch should check with SSC about this.

Launch and operations (SED chapter 6)

- The team requested the use of a torque wrench
    - Most bolts/screws should be torqued before delivery and when possible the team should provide their own torque wrench. It's possible to use one of DLR's during the campaign, but not desired.
- The team requested access to a pillar drill to fix their new PCBs, this should not be needed by there is the possibility of access to the large pillar drill at Esrange during the week – the team should not plan to use this if possible, but rather bring fully machined spares.
- The team requested use of a vacuum chamber to verify the pressuried chamber sealant following final assembly and transport., this should be OK at Esrange. The team should coordinate with the YGT about timings for this.
- The team have requested module heating once on the launcher (above 0 degrees C), this is driven by the batteries.
- The experiment requires 15 seconds for melting and cooling, and preferably should not be disturbed during this process.
- The above adds to the information required for the synchronization of the timeline with the other experiments.

Organisation, project planning & outreach (SED chapters 3.1, 3.2 & 3.3)

- The organisation seems to be progressing well – the team is still very large.
- The sample gantt chart within the document should be kept up to date.
- Outreach is good, the team have increased facebook 'likes' since IPR by nearly 100% and have performed an outreach event with secondary school children.

SED

- The SED appendix has been reduced by around 200 pages as requested.

End-to-end Test

- An end-to-end test was performed without the service system simulator due to the wrong connection on the electronics box.

Others

- The team requested to arrive a little earlier at the campaign for the vacuum test.

- The team also asked about negotiations with regards to accommodation/hire car sponsorship – they should email the YGT about this.
- The team asked about the use of Loctite – they should insure they use the correct type and be sure it's needed and be aware of the need to replace screws etc. if something fails.
- The team will send 2/3 people to the Scientific Payload Integration Week including the software and electronics responsible.
- The team may have 13/14 people at campaign, but not everyone will stay at Esrange (hence negotiation on hire car).
- The team asked about shipping restraints and were advised to speak to the shipping handler/airline directly.
- The ream asked about boxes, pelican, or zarges were recommended – the team aims to ship in December.

FINAL REMARKS

Summary of major actions for the experiment team

- Finalization of On-board data handling/storage.
- Change gender on RXSM connector.
- Modify cables (shrink tube etc.).
- Silicone sealing.
- Attach datasheet for soldering lead.

IPR Result: pass / conditional pass / fail

- Pass.

Next SED version due

- 4.1 before Campaign (exact date TBC by YGT).

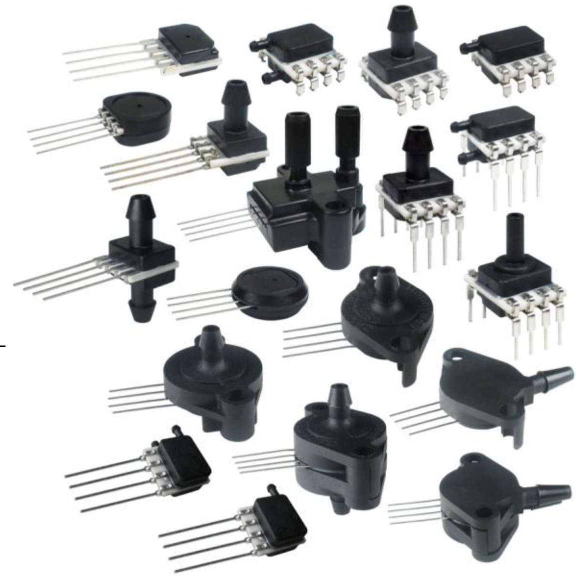
Summary of actions for EuroLaunch

- Vacuum test chamber at campaign.
- Pressurized chamber, Esrange Safety Board (ESB).
- Soldering lead, Esrange Safety Board (ESB).
- Deliver module.

APPENDIX C

Additional Technical Information

Honeywell



TruStability®
Silicon Pressure Sensors: HSC Series–High Accuracy

±1% Total Error Band, Amplified Compensated Analog Output, 1 psi to 150 psi (60 mbar to 10 bar)

DESCRIPTION

The TruStability® High Accuracy Silicon Ceramic (HSC) Series is a piezoresistive silicon pressure sensor offering a ratiometric analog output for reading pressure over the specified full scale pressure span and temperature range.

The HSC Series is fully calibrated and temperature compensated for sensor offset, sensitivity, temperature effects, and non-linearity using an on-board Application Specific Integrated Circuit (ASIC). Calibrated output values for pressure are updated at approximately 1 kHz.

The HSC Series is calibrated over the temperature range of 0 °C to 50 °C [32 °F to 122 °F]. The sensor is characterized for operation from a single power supply of either 3.3 Vdc or 5.0 Vdc.

These sensors measure absolute, differential, and gage pressures. The absolute versions have an internal vacuum reference and an output value proportional to absolute pressure. Differential versions allow application of pressure to either side of the sensing diaphragm. Gage versions are referenced to atmospheric pressure and provide an output proportional to pressure variations from atmosphere.

The TruStability® pressure sensors are intended for use with non-corrosive, non-ionic gases, such as air and other dry gases. An available option extends the performance of these sensors to non-corrosive, non-ionic liquids.

All products are designed and manufactured according to ISO 9001 standards.

FEATURES

- Industry-leading long-term stability
- Extremely tight accuracy of ±0.25% FSS BFSL (Full Scale Span Best Fit Straight Line)
- Total error band of ±1% full scale span maximum
- Modular and flexible design offers customers a variety of package styles and options, all with the same industry-leading performance specifications
- Miniature 10 mm x 10 mm [0.39 in x 0.39 in] package
- Low operating voltage
- Extremely low power consumption
- Ratiometric analog output
- High resolution (min 0.03 %FSS)
- Precision ASIC conditioning and temperature compensated over 0 °C to 50 °C [32 °F to 122 °F] temperature range
- RoHS compliant
- Virtually insensitive to mounting orientation
- Internal diagnostic functions increase system reliability
- Also available with I^2C or SPI digital output
- Absolute, differential and gage types
- Pressure ranges from 1 psi to 150 psi (60 mbar to 10 bar)
- Custom calibration available
- Various pressure port options
- Liquid media option

TruStability® Silicon Pressure Sensors: HSC Series–High Accuracy

POTENTIAL APPLICATIONS

- **Medical:**
  - Airflow monitors
  - Anesthesia machines
  - Blood analysis machines
  - Gas chromatography
  - Gas flow instrumentation
  - Kidney dialysis machines
  - Oxygen concentrators
  - Pneumatic controls
  - Respiratory machines
  - Sleep apnea equipment
  - Ventilators
- **Industrial:**
  - Barometry
  - Flow calibrators
  - Gas chromatography
  - Gas flow instrumentation
  - HVAC
  - Life sciences
  - Pneumatic controls

Table 1. Absolute Maximum Ratings[1]

Parameter	Min.	Max.	Unit
Supply voltage (V_{supply})	-0.3	6.0	Vdc
Voltage on any pin	-0.3	V_{supply} + 0.3	V
ESD susceptibility (human body model)	3	-	kV
Storage temperature	-40 [-40]	85 [185]	°C [°F]
Soldering time and temperature: Lead solder temperature (SIP, DIP) Peak reflow temperature (SMT)	 4 s max. at 250 °C [482 °F] 15 s max. at 250 °C [482 °F]		

Table 2. Operating Specifications

Parameter	Min.	Typ.	Max.	Unit
Supply voltage (V_{supply})[2]: 3.3 Vdc 5.0 Vdc *Sensors are either 3.3 Vdc or 5.0 Vdc based on listing selected.*	 3.0 4.75	 3.3[3] 5.0[3]	 3.6 5.25	Vdc
Supply current: 3.3 Vdc supply 5.0 Vdc supply	 - -	 1.6 2	 2.1 3	mA
Compensated temperature range[4]	0 [32]	-	50 [122]	°C [°F]
Operating temperature range[5]	-20 [-4]	-	85 [185]	°C [°F]
Startup time (power up to data ready)	-	-	5	ms
Response time	-	1	-	ms
Upper output clipping limit	-	-	97.5	%V_{supply}
Lower output clipping limit	2.5	-	-	%V_{supply}
Accuracy[6]	-	-	±0.25	%FSS BFSL
Total error band[7]	-	-	±1	%FSS[8]
Output resolution	0.03	-	-	%FSS[8]

±1% Total Error Band, Analog Output, 1 psi to 150 psi (60 mbar to 10 bar)

Table 3. Environmental Specifications

Parameter	Characteristic
Humidity: Dry gases only (See “Options N and D” in Figure 1.) Liquid media (See “Options T and V” in Figure 1.)	 0% to 95% RH, non-condensing 100% condensing or direct liquid media on Port 1
Vibration	MIL-STD-202F, Curve AK (20.7 g random)
Shock	MIL-STD-202F, Method 213B, Condition F
Life[9]	1 million cycles minimum
Solder reflow	J-STD-020-C

Table 4. Wetted Materials[10]

Parameter	Port 1 (Pressure Port)	Port 2 (Reference Port)
Covers	high temperature polyamide	high temperature polyamide
Substrate	alumina ceramic	alumina ceramic
Adhesives	epoxy, silicone	epoxy, silicone
Electronic components	ceramic, glass, solder, silicon	silicon, glass, gold, solder

Notes:

1. Absolute maximum ratings are the extreme limits the device will withstand without damage.
2. Ratiometricity of the sensor (the ability of the device to scale to the supply voltage) is achieved within the specified operating voltage for each option.
3. The sensor is not reverse polarity protected. Incorrect application of supply voltage or ground to the wrong pin may cause electrical failure.
4. The compensated temperature range is the temperature range over which the sensor will produce an output proportional to pressure within the specified performance limits.
5. The operating temperature range is the temperature range over which the sensor will produce an output proportional to pressure but may not remain within the specified performance limits.
6. Accuracy: The maximum deviation in output from a Best Fit Straight Line (BFSL) fitted to the output measured over the pressure range at 25 °C [77 °F]. Includes all errors due to pressure non-linearity, pressure hysteresis, and non-repeatability.
7. Total Error Band: The maximum deviation from the ideal transfer function over the entire compensated temperature and pressure range. Includes all errors due to offset, full scale span, pressure non-linearity, pressure hysteresis, repeatability, thermal effect on offset, thermal effect on span, and thermal hysteresis.
8. Full Scale Span (FSS) is the algebraic difference between the output signal measured at the maximum (Pmax.) and minimum (Pmin.) limits of the pressure range. (See Figure 1 for ranges.)
9. Life may vary depending on specific application in which sensor is utilized.
10. Contact Honeywell Customer Service for detailed material information.

CAUTION

PRODUCT DAMAGE

- Ensure liquid media is applied to Port 1 only; Port 2 is not compatible with liquids.
- Ensure liquid media contains no particulates. All TruStability® sensors are dead-ended devices. Particulates can accumulate inside the sensor, causing damage or affecting sensor output.
- Recommend that the sensor be positioned with Port 1 facing downwards; any particulates in the system are less likely to enter and settle within the pressure sensor if it is in this position.
- Ensure liquid media does not create a residue when dried; build-up inside the sensor may affect sensor output. Rinsing of a dead-ended sensor is difficult and has limited effectiveness for removing residue.
- Ensure liquid media are compatible with wetted materials. Non-compatible liquid media will degrade sensor performance and may lead to sensor failure.

Failure to comply with these instructions may result in product damage.

TruStability® Silicon Pressure Sensors: HSC Series–High Accuracy

Figure 1. Nomenclature and Order Guide

HSC _ _ _ _ _ _ _ _ _ A A _

Series

Package
D = DIP (Dual Inline Pin)
M = SMT (Surface Mount Technology)
S = SIP (Single Inline Pin)

Pressure Port (* indicates not available)

DIP	*SMT*	*SIP*
NN = No ports	**NN** = No ports	**NN** = No ports
*	*	**AA** = Dual axial barbed ports, opposite sides
AN = Single axial barbed port	**AN** = Single axial barbed port	**AN** = Single axial barbed port
LN = Single axial barbless port	**LN** = Single axial barbless port	**LN** = Single axial barbless port
*	*	**FF** = Fastener mount, dual axial barbed ports, opposite sides
*	*	**FN** = Fastener mount, single axial barbed port
*	*	**GN** = Ribbed fastener mount, single axial barbed port
*	*	**NB** = Fastener mount, dual axial ports, same side
RN = Single radial barbed port	**RN** = Single radial barbed port	**RN** = Single radial barbed port
RR = Dual radial barbed ports, same side	**RR** = Dual radial barbed ports, same side	**RR** = Dual radial barbed ports, same side
DR = Dual radial barbed ports, opposite sides	**DR** =Dual radial barbed ports, opposite sides	**DR** = Dual radial barbed ports, opposite sides
*	*	**HH** = Fastener mount, dual radial barbed ports, same side
*	*	**HN** = Fastener mount, single radial barbed port
*	*	**MN** = Manifold mount, outer diameter seal
*	*	**SN** = Manifold mount, inner diameter seal

Supply Voltage
3 = 3.3 Vdc
5 = 5.0 Vdc

Transfer Function[11]
A = 10% to 90% of Vsupply

Output Type[12]
A = Analog voltage

Pressure Range[13, 14]

1 psi to 150 psi

Absolute
015PA = 0 psi to 15 psi
030PA = 0 psi to 30 psi
060PA = 0 psi to 60 psi
100PA = 0 psi to 100 psi
150PA = 0 psi to 150 psi

Differential
001PD = ±1 psi
005PD = ±5 psi
015PD = ±15 psi
030PD = ±30 psi
060PD = ±60 psi

Gage
001PG = 0 psi to 1 psi
005PG = 0 psi to 5 psi
015PG = 0 psi to 15 psi
030PG = 0 psi to 30 psi
060PG = 0 psi to 60 psi
100PG = 0 psi to 100 psi
150PG = 0 psi to 150 psi

60 mbar to 10 bar

Absolute
001BA = 0 bar to 1 bar
1.6BA = 0 bar to 1.6 bar
2.5BA = 0 bar to 2.5 bar
004BA = 0 bar to 4 bar
006BA = 0 bar to 6 bar
010BA = 0 bar to 10 bar

Differential
060MD = ±60 mbar
100MD = ±100 mbar
160MD = ±160 mbar
250MD = ±250 mbar
400MD = ±400 mbar
600MD = ±600 mbar
001BD = ±1 bar
1.6BD = ±1.6 bar
2.5BD = ±2.5 bar
004BD = ±4 bar

Gage
060MG = 0 mbar to 60 mbar
100MG = 0 mbar to 100 mbar
160MG = 0 mbar to 160 mbar
250MG = 0 mbar to 250 mbar
400MG = 0 bar to 400 mbar
600MG = 0 bar to 600 mbar
001BG = 0 bar to 1 bar
1.6BG = 0 bar to 1.6 bar
2.5BG = 0 bar to 2.5 bar
004BG = 0 bar to 4 bar
006BG = 0 bar to 6 bar
010BG = 0 bar to 10 bar

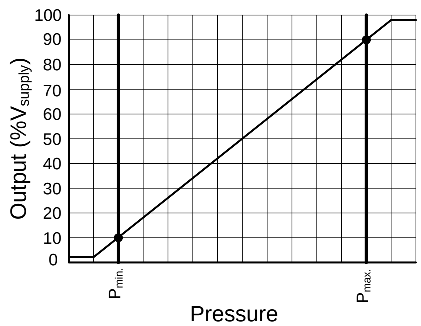
Options[15]
N = Dry gases only, no special options
D = Dry gases only, diagnostics on
T = Liquid media on Port 1, no diagnostics
V = Liquid media on Port 1, diagnostics on

Notes:

11. The transfer function limits define the output of the sensor at a given pressure input. By specifying Pmin. and Pmax., the output at Pmin. and Pmax., the complete transfer function of the sensor is defined. See Figure 2 for a graphical representation of the transfer function. Other transfer functions are available. Contact Honeywell Customer Service for more information.
12. Digital outputs (SPI or I^2C) are also available. Contact Honeywell Customer Service for more information.
13. Custom pressure ranges are available. Contact Honeywell Customer Service for more information.
14. See Table 5 for an explanation of sensor pressure types.
15. See **CAUTION** on previous page.

±1% Total Error Band, Analog Output, 1 psi to 150 psi (60 mbar to 10 bar)

Figure 2. Transfer Function Limits



$$\text{Output (V)} = \frac{0.8 \times V_{supply}}{P_{max.} - P_{min.}} \times (\text{Pressure}_{applied} - P_{min.}) + 0.10 \times V_{supply}$$

Figure 3. Completed Catalog Listing Example

HSCSANN100PGAA3
SIP package, AN pressure port, no diagnostics, 100 psi gage, analog output, 10% to 90% calibration at 3.3 Vdc.

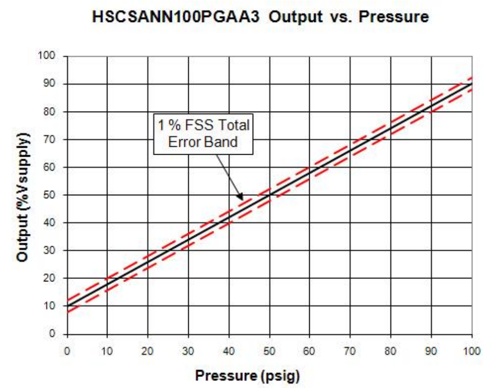


Table 5. Pressure Types

Pressure Type	Description
Absolute	Output is proportional to the difference between applied pressure and a built-in reference to vacuum. $P_{min.}$ is set at absolute zero pressure (full vacuum).
Differential	Output is proportional to the difference between the pressures applied to each port. (Port 1 – Port 2) 50% point of transfer function set at Port 1 = Port 2.
Gage	Output is proportional to the difference between applied pressure and atmospheric (ambient) pressure. $P_{min.}$. is set at atmospheric pressure.

Table 6. Pressure Range Specifications for 1 psi to 150 psi

Order Code	Pressure Range		Over-pressure[16]	Burst Pressure[17]	Common Mode Pressure[18]	Long-term Stability (1000 hr, 25 °C [77 °F])
	$P_{min.}$	$P_{max.}$				
			Absolute			
015PA	0 psi	15 psi	30 psi	60 psi	NA	±0.25% FSS
030PA	0 psi	30 psi	60 psi	120 psi	NA	±0.25% FSS
060PA	0 psi	60 psi	120 psi	240 psi	NA	±0.25% FSS
100PA	0 psi	100 psi	250 psi	250 psi	NA	±0.25% FSS
150PA	0 psi	150 psi	250 psi	250 psi	NA	±0.25% FSS
			Differential			
001PD	-1 psi	1 psi	10 psi	10 psi	150 psi	±0.35% FSS
005PD	-5 psi	5 psi	30 psi	40 psi	150 psi	±0.35% FSS
015PD	-15 psi	15 psi	30 psi	60 psi	150 psi	±0.25% FSS
030PD	-30 psi	30 psi	60 psi	120 psi	150 psi	±0.25% FSS
060PD	-60 psi	60 psi	120 psi	240 psi	250 psi	±0.25% FSS
			Gage			
001PG	0 psi	1 psi	10 psi	10 psi	150 psi	±0.35% FSS
005PG	0 psi	5 psi	30 psi	40 psi	150 psi	±0.35% FSS
015PG	0 psi	15 psi	30 psi	60 psi	150 psi	±0.25% FSS
030PG	0 psi	30 psi	60 psi	120 psi	150 psi	±0.25% FSS
060PG	0 psi	60 psi	120 psi	240 psi	250 psi	±0.25% FSS
100PG	0 psi	100 psi	250 psi	250 psi	250 psi	±0.25% FSS
150PG	0 psi	150 psi	250 psi	250 psi	250 psi	±0.25% FSS

TruStability® Silicon Pressure Sensors: HSC Series–High Accuracy

Table 7. Pressure Range Specifications for 60 mbar to 10 bar

Order Code	Pressure Range		Over-pressure[16]	Burst Pressure[17]	Common Mode Pressure[18]	Long-term Stability (1000 hr, 25 °C [77 °F])
	$P_{min.}$	$P_{max.}$				
Absolute						
001BA	0 bar	1 bar	2 bar	4 bar	NA	±0.25% FSS
1.6BA	0 bar	1.6 bar	4 bar	8 bar	NA	±0.25% FSS
2.5BA	0 bar	2.5 bar	6 bar	8 bar	NA	±0.25% FSS
004BA	0 bar	4 bar	8 bar	16 bar	NA	±0.25% FSS
006BA	0 bar	6 bar	17 bar	17 bar	NA	±0.25% FSS
010BA	0 bar	10 bar	17 bar	17 bar	NA	±0.25% FSS
Differential						
060MD	-60 mbar	60 mbar	500 mbar	700 mbar	10 bar	±0.35% FSS
100MD	-100 mbar	100 mbar	500 mbar	700 mbar	10 bar	±0.35% FSS
160MD	-160 mbar	160 mbar	500 mbar	700 mbar	10 bar	±0.35% FSS
250MD	-250 mbar	250 mbar	1.4 bar	2.5 bar	10 bar	±0.35% FSS
400MD	-400 mbar	400 mbar	1.4 bar	2.5 bar	10 bar	±0.35% FSS
600MD	-600 mbar	600 mbar	2 bar	4 bar	10 bar	±0.25% FSS
001BD	-1 bar	1 bar	2 bar	4 bar	10 bar	±0.25% FSS
1.6BD	-1.6 bar	1.6 bar	4 bar	8 bar	10 bar	±0.25% FSS
2.5BD	-2.5 bar	2.5 bar	6 bar	8 bar	10 bar	±0.25% FSS
004BD	-4 bar	4 bar	8 bar	16 bar	10 bar	±0.25% FSS
Gage						
060MG	0 mbar	60 mbar	500 mbar	700 mbar	3.5 bar	±0.35% FSS
100MG	0 mbar	100 mbar	500 mbar	700 mbar	10 bar	±0.35% FSS
160MG	0 mbar	160 mbar	500 mbar	700 mbar	10 bar	±0.35% FSS
250MG	0 mbar	250 mbar	1.4 bar	2.5 bar	10 bar	±0.35% FSS
400MG	0 mbar	400 mbar	1.4 bar	2.5 bar	10 bar	±0.35% FSS
600MG	0 mbar	600 mbar	2 bar	4 bar	10 bar	±0.35% FSS
001BG	0 bar	1 bar	2 bar	4 bar	10 bar	±0.25% FSS
1.6BG	0 bar	1.6 bar	4 bar	8 bar	10 bar	±0.25% FSS
2.5BG	0 bar	2.5 bar	6 bar	8 bar	10 bar	±0.25% FSS
004BG	0 bar	4 bar	8 bar	16 bar	16 bar	±0.25% FSS
006BG	0 bar	6 bar	17 bar	17 bar	17 bar	±0.25% FSS
010BG	0 bar	10 bar	17 bar	17 bar	17 bar	±0.25% FSS

Notes:

16. Overpressure: The maximum pressure which may safely be applied to the product for it to remain in specification once pressure is returned to the operating pressure range. Exposure to higher pressures may cause permanent damage to the product. Unless otherwise specified this applies to all available pressure ports at any temperature with the operating temperature range.
17. Burst pressure: The maximum pressure that may be applied to any port of the product without causing escape of pressure media. Product should not be expected to function after exposure to any pressure beyond the burst pressure.
18. Common mode pressure: The maximum pressure that can be applied simultaneously to both ports of a differential pressure sensor without causing changes in specified performance.

Table 8. Pinout for DIP and SMT Packages

Output Type	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8
analog	NC	V_{supply}	OUTPUT+	GND	NC	NC	NC	NC

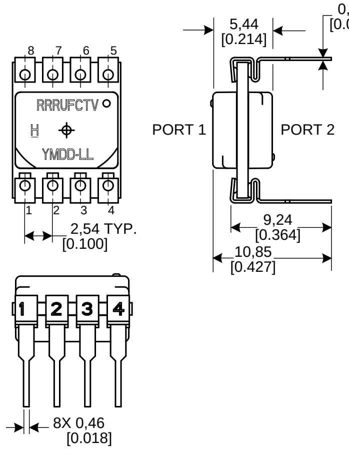
Table 9. Pinout for SIP Packages

Output Type	Pin 1	Pin 2	Pin 3	Pin 4
analog	NC	V_{supply}	OUTPUT+	GND

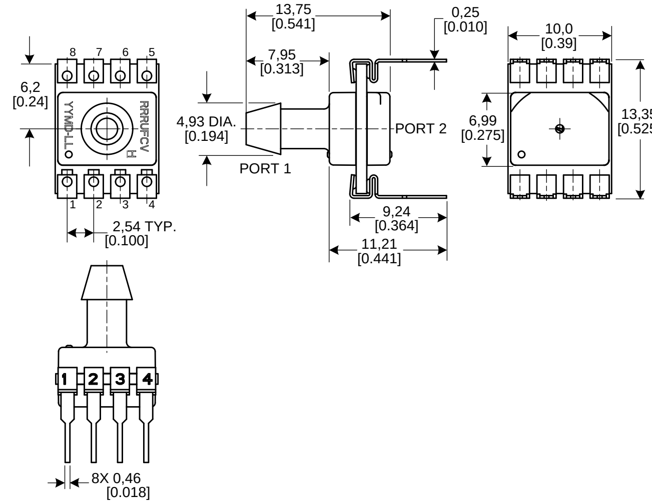
±1% Total Error Band, Analog Output, 1 psi to 150 psi (60 mbar to 10 bar)

Figure 4. DIP Pressure Port Dimensional Drawings (For reference only: mm [in])

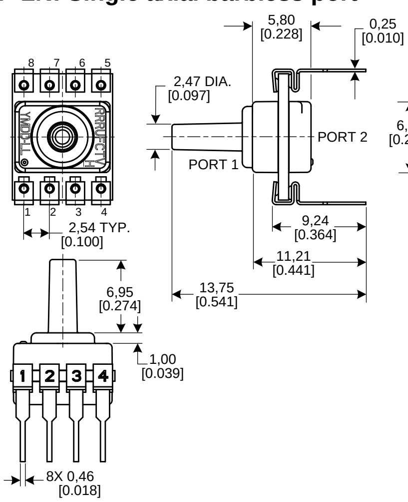
DIP NN: No ports



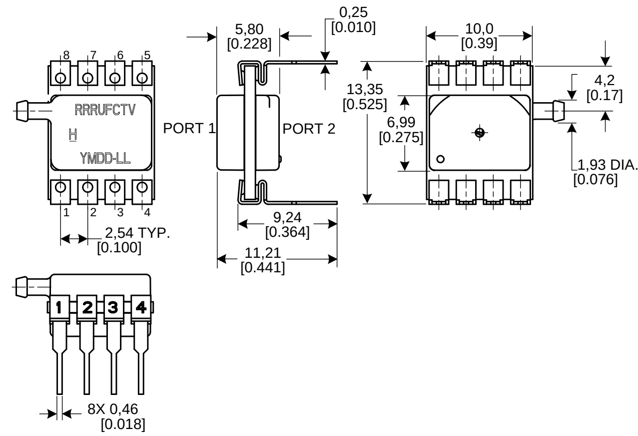
DIP AN: Single axial barbed port



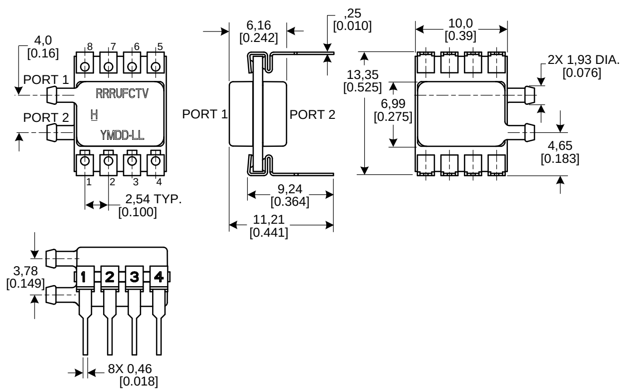
DIP LN: Single axial barbless port



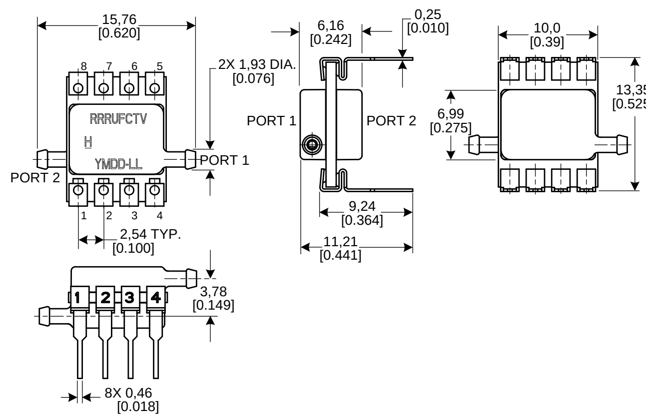
DIP RN: Single radial barbed port



DIP RR: Dual radial barbed ports, same side



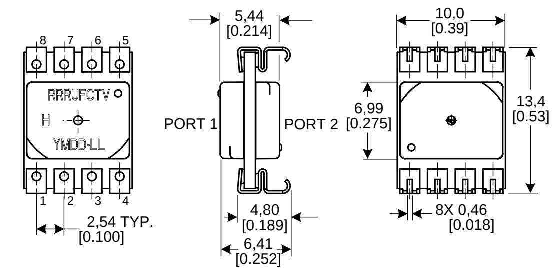
DIP DR: Dual radial barbed ports, opposite sides



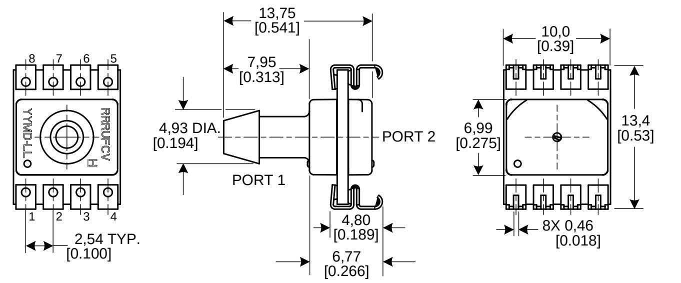
TruStability® Silicon Pressure Sensors: HSC Series–High Accuracy

Figure 5. SMT Pressure Port Dimensional Drawings (For reference only: mm [in])

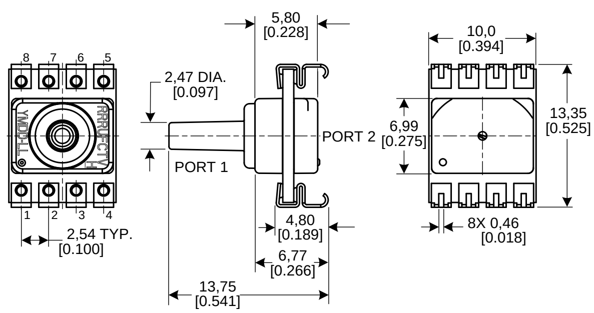
SMT NN: No ports



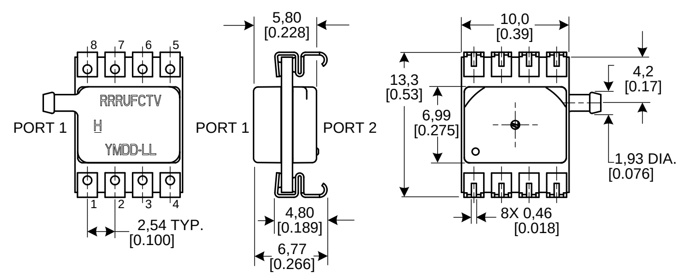
SMT AN: Single axial barbed port



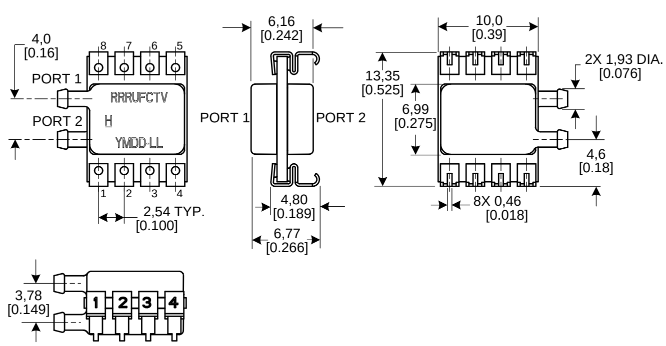
SMT LN: Single axial barbless port



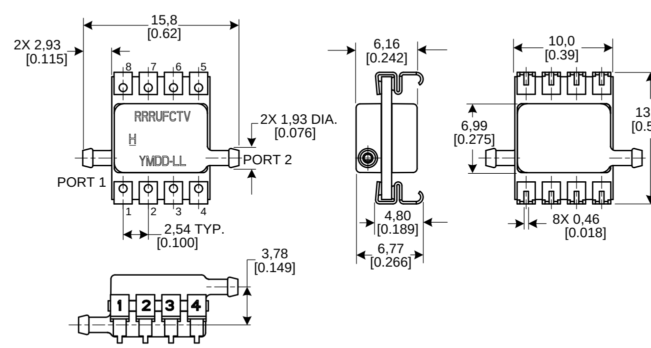
SMT RN: Single radial barbed port



SMT RR: Dual radial barbed ports, same side

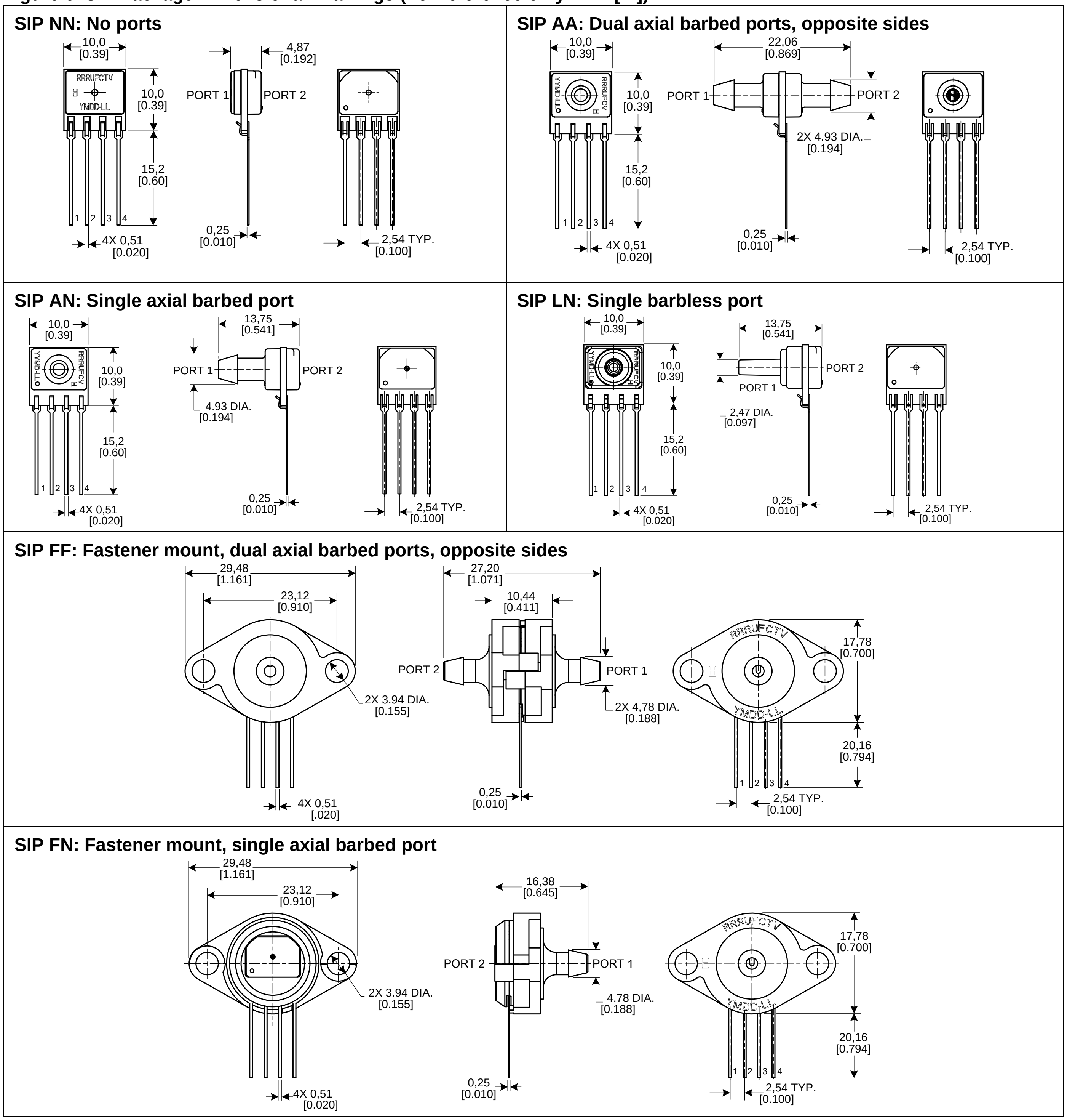


SMT DR: Dual radial barbed ports, opposite sides



±1% Total Error Band, Analog Output, 1 psi to 150 psi (60 mbar to 10 bar)

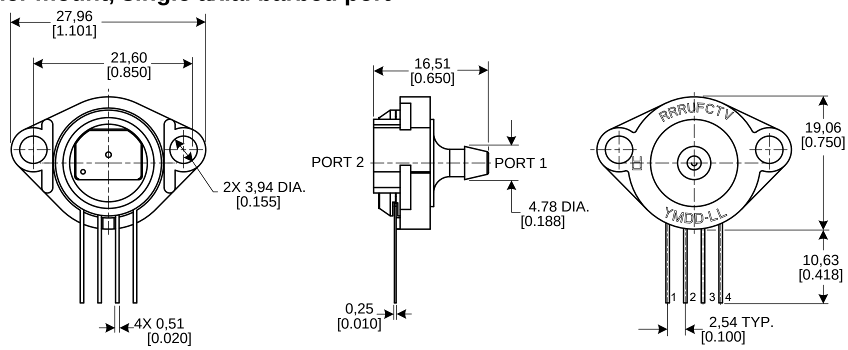
Figure 6. SIP Package Dimensional Drawings (For reference only: mm [in])



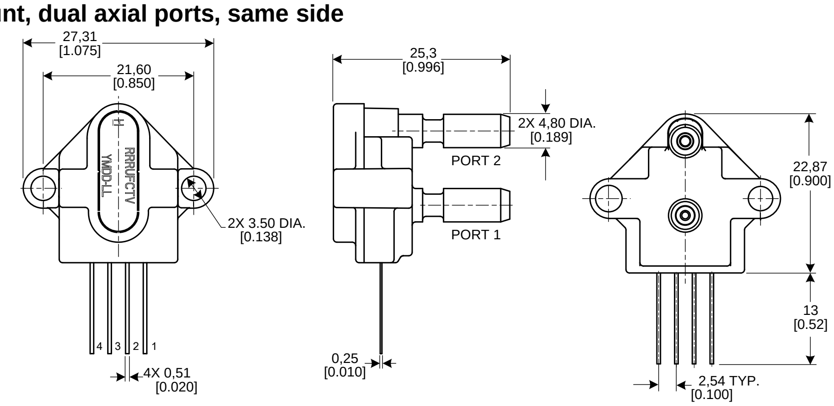
TruStability® Silicon Pressure Sensors: HSC Series–High Accuracy

Figure 6. SIP Package Dimensional Drawings (continued)

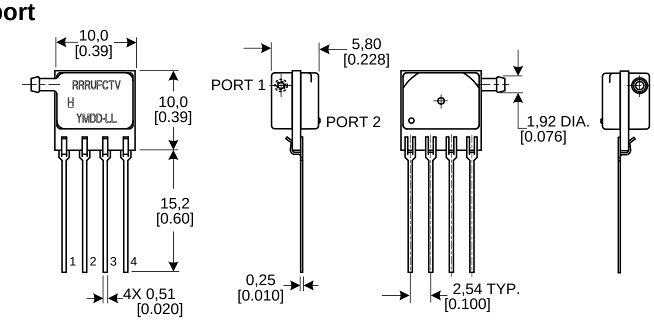
SIP GN: Ribbed fastener mount, single axial barbed port



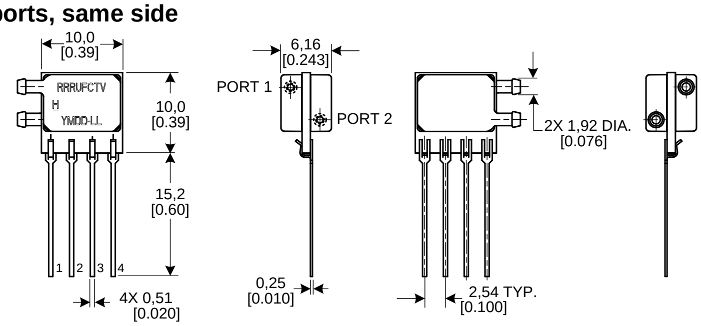
SIP NB: Fastener mount, dual axial ports, same side



SIP RN: Single radial barbed port

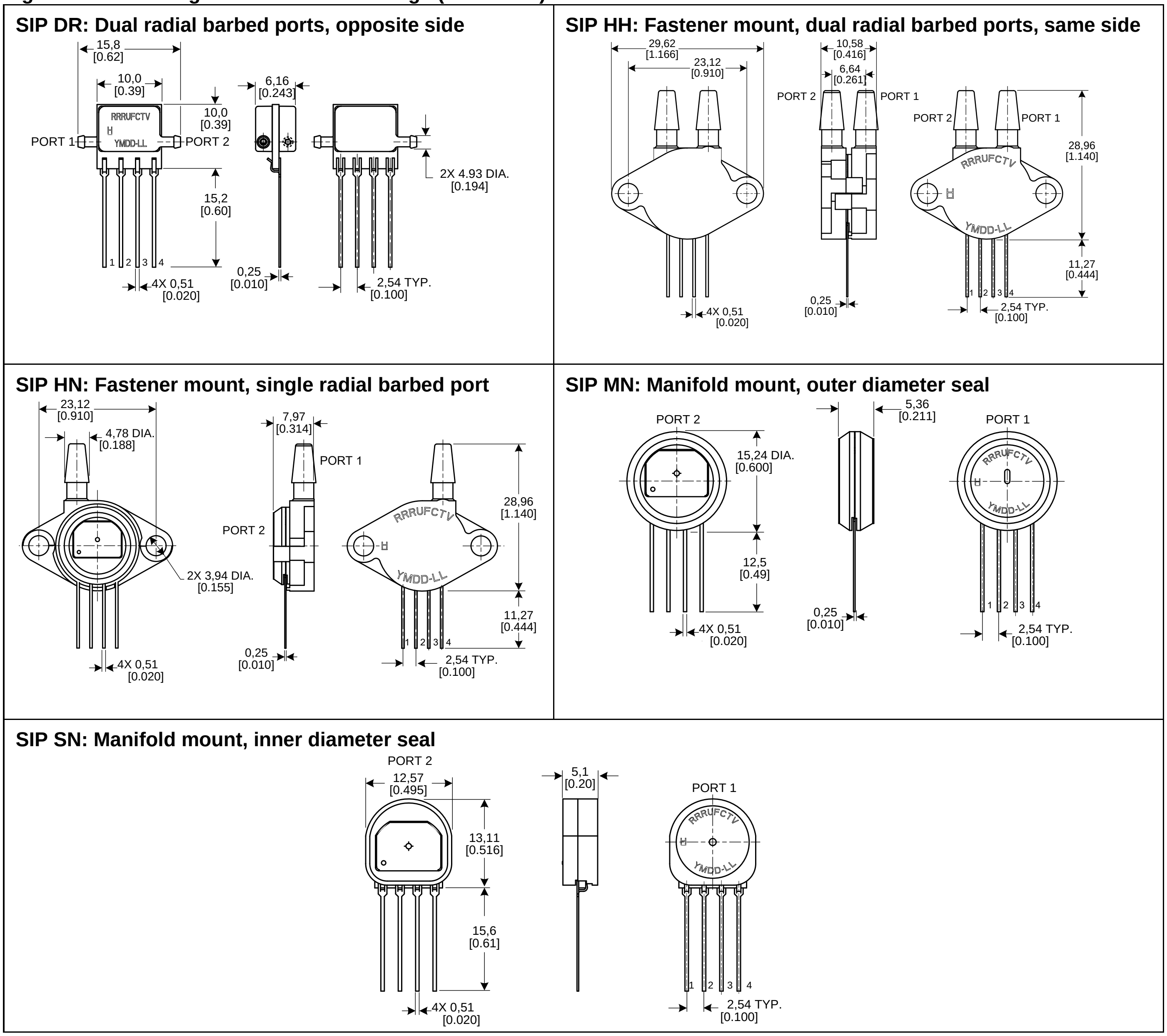


SIP RR: Dual radial barbed ports, same side



±1% Total Error Band, Analog Output, 1 psi to 150 psi (60 mbar to 10 bar)

Figure 6. SIP Package Dimensional Drawings (continued)



⚠ WARNING

PERSONAL INJURY

DO NOT USE these products as safety or emergency stop devices or in any other application where failure of the product could result in personal injury.

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⚠ WARNING

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- Complete installation, operation, and maintenance information is provided in the instructions supplied with each product.

Failure to comply with these instructions could result in death or serious injury.

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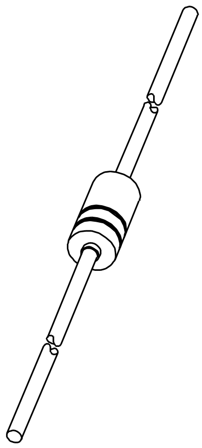
March 2011

DATA SHEET



KTY84-1 series
Silicon temperature sensors

Product specification 1998 Apr 09
Supersedes data of 1996 Dec 06
File under Discrete Semiconductors, SC17

Philips
Semiconductors

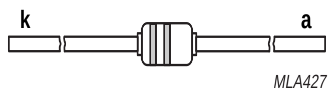
PHILIPS

Silicon temperature sensors | KTY84-1 series

DESCRIPTION

The temperature sensors in the KTY84-1 series have a positive temperature coefficient of resistance and are suitable for use in measurement and control systems over a temperature range of –40 to +300 °C. The sensors are encapsulated in the SOD68 (DO-34) leaded package.

Tolerances of 0.5% or other special selections are available on request.



The first (green) band indicates the negative connection.
The second (coloured) band provides type identity.
The sensor must be operated with the lower potential at the marked connection.

Fig.1 Simplified outline (SOD68; DO-34).

MARKING

TYPE NUMBER	MARKING BAND COLOUR
KTY84-130	yellow
KTY84-150	grey
KTY84-151	black
KTY84-152	blue

QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
R_{100}	sensor resistance	T_{amb} = 100 °C; I_{cont} = 2 mA			
	KTY84-130		970	1030	Ω
	KTY84-150		950	1050	Ω
	KTY84-151		950	1000	Ω
	KTY84-152		1000	1050	Ω
T_{amb}	ambient operating temperature		–40	+300	°C

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
I_{cont}	continuous sensor current	in free air; T_{amb} = 25 °C; note 1	–	10	mA
		in free air; T_{amb} = 300 °C	–	2	mA
T_{amb}	ambient operating temperature		–40	+300	°C
T_{stg}	storage temperature		–55	+300	°C

Note

1. For temperatures greater than 200 °C, a sensor current of I_{cont} = 2 mA must be used.

CHARACTERISTICS

T_{amb} = 100 °C, in liquid, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
R_{100}	sensor resistance	I_{cont} = 2 mA				
	KTY84-130		970	–	1030	Ω
	KTY84-150		950	–	1050	Ω
	KTY84-151		950	–	1000	Ω
	KTY84-152		1000	–	1050	Ω
TC	temperature coefficient		–	0.61	–	%/K
R_{250}/R_{100}	resistance ratio	T_{amb} = 250 °C and 100 °C	2.111	2.166	2.221	
R_{25}/R_{100}	resistance ratio	T_{amb} = 25 °C and 100 °C	0.595	0.603	0.611	
τ	thermal time constant; note 1	in still air	–	20	–	s
		in still liquid; note 2	–	1	–	s
		in flowing liquid; note 2	–	0.5	–	s
	rated temperature range		–40	–	+300	°C

Notes

1. The thermal time constant is the time taken for the sensor to reach 63.2% of the total temperature difference. For example, if a sensor with a temperature of 25 °C is moved to an environment with an ambient temperature of 100 °C, the time for the sensor to reach a temperature of 72.4 °C is the thermal time constant.
2. Inert liquid, e.g. FC43 manufactured by the 3M company.

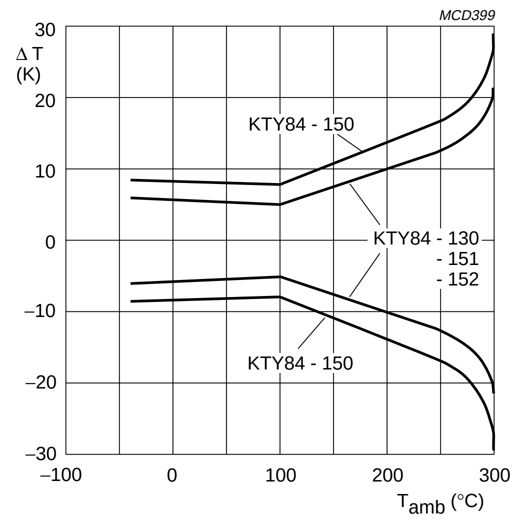
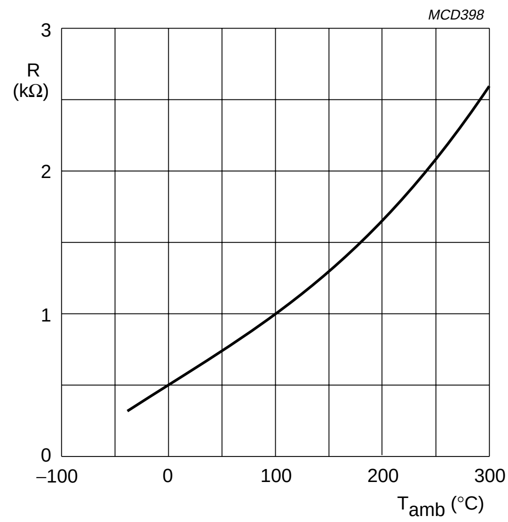


Fig.2 Maximum expected temperature error (ΔT).



I_{cont} = 2 mA.

Fig.3 Sensor resistance as a function of ambient temperature; average values.

Table 1 Ambient temperature, corresponding resistance, temperature coefficient and maximum expected temperature error for KTY84-130 and KTY84-150

I_{cont} = 2 mA.

AMBIENT TEMPERATURE		TEMP. COEFF.	KTY84-130				KTY84-150			
			RESISTANCE (Ω)			TEMP. ERROR (K)	RESISTANCE (Ω)			TEMP. ERROR (K)
(°C)	(°F)	(%/K)	MIN.	TYP.	MAX.		MIN.	TYP.	MAX.	
–40	–40	0.84	340	359	379	±6.48	332	359	386	±8.85
–30	–22	0.83	370	391	411	±6.36	362	391	419	±8.76
–20	–4	0.82	403	424	446	±6.26	394	424	455	±8.7
–10	14	0.80	437	460	483	±6.16	428	460	492	±8.65
0	32	0.79	474	498	522	±6.07	464	498	532	±8.61
10	50	0.77	514	538	563	±5.98	503	538	574	±8.58
20	68	0.75	555	581	607	±5.89	544	581	618	±8.55
25	77	0.74	577	603	629	±5.84	565	603	641	±8.54
30	86	0.73	599	626	652	±5.79	587	626	665	±8.53
40	104	0.71	645	672	700	±5.69	632	672	713	±8.5
50	122	0.70	694	722	750	±5.59	679	722	764	±8.46
60	140	0.68	744	773	801	±5.47	729	773	817	±8.42
70	158	0.66	797	826	855	±5.34	781	826	872	±8.37
80	176	0.64	852	882	912	±5.21	835	882	929	±8.31
90	194	0.63	910	940	970	±5.06	891	940	989	±8.25
100	212	0.61	970	1000	1030	±4.9	950	1000	1050	±8.17
110	230	0.60	1029	1062	1096	±5.31	1007	1062	1117	±8.66
120	248	0.58	1089	1127	1164	±5.73	1067	1127	1187	±9.17
130	266	0.57	1152	1194	1235	±6.17	1128	1194	1259	±9.69
140	284	0.55	1216	1262	1309	±6.63	1191	1262	1334	±10.24
150	302	0.54	1282	1334	1385	±7.1	1256	1334	1412	±10.8
160	320	0.53	1350	1407	1463	±7.59	1322	1407	1492	±11.37
170	338	0.52	1420	1482	1544	±8.1	1391	1482	1574	±11.96
180	356	0.51	1492	1560	1628	±8.62	1461	1560	1659	±12.58
190	374	0.49	1566	1640	1714	±9.15	1533	1640	1747	±13.2
200	392	0.48	1641	1722	1803	±9.71	1607	1722	1837	±13.85
210	410	0.47	1719	1807	1894	±10.28	1683	1807	1931	±14.51
220	428	0.46	1798	1893	1988	±10.87	1760	1893	2026	±15.19
230	446	0.45	1879	1982	2085	±11.47	1839	1982	2125	±15.88
240	464	0.44	1962	2073	2184	±12.09	1920	2073	2226	±16.59
250	482	0.44	2046	2166	2286	±12.73	2003	2166	2329	±17.32
260	500	0.42	2132	2261	2390	±13.44	2087	2261	2436	±18.15
270	518	0.41	2219	2357	2496	±14.44	2172	2357	2543	±19.36
280	536	0.38	2304	2452	2600	±15.94	2255	2452	2650	±21.21
290	554	0.34	2384	2542	2700	±18.26	2333	2542	2751	±24.14
300	572	0.29	2456	2624	2791	±22.12	2404	2624	2844	±29.05

Table 2 Ambient temperature, corresponding resistance, temperature coefficient and maximum expected temperature error for KTY84-151 and KTY84-152

I_{cont} = 2 mA.

AMBIENT TEMPERATURE		TEMP. COEFF.	KTY84-151				KTY84-152			
			RESISTANCE (Ω)			TEMP. ERROR	RESISTANCE (Ω)			TEMP. ERROR
(°C)	(°F)	(%/K)	MIN.	TYP.	MAX.	(K)	MIN.	TYP.	MAX.	(K)
–40	–40	0.84	332	350	368	±5.97	350	368	386	±5.82
–30	–22	0.83	362	381	399	±5.84	381	400	419	±5.69
–20	–4	0.82	394	414	433	±5.72	415	435	455	±5.57
–10	14	0.80	428	449	469	±5.62	451	472	492	±5.46
0	32	0.79	464	486	507	±5.51	489	511	532	±5.35
10	50	0.77	503	525	547	±5.41	530	552	574	±5.25
20	68	0.75	544	566	589	±5.31	573	595	618	±5.14
25	77	0.74	565	588	611	±5.25	595	618	641	±5.08
30	86	0.73	587	610	633	±5.2	618	641	665	±5.03
40	104	0.71	632	656	679	±5.08	665	689	713	±4.91
50	122	0.70	679	704	728	±4.96	715	740	764	±4.78
60	140	0.68	729	754	778	±4.83	767	792	817	±4.64
70	158	0.66	781	806	831	±4.68	822	847	872	±4.5
80	176	0.64	835	860	885	±4.53	879	904	929	±4.34
90	194	0.63	891	916	942	±4.37	938	963	989	±4.17
100	212	0.61	950	975	1000	±4.19	1000	1025	1050	±3.99
110	230	0.60	1007	1036	1064	±4.58	1060	1089	1117	±4.37
120	248	0.58	1067	1099	1131	±4.99	1123	1155	1187	±4.77
130	266	0.57	1128	1164	1199	±5.41	1187	1223	1259	±5.19
140	284	0.55	1191	1231	1271	±5.84	1254	1294	1334	±5.62
150	302	0.54	1256	1300	1345	±6.3	1322	1367	1412	±6.07
160	320	0.53	1322	1372	1421	±6.77	1392	1442	1492	±6.53
170	338	0.52	1391	1445	1500	±7.25	1464	1519	1574	±7.01
180	356	0.51	1461	1521	1581	±7.75	1538	1599	1659	±7.51
190	374	0.49	1533	1599	1664	±8.27	1614	1681	1747	±8.02
200	392	0.48	1607	1679	1751	±8.81	1692	1765	1837	±8.55
210	410	0.47	1683	1761	1839	±9.36	1772	1852	1931	±9.09
220	428	0.46	1760	1846	1931	±9.93	1854	1940	2026	±9.66
230	446	0.45	1839	1932	2024	±10.51	1937	2031	2125	±10.23
240	464	0.44	1920	2021	2121	±11.11	2022	2125	2226	±10.83
250	482	0.44	2003	2112	2220	±11.73	2110	2220	2329	±11.44
260	500	0.42	2087	2205	2321	±12.42	2198	2318	2436	±12.12
270	518	0.41	2172	2298	2424	±13.37	2288	2416	2543	±13.06
280	536	0.38	2257	2391	2525	±14.79	2376	2513	2650	±14.46
290	554	0.34	2335	2479	2622	±16.98	2459	2606	2751	±16.61
300	572	0.29	2406	2558	2710	±20.61	2533	2689	2844	±20.18

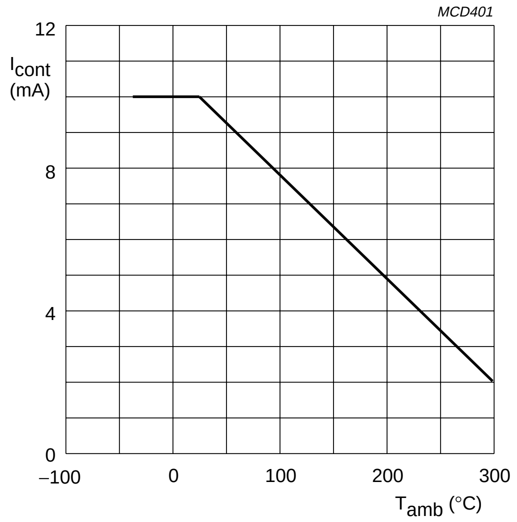
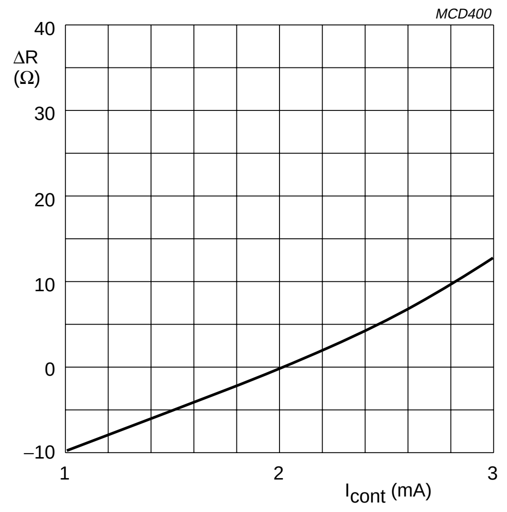


Fig.4 Maximum operating current for safe operation.

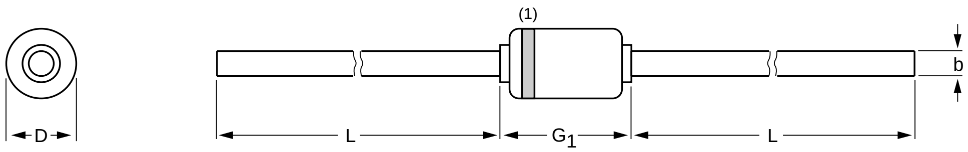


T_{amb} = 100 °C.

Fig.5 Deviation of sensor resistance as a function of operating current in still liquid.

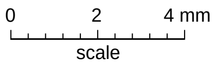
PACKAGE OUTLINE

Hermetically sealed glass package; axial leaded; 2 leads **SOD68**



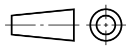
DIMENSIONS (mm are the original dimensions)

UNIT	b max.	D max.	G_1 max.	L min.
mm	0.55	1.6	3.04	25.4



Note

1. The marking band indicates the cathode.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOD68		DO-34				97-06-09

DEFINITIONS

Data Sheet Status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

LIFE SUPPORT APPLICATIONS

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NOTES

NOTES

NOTES

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[C3] Microcontroller

ATmega328

Atmel

Atmel 8-bit Microcontroller with 4/8/16/32KBytes In-System Programmable Flash

ATmega48A; ATmega48PA; ATmega88A; ATmega88PA; ATmega168A; ATmega168PA; ATmega328; ATmega328P

SUMMARY

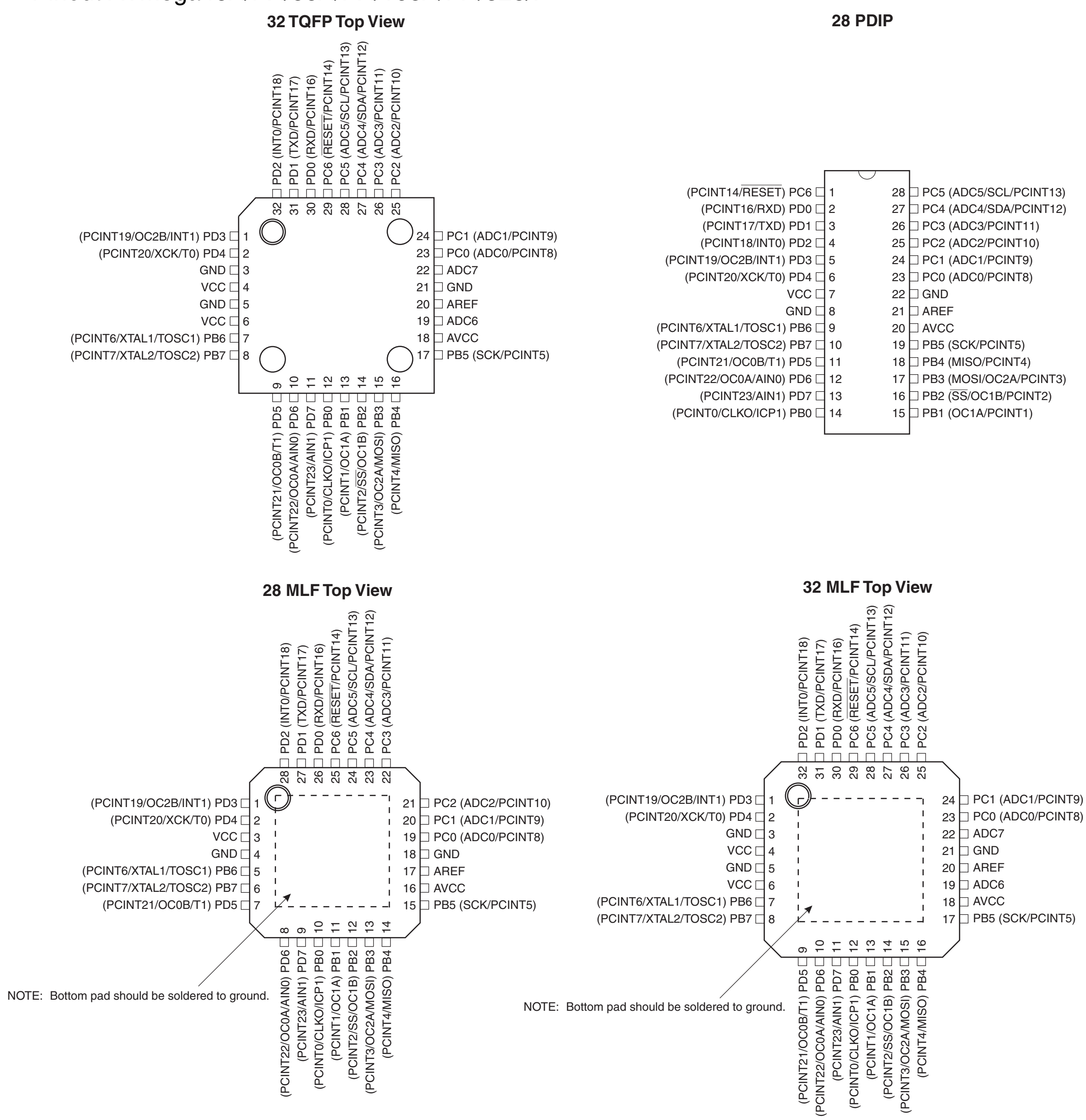
Features

- High Performance, Low Power Atmel®AVR® 8-Bit Microcontroller Family
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 4/8/16/32KBytes of In-System Self-Programmable Flash program memory
  - 256/512/512/1KBytes EEPROM
  - 512/1K/1K/2KBytes Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C[(1)]
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - Programming Lock for Software Security
- Atmel® QTouch® library support
  - Capacitive touch buttons, sliders and wheels
  - QTouch and QMatrix® acquisition
  - Up to 64 sense channels
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Six PWM Channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
    Temperature Measurement
  - 6-channel 10-bit ADC in PDIP Package
    Temperature Measurement
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Byte-oriented 2-wire Serial Interface (Philips I^2C compatible)
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby

- **I/O and Packages**
  - **23 Programmable I/O Lines**
  - **28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF**
- **Operating Voltage:**
  - **1.8 - 5.5V**
- **Temperature Range:**
  - **-40°C to 85°C**
- **Speed Grade:**
  - **0 - 4MHz@1.8 - 5.5V, 0 - 10MHz@2.7 - 5.5.V, 0 - 20MHz @ 4.5 - 5.5V**
- **Power Consumption at 1MHz, 1.8V, 25°C**
  - **Active Mode: 0.2mA**
  - **Power-down Mode: 0.1µA**
  - **Power-save Mode: 0.75µA (Including 32kHz RTC)**

1. Pin Configurations

Figure 1-1. Pinout ATmega48A/PA/88A/PA/168A/PA/328/P



High Temperature Series
Nickel-Metal Hydride
VHT 7/5 Cs

The Ni-MH VHT range has been specially designed to fit the emergency lighting and high temperature power back-up requirements. This range complements the Ni-Cd VT range.

The VHT 7/5 Cs is designed to accept a permanent charge in high temperature environments such as in security lighting equipment. With an IEC capacity of 4.0 Ah, the VHT 7/5 Cs particulary suits slim design fixtures as it provides the same capacity as a Ni-Cd D cell in a smaller diameter.

To meet customers' requirements, Saft provides custom-designed and standardized battery packs.

For your battery design and system needs, please contact Saft's engineers.

Applications
- Emergency lighting
- Back-up systems

Main advantages
- Excellent charge efficiency at high temperatures
- Permanent charge
- Superior storage retention

Technology
- Foam positive electrode
- Metal-hydride negative electrode

Temperature range in discharge
- 10°C to + 55°C

Storage
Recommended: + 5°C to + 25°C
Relative humidity: 65 ± 5%

Electrical characteristics	
Nominal voltage (V)	1.2
Typical capacity (mAh)*	4200
IEC rated capacity (mAh)*	4000
IEC designation	HRMT 23/62
Impedance at 1000 Hz (mΩ)	20

* Charge 16 h at C/10, discharge at C/5.

Dimensions	
Diameter (mm)	22.0 ± 0.05
Height (mm)	60.0 ± 0.3
Top projection (mm)	0.85 ± 0.2
Top flat area diameter (mm)	10.0 ± 0.1
Weight (g)	74

Dimensions are given for bare cells.

Charge conditions			
Rate	Time (h)	Temp. (°C)	Charge current (mA)
Standard	16	- 10 to + 55	400
Permanent	-	-	up to 200

Maximum discharge current	
Continuous (A) at + 20°C	15
Peak (A) at + 20°C*	130

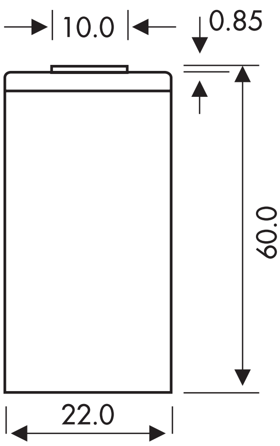
* Peak duration: 0.3 second - final discharge voltage 0.6 volt/cell.

saft

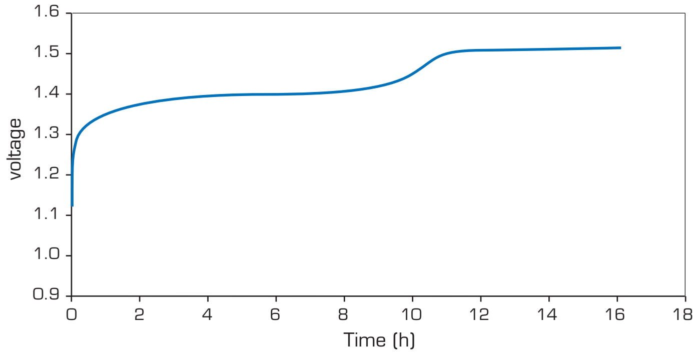
Typical performances

For graphs shown, C is the IEC_5 capacity.

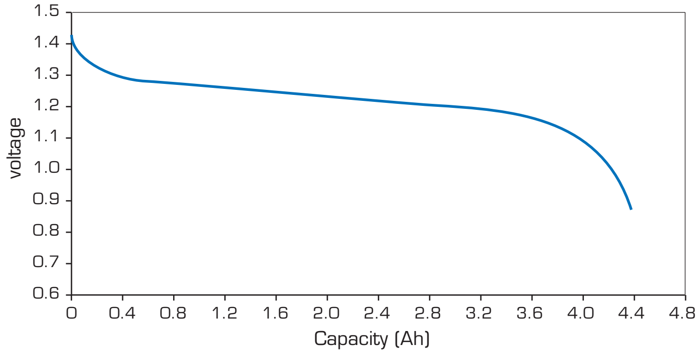
Dimensions are in mm.



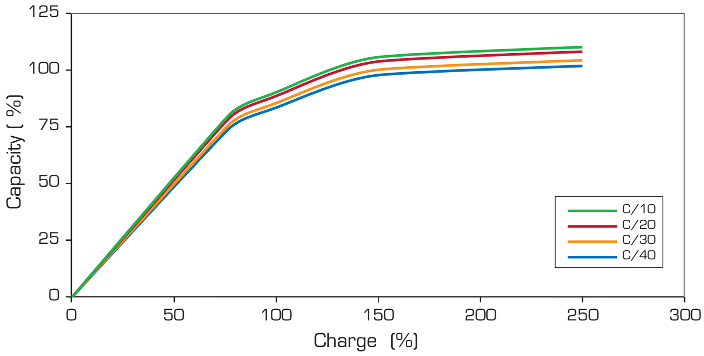
Charge 16h at C/10 at room temperature



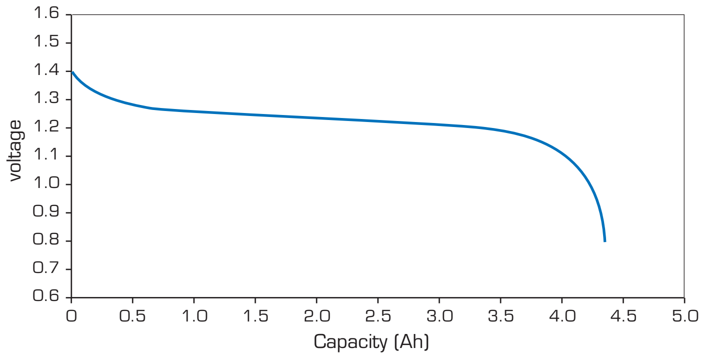
Discharge at C/5 after charge 16h at C/10 at room temperature



Capacity after different charge rate at +40°C



Discharge at 0.25C at +55°C after charge at C/20 at +55°C



Data are given for single cells. Please consult Saft for any use of this cell in other conditions than those given in this data sheet.

Saft
Rechargeable Battery Systems
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Fax: +33 (0)1 49 93 19 68
Email: rbs.info@saftbatteries.com

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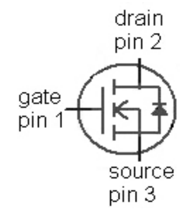
*Opti**MOS***®3 Power-Transistor

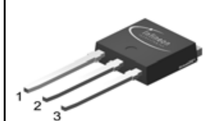
Product Summary

V_{DS}	30	V
$R_{DS(on),max}$	3.9	mΩ
I_D	50	A

Features

- Fast switching MOSFET for SMPS
- Optimized technology for DC/DC converters
- Qualified according to JEDEC[1)] for target applications
- N-channel, logic level
- Excellent gate charge x $R_{DS(on)}$ product (FOM)
- Very low on-resistance $R_{DS(on)}$
- Avalanche rated
- Pb-free plating; RoHS compliant



Type	IPF039N03L G	IPU039N03L G
		
Package	PG-TO252-3-23	PG-TO251-3-21
Marking	039N03L	039N03L

Maximum ratings, at T_j=25 °C, unless otherwise specified

Parameter	**Symbol**	**Conditions**	**Value**	**Unit**
Continuous drain current	I_D	V_{GS}=10 V, T_C=25 °C	50	A
		V_{GS}=10 V, T_C=100 °C	50	
		V_{GS}=4.5 V, T_C=25 °C	50	
		V_{GS}=4.5 V, T_C=100 °C	50	
Pulsed drain current[2)]	$I_{D,pulse}$	T_C=25 °C	350	
Avalanche current, single pulse[3)]	I_{AS}	T_C=25 °C	50	
Avalanche energy, single pulse	E_{AS}	I_D=50 A, R_{GS}=25 Ω	115	mJ
Reverse diode d*v*/d*t*	d*v*/d*t*	I_D=50 A, V_{DS}=24 V, d*i*/d*t*=200 A/µs, $T_{j,max}$=175 °C	6	kV/µs
Gate source voltage	V_{GS}		±20	V

1) J-STD20 and JESD22

Maximum ratings, at T_j=25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value	Unit
Power dissipation	P_{tot}	T_C=25 °C	94	W
Operating and storage temperature	T_j, T_{stg}		-55 ... 175	°C
IEC climatic category; DIN IEC 68-1			55/175/56	

Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	
Thermal characteristics						
Thermal resistance, junction - case	R_{thJC}		-	-	1.6	K/W
SMD version, device on PCB	R_{thJA}	minimal footprint	-	-	75	
		6 cm² cooling area[4]	-	-	50	

Electrical characteristics, at T_j=25 °C, unless otherwise specified

Parameter	Symbol	Conditions	min.	typ.	max.	Unit
Static characteristics						
Drain-source breakdown voltage	$V_{(BR)DSS}$	V_{GS}=0 V, I_D=1 mA	30	-	-	V
Gate threshold voltage	$V_{GS(th)}$	V_{DS}=V_{GS}, I_D=250 µA	1	-	2.2	
Zero gate voltage drain current	I_{DSS}	V_{DS}=30 V, V_{GS}=0 V, T_j=25 °C	-	0.1	1	µA
		V_{DS}=30 V, V_{GS}=0 V, T_j=125 °C	-	10	100	
Gate-source leakage current	I_{GSS}	V_{GS}=20 V, V_{DS}=0 V	-	10	100	nA
Drain-source on-state resistance[5]	$R_{DS(on)}$	V_{GS}=4.5 V, I_D=30 A	-	4.2	5.2	mΩ
		V_{GS}=10 V, I_D=30 A	-	3.3	3.9	
Gate resistance	R_G		-	1.6	-	Ω
Transconductance	g_{fs}	$\|V_{DS}\|>2\|I_D\|R_{DS(on)max}$, I_D=30 A	48	96	-	S

[2] See figure 3 for more detailed information

[3] See figure 13 for more detailed information

[4] Device on 40 mm x 40 mm x 1.5 mm epoxy PCB FR4 with 6 cm2 (one layer, 70 µm thick) copper area for drain connection. PCB is vertical in still air.

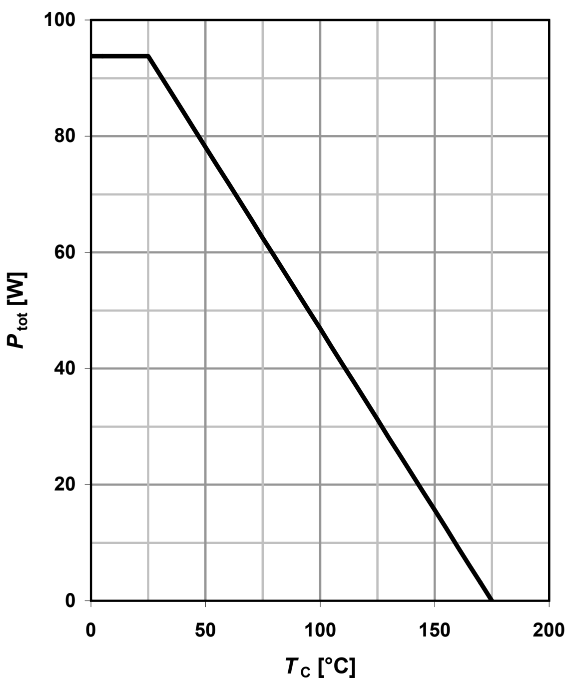
[5] Measured from drain tab to source pin

Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	
Dynamic characteristics						
Input capacitance	C_{iss}	V_{GS}=0 V, V_{DS}=15 V, f=1 MHz	-	4000	5300	pF
Output capacitance	C_{oss}		-	1400	1900	
Reverse transfer capacitance	C_{rss}		-	81	120	
Turn-on delay time	$t_{d(on)}$	V_{DD}=15 V, V_{GS}=10 V, I_D=30 A, R_G=1.6 Ω	-	9	-	ns
Rise time	t_r		-	7	-	
Turn-off delay time	$t_{d(off)}$		-	35	-	
Fall time	t_f		-	5	-	
Gate Charge Characteristics[6)]						
Gate to source charge	Q_{gs}	V_{DD}=15 V, I_D=30 A, V_{GS}=0 to 4.5 V	-	12	-	nC
Gate charge at threshold	$Q_{g(th)}$		-	6.3	-	
Gate to drain charge	Q_{gd}		-	5.6	-	
Switching charge	Q_{sw}		-	11	-	
Gate charge total	Q_g		-	25	-	
Gate plateau voltage	$V_{plateau}$		-	2.9	-	V
Gate charge total	Q_g	V_{DD}=15 V, I_D=30 A, V_{GS}=0 to 10 V	-	51	-	
Gate charge total, sync. FET	$Q_{g(sync)}$	V_{DS}=0.1 V, V_{GS}=0 to 4.5 V	-	22	-	nC
Output charge	Q_{oss}	V_{DD}=15 V, V_{GS}=0 V	-	37	-	
Reverse Diode						
Diode continuous forward current	I_S	T_C=25 °C	-	-	50	A
Diode pulse current	$I_{S,pulse}$		-	-	350	
Diode forward voltage	V_{SD}	V_{GS}=0 V, I_F=30 A, T_j=25 °C	-	0.85	1.1	V
Reverse recovery charge	Q_{rr}	V_R=15 V, I_F=I_S, di_F/dt=400 A/µs	-	-	20	nC

6) See figure 16 for gate charge parameter definition

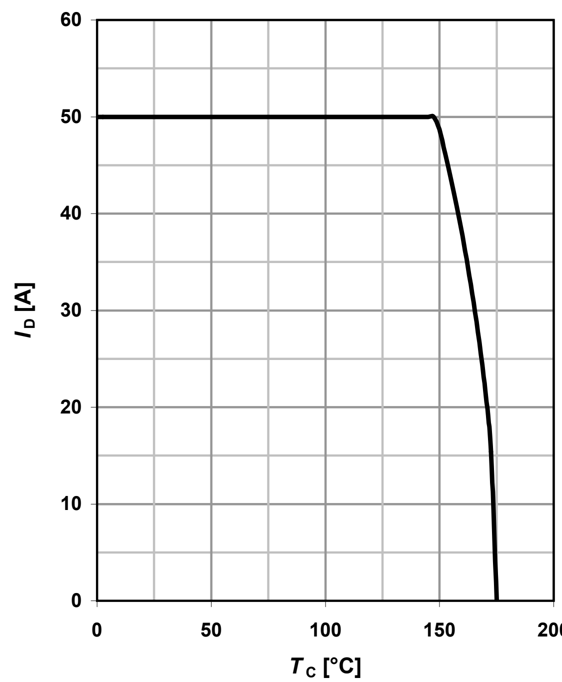
1 Power dissipation

P_{tot}=f(T_C)



2 Drain current

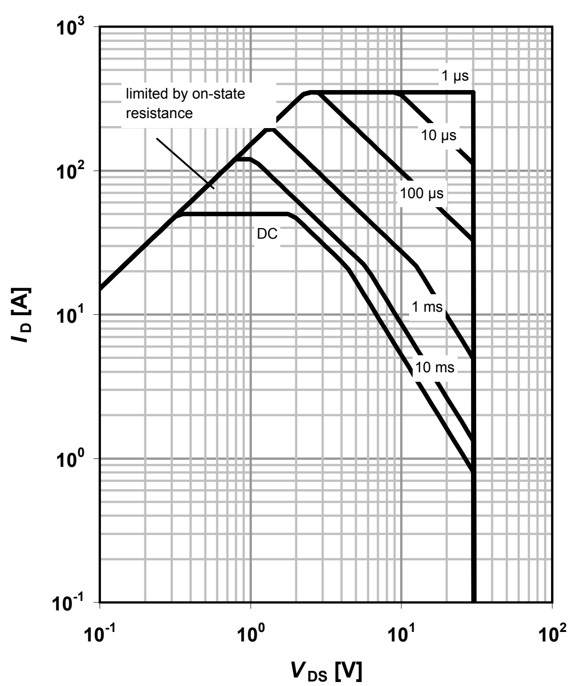
I_D=f(T_C); V_{GS}≥10 V



3 Safe operating area

I_D=f(V_{DS}); T_C=25 °C; D=0

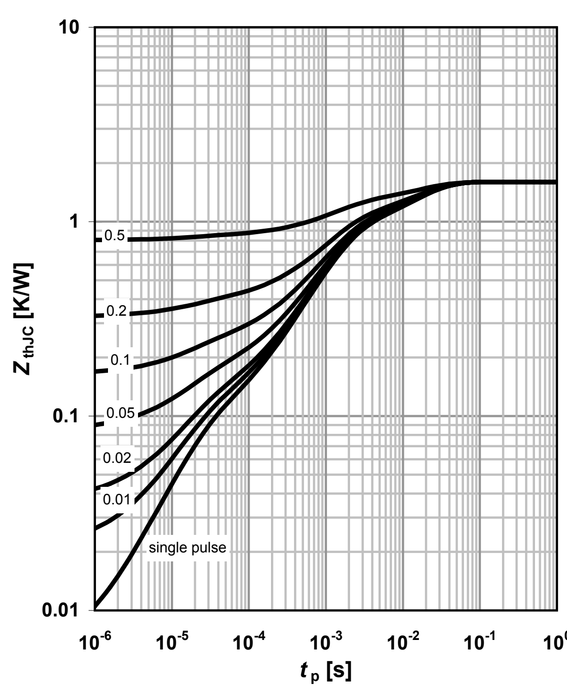
parameter: t_p



4 Max. transient thermal impedance

Z_{thJC}=f(t_p)

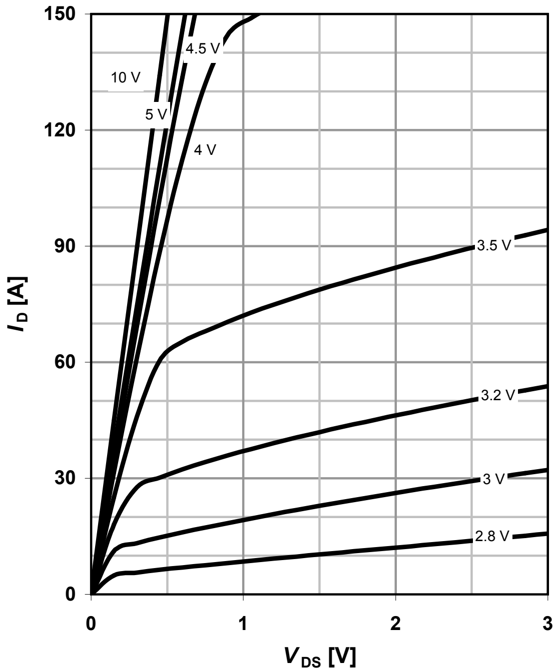
parameter: $D=t_p/T$



5 Typ. output characteristics

I_D=f(V_{DS}); T_j=25 °C

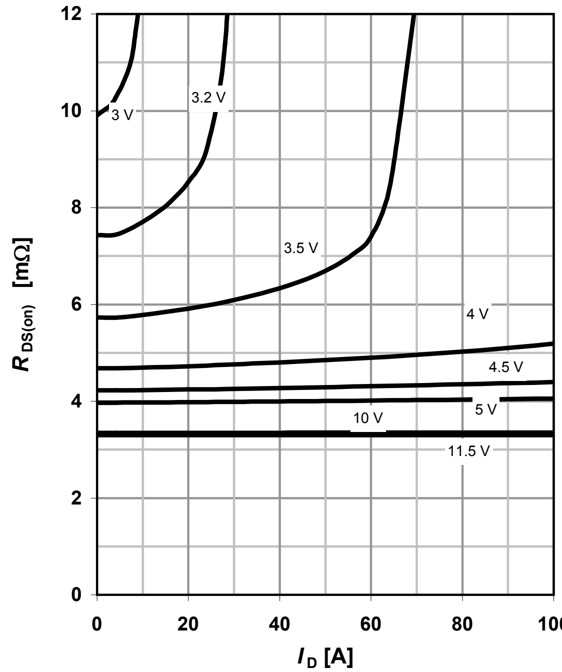
parameter: V_{GS}



6 Typ. drain-source on resistance

$R_{DS(on)}$=f(I_D); T_j=25 °C

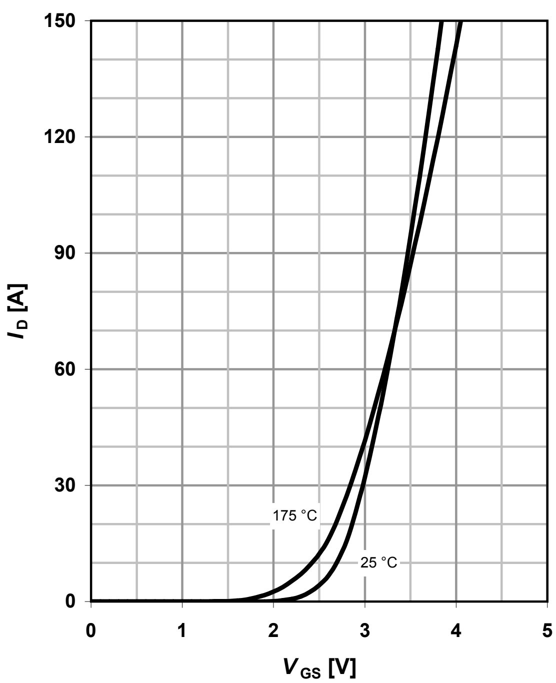
parameter: V_{GS}



7 Typ. transfer characteristics

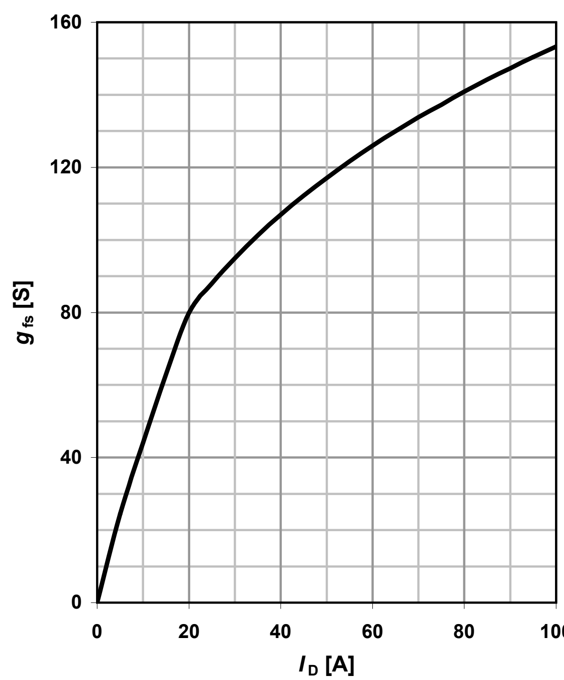
I_D=f(V_{GS}); $|V_{DS}|>2|I_D|R_{DS(on)max}$

parameter: T_j



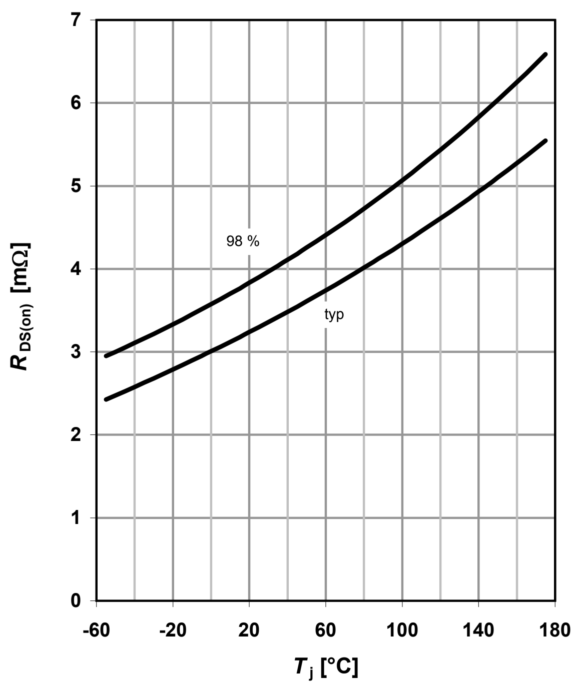
8 Typ. forward transconductance

g_{fs}=f(I_D); T_j=25 °C



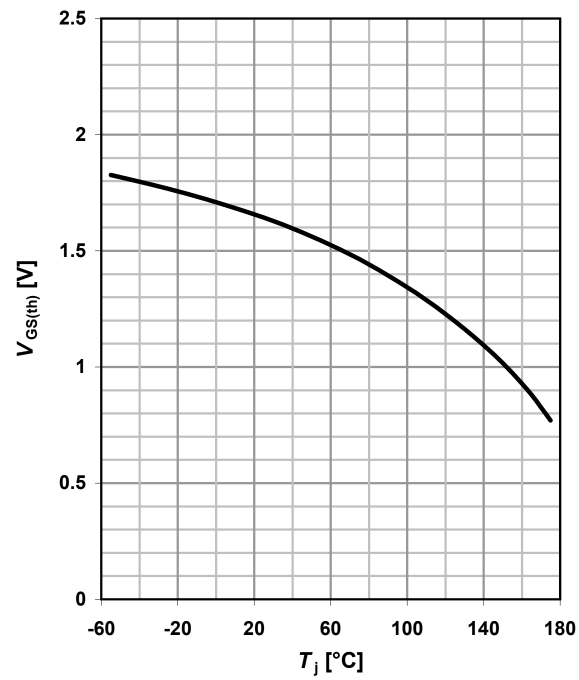
9 Drain-source on-state resistance

$R_{DS(on)}$=f(T_j); I_D=30 A; V_{GS}=10 V



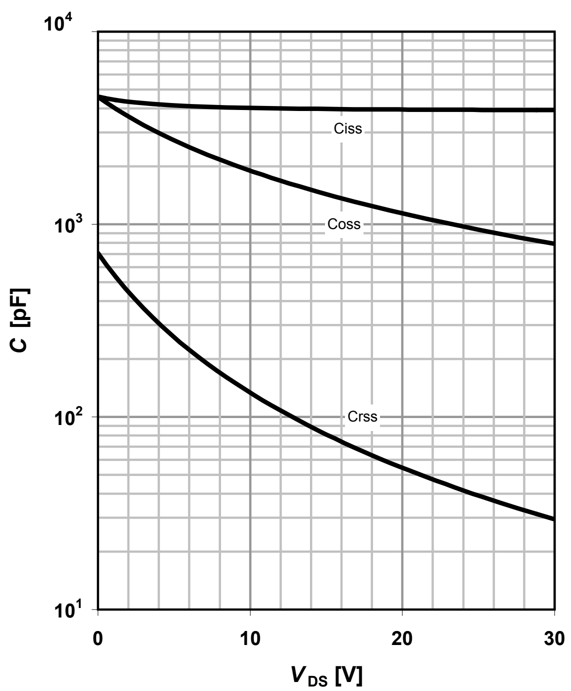
10 Typ. gate threshold voltage

$V_{GS(th)}$=f(T_j); V_{GS}=V_{DS}; I_D=250 µA



11 Typ. capacitances

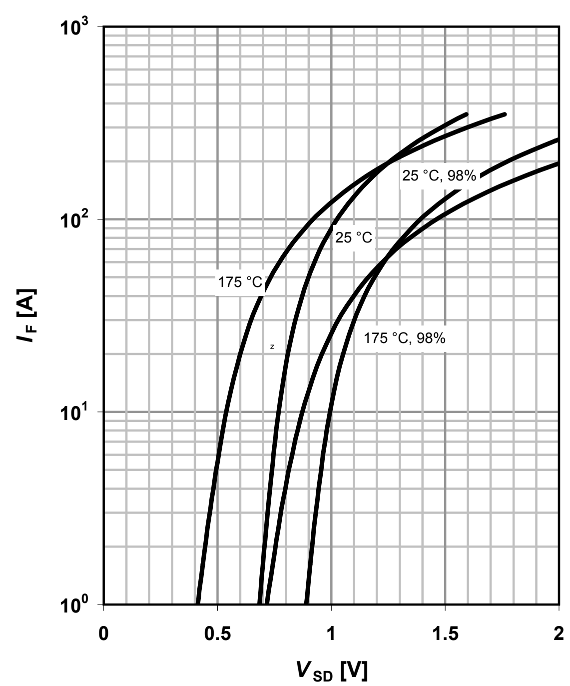
C=f(V_{DS}); V_{GS}=0 V; f=1 MHz



12 Forward characteristics of reverse diode

I_F=f(V_{SD})

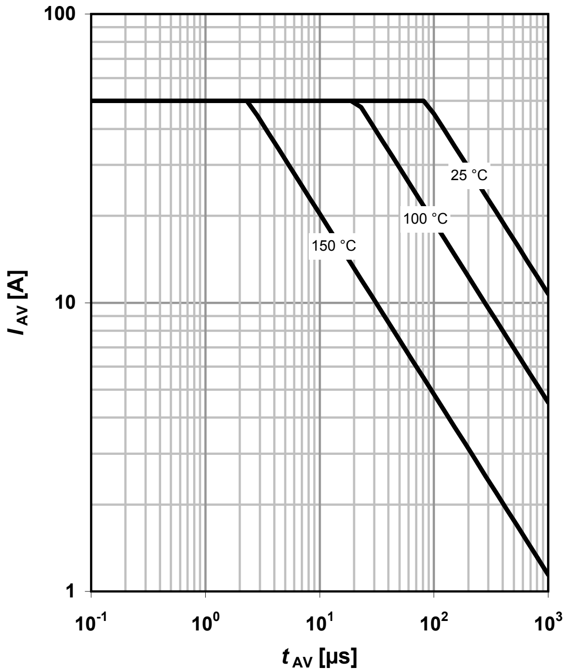
parameter: T_j



13 Avalanche characteristics

I_{AS}=f(t_{AV}); R_{GS}=25 Ω

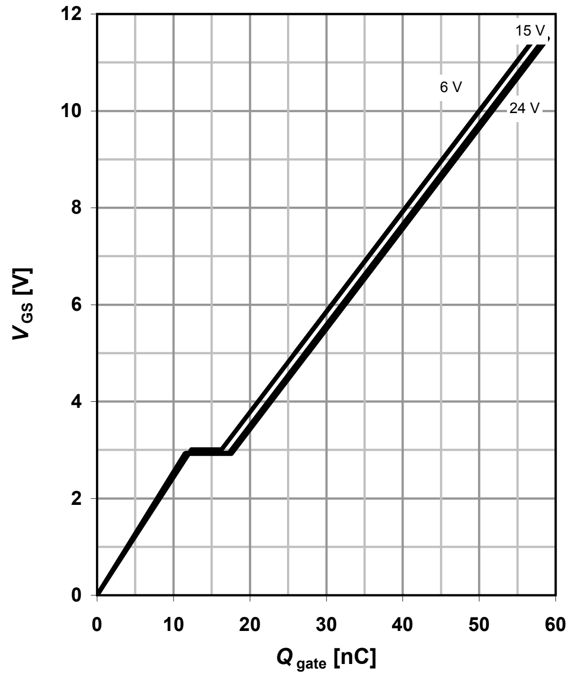
parameter: $T_{j(start)}$



14 Typ. gate charge

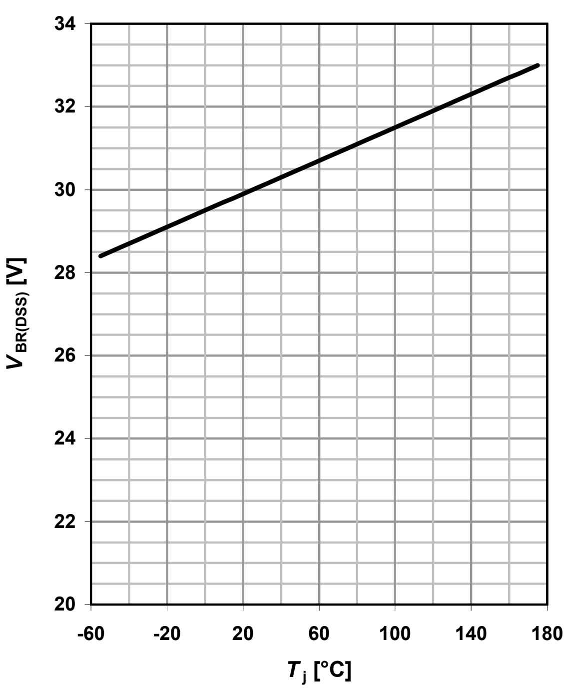
V_{GS}=f(Q_{gate}); I_D=30 A pulsed

parameter: V_{DD}

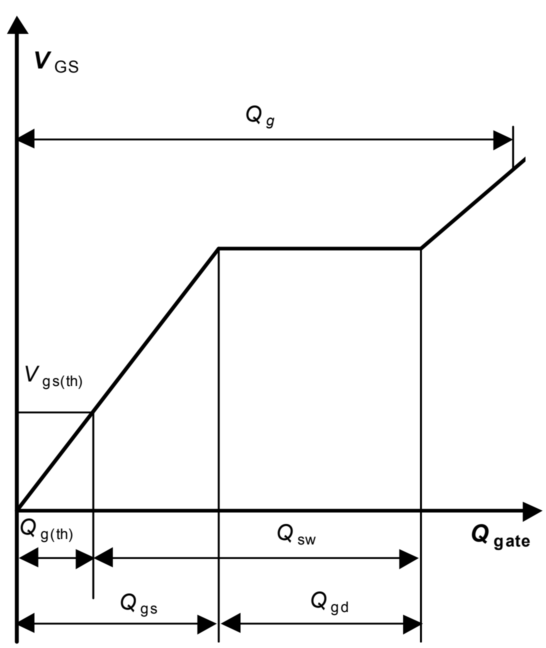


15 Drain-source breakdown voltage

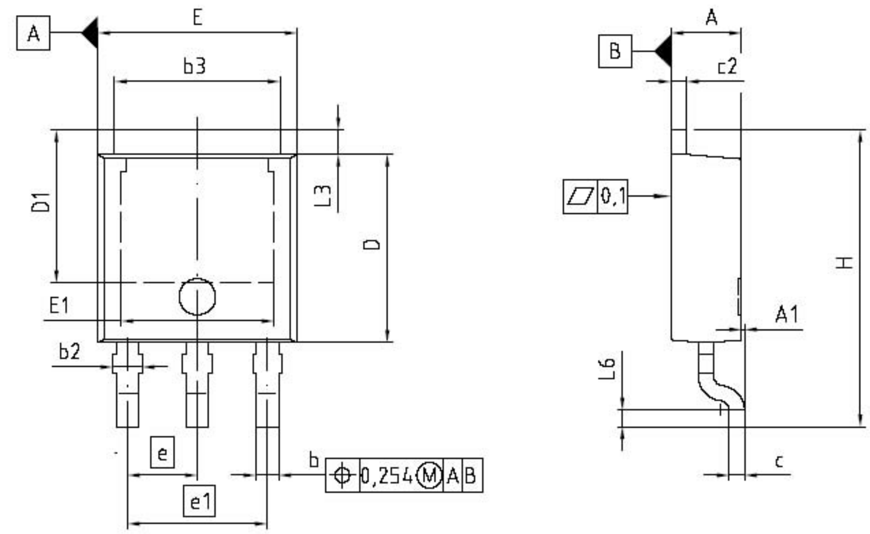
$V_{BR(DSS)}$=f(T_j); I_D=1 mA

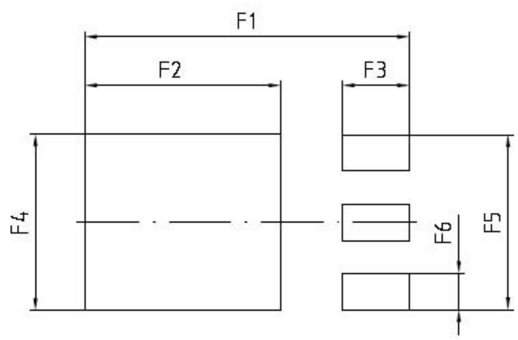


16 Gate charge waveforms



Package Outline **PG-TO252-3-23**



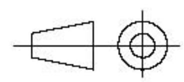


DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	2.159	2.413	0.085	0.095
A1	0.000	0.150	0.000	0.006
b	0.635	0.889	0.025	0.035
b2	0.650	1.150	0.026	0.045
b3	5.004	5.500	0.197	0.217
c	0.457	0.580	0.018	0.023
c2	0.460	0.980	0.018	0.039
D	5.969	6.223	0.235	0.245
D1	5.020	5.842	0.198	0.230
E	6.400	6.731	0.252	0.265
E1	4.850	5.207	0.191	0.205
e	2.286		0.090	
e1	4.572		0.180	
N	3		3	
H	9.400	10.480	0.370	0.413
L3	0.900	1.143	0.035	0.045
L4	0.584	0.950	0.023	0.037
L6	0.510	0.686	0.020	0.027
F1	10.500	10.700	0.413	0.421
F2	6.300	6.500	0.248	0.256
F3	2.100	2.300	0.083	0.091
F4	5.700	5.900	0.224	0.232
F5	5.660	5.860	0.222	0.231
F6	1.100	1.300	0.043	0.051

REFERENCE
- / -

SCALE
0
2.0
0 2.0 4mm

EUROPEAN PROJECTION

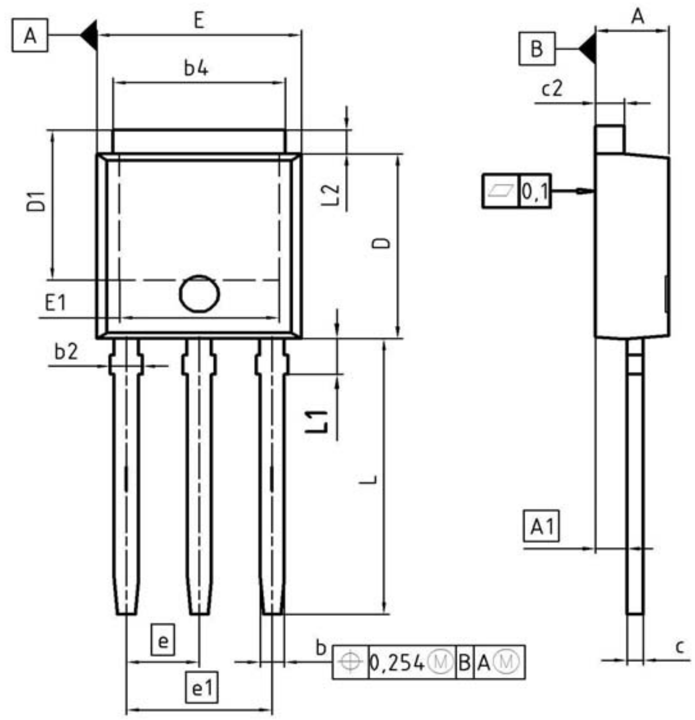


ISSUE DATE
21-09-2005

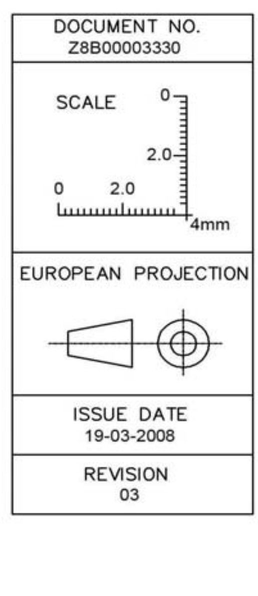
FILE
TO252_2

Package Outline **PG-TO251-3-21**

PG-TO251-3-11: Outline



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	2.16	2.41	0.085	0.095
A1	0.90	1.14	0.035	0.045
b	0.64	0.89	0.025	0.035
b2	0.65	1.15	0.026	0.045
b4	4.95	5.50	0.195	0.217
c	0.46	0.60	0.018	0.024
c2	0.46	0.89	0.018	0.035
D	5.97	6.22	0.235	0.245
D1	5.04	5.77	0.198	0.227
E	6.35	6.73	0.250	0.265
E1	4.70	5.21	0.185	0.205
e	2.29		0.090	
e1	4.57		0.180	
N	3		3	
L	8.89	9.65	0.350	0.380
L1	1.90	2.29	0.075	0.090
L2	0.89	1.37	0.035	0.054



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Säkerhetsdatablad:

Henkel Technologies

Reviderad datum: 22/01/2004
Utfärdat: 09/09/2004

1. NAMNET PÅ PRODUKTEN OCH FÖRETAGET

Handelsnamn: Loctite(R) 270
Produkt/IDH nummer: 21436
Produkttyp: Anaerob
Region: Europa
Företagsadress:
Henkel Technologies Norden AB
Box 8823
SE-402 71 Göteborg
Sweden
Tel. nummer: +46 31 750 54 00
Faxnummer: +46 31 750 53 91
Nödnummer: +353-1-4599301/+353-87-2629625/+353-1-4046444

2. SAMMANSÄTTNING/ÄMNENAS KLASSIFICERING

Produkttyp: Produkt baserad på polyetylenglykol dimetakrylat.

Komponenter **CAS No.**	**EINECS-Nr.**	**%**	**Klassificering**
Kumenväteperoxid 80-15-9	201-254-7	1 - 5	C;R34 N;R51/53 O;R7 T;R23 Xn;R21/22-48/20/22
Dimetyltoluidin 609-72-3	210-199-8	0.1 - 1.0	R33 R52/53 T;R23/24/25

Ytterligare information:
För förklaring av de listade riskfraserna se punkt 16.

3. FARLIGA EGENSKAPER

De viktigaste exponeringsvägarna: Hud, Andningsorgan, Ögon

Irriterar ögonen och andningsorganen.

Upprepad eller långvarig kontakt med sargad eller känslig hud kan ge hudallergi.

4. FÖRSTA HJÄLPEN

Inandning: För den drabbade till frisk luft. Om illamående kvarstår uppsök läkare.

Stänk i ögon: Skölj genast med mycket vatten i minst 15 minuter. Om besvären kvarstår, kontakta läkare.

Förtäring: Skölj munnen med vatten. Drick stora mänger vatten. Framkalla inte kräkning. Kontakta läkare.

Hudkontakt: Tvätta med tvål och mycket vatten. Om hudirritation kvarstår, kontakta läkare.

5. ÅTGÄRDER VID BRAND

Lämpliga brandsläckningsmedel: Utsätts produkten för brand ska pulver, skum eller koldioxid användas för att släcka.

Särskilda brandbekämpningsprocedurer: Använd inbyggd andningsapparat.

Förbränningsprodukter: Termisk sönderdelning kan leda till utsläpp av irriterande gaser och ångor. Koloxider. Oxider av kväve.

6. ÅTGÄRDER VID OAVSIKTLIGA UTSLÄPP

Försiktighetsåtgärder beträffande miljön: Ventilera utrymmet. Försök hindra att materialet kommer ned i avlopp eller vattendrag.

Åtgärder vid omhändertagande av spill: Skrapa och samla upp det spillda materialet i slutna behållare för vidare destruktion. Se punkt 13.

7. HANTERING OCH LAGRING

Hantering: Använd endast på väl ventilerade platser. Undvik kontakt med huden och ögonen. Se punkt 8.

Lagring: Förvaras i ursprungsbehållare vid 8-21°C (46,4-69,8°F). Restmaterial får inte återföras till behållarna eftersom kontamination kan reducera bulkproduktens hållbarhet.

8. PERSONLIGA SKYDDSÅTGÄRDER / BEGRÄNSNING AV EXPONERINGEN

Tekniska åtgärder: Sörj för god industrihygien.

Andningsskydd: Sörj för god ventilation.

Skydd för huden: Undvik kontakt med huden och ögonen. Butyl- eller nitrilgummihandskar rekommenderas.

Skyddsglasögon eller ansiktsskydd: Skyddsglasögon bör användas.

9. FYSIKALISKA OCH KEMISKA EGENSKAPER

Tillstånd:	Vätska
Färg:	Grön
Lukt:	Karakteristisk
pH:	3 - 6
Ångtryck:	Mindre än 0.1 mm Hg vid 25ºC (77ºF)
Densitet:	1.08
Flampunkt:	Högre än 100°C (212°F)
Löslighet i vatten:	Icke blandbar
Löslighet i aceton:	Blandbar
Koncentrationen av FOF:	< 3%

10. STABILITET OCH REAKTIVITET

Stabilitet: Stabil vid rekommenderade lagringsförhållanden.

Polymerisation: Riskabel polymerisering kan ske vid närvaro av överskott av peroxider och metallföroreningar.

Farliga sönderdelningsprodukter: Termisk sönderdelning kan leda till utsläpp av irriterande gaser och ångor. Oxider av kol. Oxider av kväve.

Material som skall undvikas: Starka syror och oxiderande ämnen, oxygen scavengers. Starka alkalier, reducerande ämnen. Övriga polymerisationsinitierare.

Förhållanden som skall undvikas: Höga temperaturer. Se "Hantering och förvaring" (avsnitt 7) och "Oförenlighet" (avsnitt 10).

11. TOXIKOLOGISK INFORMATION

Komponenter CAS No.	LD50 & LC50 (NIOSH) :
Kumenväteperoxid 80-15-9	Inhalation LC50 (Mouse) = 200 ppm Inhalation LC50 (Rat) = 220 ppm Oral LD50 (Rat) = 382 mg/kg

Inandning: Irriterar andningsorganen.

Hud: Normalt ingen allergiframkallande produkt men vid upprepad eller långvarig kontakt med skadad eller känslig hud kan allergi uppstå.

Ögon: Irriterar ögonen.

Förtäring: Kan ge irritation i matsmältningsorganen.

12. EKOTOXIKOLOGISK INFORMATION

Rörlighet: Inga tillgängliga data.

Bioackumulering: Inga tillgängliga data.

Ekotoxicitetseffekter: Förvaras på avstånd från avlopp och öppet vatten.

Persistens/Nedbrytbarhet: Inga tillgängliga data.

WGK Vattenklassificering (VwVwS) Klass 1

13. AVFALLSHANTERING

Produkt:
Avfallshantering Produkt deponeras enligt lokala och nationella lagar och förordningar. Avfallsbidraget från denna produkt är ytterst obetydligt i förhållande till detaljen där den används.

Europeiska avfallskatalogen: 08 04 09 Rester av bindemedel och tätningsmedel som innehåller organiska lösningsmedel och andra farliga ämnen.

Förpackning:
Avfallshantering Förbrukade förpackningar kontaminerade med denna produkt ska hanteras som miljöfarligt avfall och deponeras enligt lokala och nationella lagar och förordningar

14. TRANSPORTINFORMATION

ICAO/IATA (flygtransport):

UN-nummer: Ingen
Transportbeteckning: Inga restriktioner
Klass: Ingen
Förpackningsgrupp: Ingen

IMO/IMDG (sjötransport)

UN-nummer: Ingen
Transportbeteckning: Utan restriktioner
Klass: Ingen
Förpackningsgrupp: Ingen

EmS: Ingen

ADR/RID (landsvägs-/järnvägstransport)

UN-nummer: Ingen
Transportbeteckning: Utan restriktioner
Klass: Ingen
Förpackningsgrupp: Ingen
Klassificeringskod : Ingen

15. GÄLLANDE BESTÄMMELSER

Farosymboler: Xi - Irriterande.

R-fraser: R36/37 - Irriterar ögonen och andningsorganen.

S-fraser
S25 - Undvik kontakt med ögonen.
S26 - Vid kontakt med ögonen, spola genast med mycket vatten och kontakta läkare.
S51 - Sörj för god ventilation.

Övrig information: Ingen

16. ÖVRIG INFORMATION

Tillverkad av: Vanessa Doherty PSRA Specialist, Product Safety & Regulatory Affairs - Europe

Hänvisning till härdade plaster: Arbetarskyddsstyrelsens riktlinjer AFS 1996:4 Härdplaster gäller för denna produkt.

Informationen i detta varuinformationsblad har erhållits från ansedda källor och är så vitt vi kan bedömma riktiga vid nämnda datum. Varken Loctite eller dess dotterbolag påtar sig något ansvar för användning av denna information. Ej heller för användning, applicering eller behandling av här i nämnda produkter. Användaren bör uppmärksamma de möjliga riskerna som är förknippade med felaktig användning av produkten. Detta säkerhetsdatablad har framställts i enlighet med Council Directive 67/548/EEC och dess efterföljande ändringar, samt i enlighet med Commission Directive 1999/45/EC.

Förklaring av R-fraserna i punkt 2
R34 - Frätande.
R 7 - Kan orsaka brand.
R33 - Kan ansamlas i kroppen och ge skador.
R36 - Irriterar ögonen.
R21/22 - Farligt vid hudkontakt och förtäring.
R23/24/25 - Giftigt vid inandning, hudkontakt och förtäring.
R48/20/22 - Farligt: risk för allvarliga hälsoskador vid långvarig exponering genom inandning och förtäring.
R51/53 - Giftigt för vattenlevande organismer, kan orsaka skadliga långtidseffekter i vattenmiljön.
R52/53 - Skadligt för vattenlevande organismer, kan orsaka skadliga långtidseffekter i vattenmiljön.

Fast Cure, Non-Corrosive Silicone Adhesive Sealant TSE397

Product Description

TSE397 is a one-component, fast cure, non-corrosive silicone adhesive sealant that cures on exposure to atmospheric moisture to form an elastic silicone rubber. TSE397 has a pourable consistency and excellent corrosion-free adhesion to metals, including copper, plastics, ceramics, glass, etc. without the use of primers.

Key Features and Typical Benefits

- Non-corrosive to metals: meets MIL-A-46146B corrosion test
- Fast cure
- Low odor: releases an alcohol vapor during cure
- Primerless adhesion to many substrates
- Excellent high and low temperature resistance: from –55°C to 200°C
- Excellent weatherability, ozone, and chemical resistance
- Excellent electrical insulation properties
- UL94 HB recognized (File No: E56745): TSE397-B, TSE397-C, TSE397-W
- Simple and easy-to-use one-component system

Typical Property Data (JIS K 6249)

UNCURED PROPERTIES		
Appearance		Flowable paste
Viscosity (23°C)	Pa•s {P}	50 {50}
Tack Free Time (23°C)	min	10
Corrosion (MIL-A-46146B)		None
CURED PROPERTIES (7 days @ 23°C / 50%RH)		
Appearance		Elastic rubber
Density (23°C)	g/cm^3	1.04
Hardness (Type A)		13
Tensile Strength	MPa {kgf/cm^2}	1.2 {12}
Elongation	%	360
Adhesive Strength*1	MPa {kgf/cm^2}	1.0 {10}
Thermal Conductivity*2	W/m•K	0.18
Volume Resistivity	MΩ•m {Ω•cm}	2.0×10^{7} {2.0×10^{15}}
Dielectric Strength	kV/mm	22
Dielectric Constant (60Hz)		2.9
Dielectric Loss (60Hz)		0.005

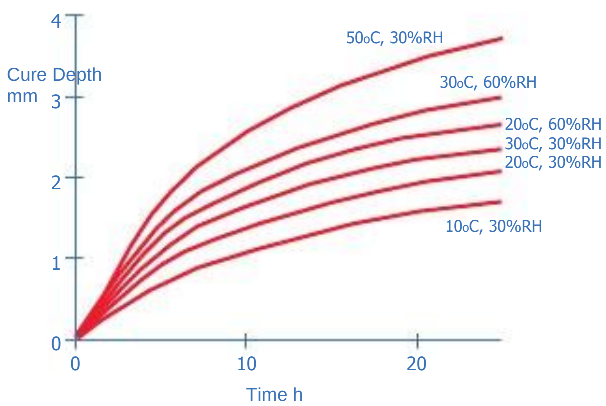
*1 Aluminum lap shear
*2 In-house test method
Typical property data values should not be used as specifications.

Potential Applications

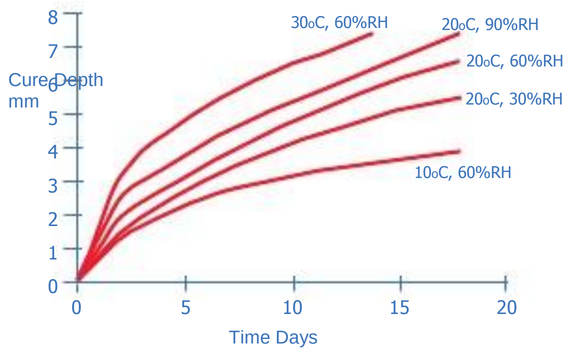
- Insulating adhesive seal and coating for electrical and electronic parts
- Waterproof sealant for electrical, electronic and communication equipment
- General adhesive for metals, glass, plastics, etc.

Curing Properties

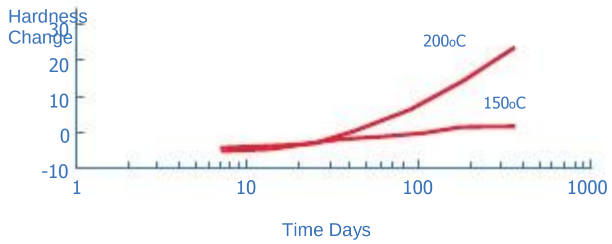
Short-term

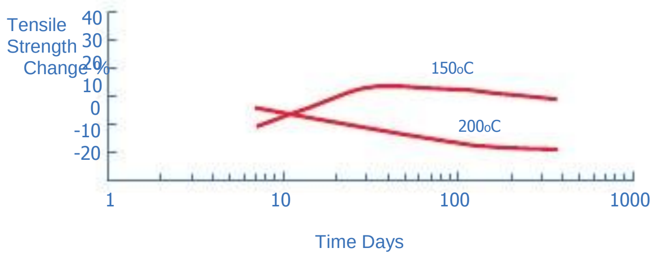


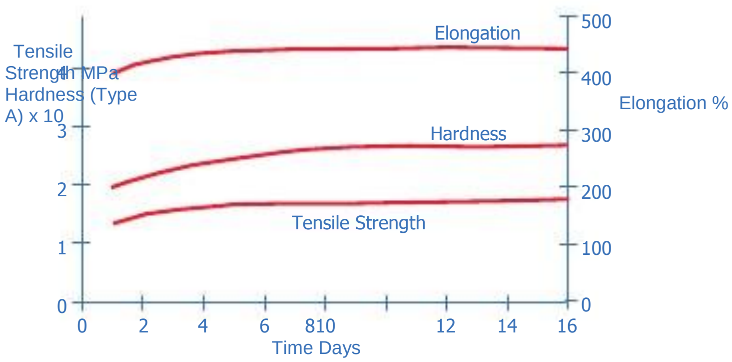
Long-term



Heat Resistance







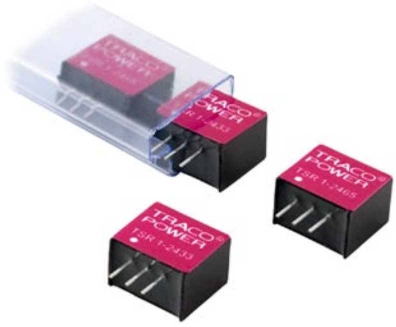
TRACO POWER

DC/DC Converters

TSR-1 Series, 1 A

Features

- Up to 96 % efficiency
  – No heat-sink required
- Pin compatible with LMxx linear regulators
- SIP-package fits existing TO-220 footprint
- Built in filter capacitors
- Operation temp. range –40°C to +85°C
- Short circuit protection
- Wide input operating range
- Excellent line / load regulation
- Low standby current
- 3-year product warranty



The new TSR-1 series step-down switching regulators are drop-in replacement for inefficient 78xx linear regulators. A high efficiency up to 96 % allows full load operation up to +60 °C ambient temperature without the need of any heat-sink or forced cooling.
The TSR-1 switching regulators provide other significant features over linear regulators, i.e. better output accuracy (±2 %), lower standby current of 2 mA and no requirement of external capacitors. The high efficiency and low standby power consumption makes these regulators an ideal solution for many battery powered applications.

Models

Order code	Input voltage range	Output voltage	Output current	Efficiency typ.	
			max.	@ Vin min.	@ Vin max.
TSR 1-2412	**4.6 – 36 VDC***	1.2 VDC		74 %	62 %
TSR 1-2415	**4.6 – 36 VDC***	1.5 VDC		78 %	65 %
TSR 1-2418	**4.6 – 36 VDC***	1.8 VDC		82 %	69 %
TSR 1-2425	**4.6 – 36 VDC***	2.5 VDC		87 %	75 %
TSR 1-2433	**4.75 – 36 VDC***	3.3 VDC	**1.0 A**	91 %	78 %
TSR 1-2450	**6.5 – 36 VDC***	5.0 VDC		94 %	84 %
TSR 1-2465	**9.0 – 36 VDC***	6.5 VDC		93 %	87 %
TSR 1-2490	**12 – 36 VDC***	9.0 VDC		95 %	90 %
TSR 1-24120	**15 – 36 VDC***	12 VDC		95 %	92 %
TSR 1-24150	**18 – 36 VDC***	15 VDC		96 %	94 %

* For input voltage higher than 32 VDC an input capcitor 22 µF / 50 V is required. See application notes (page 3)

Input Specifications

Maximum input current (@ Vin min. and 1 A output current)		1 A
No load input current		1 mA typ.
Reflected ripple current		150 mA see application notes (page 3) for to meet EN55022 class A
Input filter		internal capacitors

Output Specifications

Voltage set accuracy		±2 % (at full load)
Regulation	– Input variation – Load variation (10 – 100 %) 1.2 & 1.5 VDC models: other models:	0.2 % 0.6 % 0.4 %
Overshoot startup voltage		1.0 % max.
Minimum load		not required
Ripple and noise (20 MHz Bandwidth)	1.2 – 6.5 VDC models: 9 – 15 VDC models:	50 mVpk-pk max. 75 mVpk-pk max.
Temperature coefficient		±0.015 % / °C max.
Dynamic load response 50% load change (upper half)		150 mV max. peak variation 250 µS max. response time
Startup rise time 10 % to 90 % Vout		2 mS
Short circuit protection		continuous, automatic recovery
Current limitation		@ 2.5 A typ.
Capacitive load		470 µF max.

General Specifications

Temperature ranges	– Operating – Storage	–40°C to +85°C –55°C to +125°C
Derating		2.4 %/K above 60°C
Thermal shock		acc. MIL-STD-810F
Humidity (non condensing)		95 % rel H max.
Reliability, calculated MTBF (MIL-HDBK-217F, @ 25°C, ground benign)		>5'350'000 h
Isolation voltage		none
Isolation capacity	– Input/Output	40 pF typ.
Isolation resistance	– Input/Output	>1'000 Mohm
Switching frequency		500 kHz typ.
Safety standards		UL 60950-1, EN 60950-1, IEC 60950-1

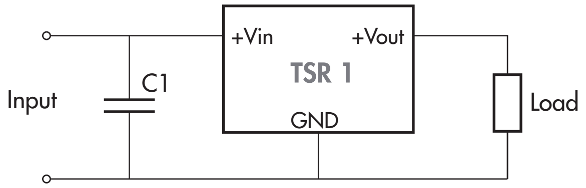
Physical Specifications

Casing material	non-conductive plastic
Potting material	epoxy (flammability to UL 94V-0 rated)
Package weight	1.9 g (0.07 oz)
Soldering profile	max. 265°C / 10 sec. (wave soldering)

All specifications valid at nominal input voltage, full load and +25°C after warm-up time unless otherwise stated.

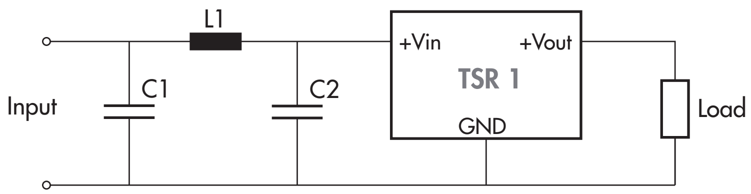
Applications notes

For input voltage higher than 32 VDC (max. 36 VDC)



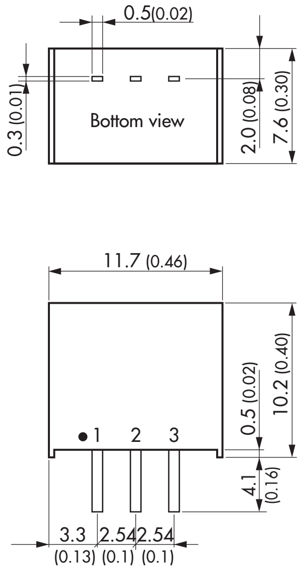
C1 = 22 µF / 50 V

Input filter to meet EN 55022 class A



C1 = 4.7 µF / 50 V
C2 = 4.7 µF / 50 V
L1 = 8.2 µH / 1.5 A / 0.08 Ohm

Outline Dimensions



Pin-Out	
1	+Vin
2	GND
3	+Vout

Dimensions in [mm], () = Inch
Pin pitch tolerances: ±0.25 (±0.01)
Pin profile tolerance: ±0.1 (±0.004)
Other tolerances: ±0.5 (±0.02)

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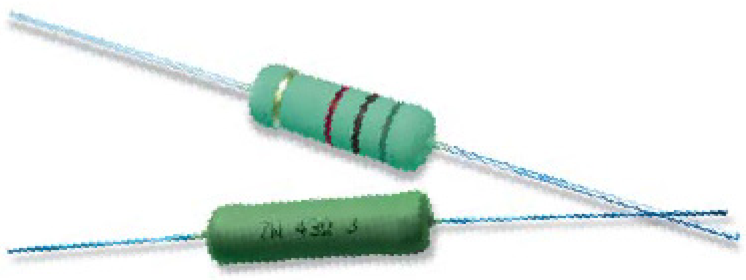
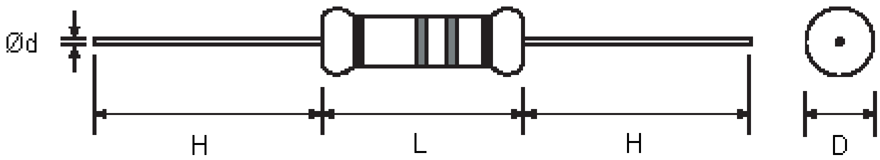
Wire Wound Fixed Resistors

multicomp



Features:

- Colour coating is “green”
- Non-inductive type available
- Excellent flame resistance
- Too low or too high ohm value can be supplied on a case to case basis
- Special fusing wire-wound resistors can be supplied on a case to case basis



Standard : 2%, 5% 10% - E 24 Series
1% - E 96 Series

Performance Specifications:

Temperature coefficient	: < 20 Ω: ± 400 PPM / °C; ≥ 20 Ω: ± 300 PPM / °C.
Short time overload	: ± (2% + 0.05 Ω) maximum, with no evidence of mechanical damage.
Dielectric withstanding voltage	: No evidence flashover, mechanical damage, arcing or insulation breakdown.
Pulse overload	: ± (5% + 0.05 Ω) maximum, with no evidence of mechanical damage.
Terminal strength	: No evidence of mechanical damage.
Resistance to soldering heat	: ± (1% + 0.05 Ω) maximum, with no evidence of mechanical damage.
Solderability	: Minimum 95% coverage.
Temperature cycling	: ± (2% + 0.05 Ω) maximum, with no evidence of mechanical damage.
Load life in humidity	: ± (5% + 0.05 Ω) maximum, with no evidence of mechanical damage.
Load life	: ± (5% + 0.05 Ω) maximum, with no evidence of mechanical damage.
Non-flame	: No evidence of flaming or arcing.

Specification Table

Style	Power Rating at 70°C	Dimension (mm)					Resistance Range	Std Packing Qty	Part Number
		D ±1	L ±1	d ±0.05	H ±3	PT			
Normal Size									
MCKNP 50	1/2 W (0.5 W)	3.5	10	0.54	28	52	0.1 Ω to 39 Ω	1,000	MCKNP0W2
MCKNP 100	1 W	5	12	0.7	25		0.1 Ω to 50 Ω		MCKNP01W
MCKNP 200	2 W	5.5	16		28	64	0.1 Ω to 120 Ω		MCKNP02W
MCKNP 300	3 W	6.5	17.5	0.75			0.1 Ω to 200 Ω		MCKNP03W

Dimensions : Millimetres

Wire Wound Fixed Resistors

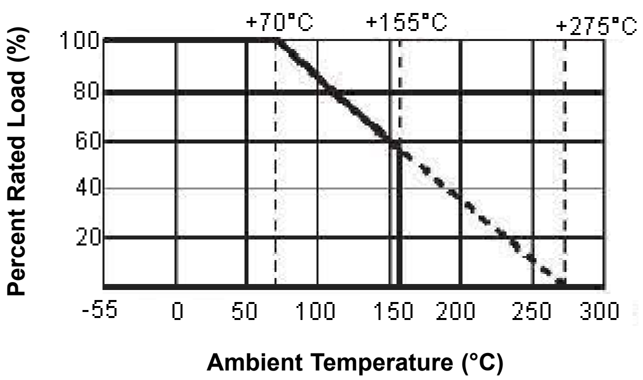
multicomp

Specification Table

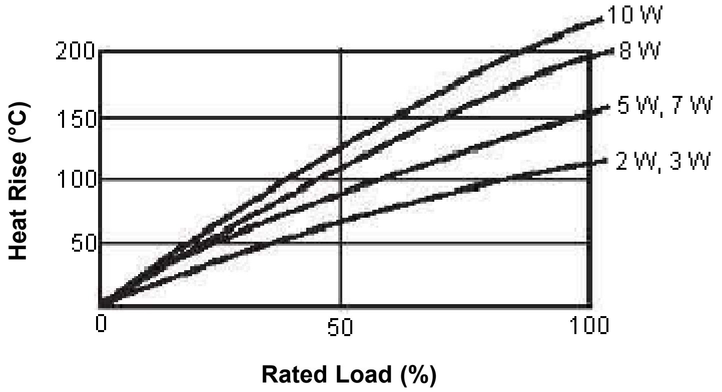
Style	Power Rating at 70°C	Dimension (mm)					Resistance Range	Std Packing Qty	Part Number
		D ±1	L ±1	d ±0.05	H ±3	PT			
Small Size									
MCKNP 100-S	1 W	3.5	10	0.54	28	52	0.1 Ω to 39 Ω	1,000	MCKNP01S
MCKNP 200-S	2 W	5	12	0.7	25		0.1 Ω to 50 Ω		MCKNP02S
MCKNP 300-S	3 W	5.5	16		28	64	0.1 Ω to 120 Ω		MCKNP03S
MCKNP 500-S	5 W	6.5	17.5	0.75			0.1 Ω to 200 Ω	500	MCKNP05S
MCKNP 700-S	7 W	8.5	25		38	B/B	0.5 Ω to 470 Ω	1,000	MCKNP07S
MCKNP 1000-S	10 W		53				1 Ω to 1.5 KΩ	1,800	MCKNP0AS
Extra Small Size									
MCKNP 300-SS	3 W	5.5	13.5	0.7	28	64	0.1 Ω to 50 KΩ	1,000	MCKNP03U

Dimensions : Millimetres

Derating Curve



Heat Rise Chart



Part Number Table

Description	Part Number
Resistor, Wire Wound, 0R25, 5%, 0.5W	MCKNP0W2J025KA10
Resistor, Wire Wound, 10R, 5%, 0.5W	MCKNP0W2J0100A10
Resistor, Wire Wound, 25R, 5%, 0.5W	MCKNP0W2J0250A10
Resistor, Wire Wound, 47R, 5%, 0.5W	MCKNP0W2J0470A10
Resistor, Wire Wound, 130R, 5%, 0.5W	MCKNP0W2J0131A10
Resistor, Wire Wound, 470R, 5%, 0.5W	MCKNP0W2J0471A10
Resistor, Wire Wound, 0R22, 5%, 1W	MCKNP01WJ022KA10
Resistor, Wire Wound, 0R33, 5%, 1W	MCKNP01WJ033KA10

Part Number Table

Description	Part Number
Resistor, Wire Wound, 0R5, 5%, 1W	MCKNP01WJ050KA10
Resistor, Wire Wound, 0R62, 5%, 1W	MCKNP01WJ062KA10
Resistor, Wire Wound, 1R, 5%, 1W	MCKNP01WJ010JA10
Resistor, Wire Wound, 2R2, 5%, 1W	MCKNP01WJ022JA10
Resistor, Wire Wound, 5R6, 5%, 1W	MCKNP01WJ056JA10
Resistor, Wire Wound, 6R8, 5%, 1W	MCKNP01WJ068JA10
Resistor, Wire Wound, 10R, 5%, 1W	MCKNP01WJ0100A10
Resistor, Wire Wound, 33R, 5%, 1W	MCKNP01WJ0330A10
Resistor, Wire Wound, 39R, 5%, 1W	MCKNP01WJ0390A10
Resistor, Wire Wound, 47R, 5%, 1W	MCKNP01WJ0470A10
Resistor, Wire Wound, 50R, 5%, 1W	MCKNP01WJ0500A10
Resistor, Wire Wound, 100R, 5%, 1W	MCKNP01WJ0101A10
Resistor, Wire Wound, 240R, 5%, 1W	MCKNP01WJ0241A10
Resistor, Wire Wound, 250R, 5%, 1W	MCKNP01WJ0251A10
Resistor, Wire Wound, 470R, 5%, 1W	MCKNP01WJ0471A10
Resistor, Wire Wound, 500R, 5%, 1W	MCKNP01WJ0501A10
Resistor, Wire Wound, 0R1, 5%, 1WS	MCKNP01SJ010KA10
Resistor, Wire Wound, 0R15, 5%, 1WS	MCKNP01SJ015KA10
Resistor, Wire Wound, 0R33, 5%, 1WS	MCKNP01SJ033KA10
Resistor, Wire Wound, 0R4, 5%, 1WS	MCKNP01SJ040KA10
Resistor, Wire Wound, 0R5, 5%, 1WS	MCKNP01SJ050KA10
Resistor, Wire Wound, 0R55, 5%, 1WS	MCKNP01SJ055KA10
Resistor, Wire Wound, 1R, 5%, 1WS	MCKNP01SJ010JA10
Resistor, Wire Wound, 1R5, 5%, 1WS	MCKNP01SJ015JA10
Resistor, Wire Wound, 1R8, 5%, 1WS	MCKNP01SJ018JA10
Resistor, Wire Wound, 2R2, 5%, 1WS	MCKNP01SJ022JA10
Resistor, Wire Wound, 3R3, 5%, 1WS	MCKNP01SJ033JA10
Resistor, Wire Wound, 4R7, 5%, 1WS	MCKNP01SJ047JA10
Resistor, Wire Wound, 5R1R, 5%, 1WS	MCKNP01SJ051JA10
Resistor, Wire Wound, 5R6, 5%, 1WS	MCKNP01SJ056JA10
Resistor, Wire Wound, 6R8, 5%, 1WS	MCKNP01SJ068JA10
Resistor, Wire Wound, 10R, 5%, 1WS	MCKNP01SJ0100A10
Resistor, Wire Wound, 12R, 5%, 1WS	MCKNP01SJ0120A10
Resistor, Wire Wound, 15R, 5%, 1WS	MCKNP01SJ0150A10

Part Number Table

Description	Part Number
Resistor, Wire Wound, 18R, 5%, 1WS	MCKNP01SJ0180A10
Resistor, Wire Wound, 20R, 5%, 1WS	MCKNP01SJ0200A10
Resistor, Wire Wound, 22R, 5%, 1WS	MCKNP01SJ0220A10
Resistor, Wire Wound, 24R, 5%, 1WS	MCKNP01SJ0240A10
Resistor, Wire Wound, 27R, 5%, 1WS	MCKNP01SJ0270A10
Resistor, Wire Wound, 33R, 5%, 1WS	MCKNP01SJ0330A10
Resistor, Wire Wound, 39R, 5%, 1WS	MCKNP01SJ0390A10
Resistor, Wire Wound, 47R, 5%, 1WS	MCKNP01SJ0470A10
Resistor, Wire Wound, 56R, 5%, 1WS	MCKNP01SJ0560A10
Resistor, Wire Wound, 68R, 5%, 1WS	MCKNP01SJ0680A10
Resistor, Wire Wound, 100R, 5%, 1WS	MCKNP01SJ0101A10
Resistor, Wire Wound, 150R, 5%, 1WS	MCKNP01SJ0151A10
Resistor, Wire Wound, 220R, 5%, 1WS	MCKNP01SJ0221A10
Resistor, Wire Wound, 470R, 5%, 1WS	MCKNP01SJ0471A10
Resistor, Wire Wound, 0R1, 5%, 2W	MCKNP02WJ010KA19
Resistor, Wire Wound, 0R33, 5%, 2W	MCKNP02WJ033KA19
Resistor, Wire Wound, 0R47, 5%, 2W	MCKNP02WJ047KA19
Resistor, Wire Wound, 1R, 5%, 2W	MCKNP02WJ010JA19
Resistor, Wire Wound, 4R7, 5%, 2W	MCKNP02WJ047JA19
Resistor, Wire Wound, 5R6, 5%, 2W	MCKNP02WJ056JA19
Resistor, Wire Wound, 6R8, 5%, 2W	MCKNP02WJ068JA19
Resistor, Wire Wound, 10R, 5%, 2W	MCKNP02WJ0100A19
Resistor, Wire Wound, 15R, 5%, 2W	MCKNP02WJ0150A19
Resistor, Wire Wound, 22R, 5%, 2W	MCKNP02WJ0220A19
Resistor, Wire Wound, 33R, 5%, 2W	MCKNP02WJ0330A19
Resistor, Wire Wound, 68R, 5%, 2W	MCKNP02WJ0680A19
Resistor, Wire Wound, 100R, 5%, 2W	MCKNP02WJ0101A19
Resistor, Wire Wound, 120R, 5%, 2W	MCKNP02WJ0121A19
Resistor, Wire Wound, 130R, 5%, 2W	MCKNP02WJ0131A19
Resistor, Wire Wound, 200R, 5%, 2W	MCKNP02WJ0201A19
Resistor, Wire Wound, 270R, 5%, 2W	MCKNP02WJ0271A19
Resistor, Wire Wound, 1K, 5%, 2W	MCKNP02WJ0102A19
Resistor, Wire Wound, 0R1, 5%, 2WS	MCKNP02SJ010KA10
Resistor, Wire Wound, 0R18, 5%, 2WS	MCKNP02SJ018KA10
Resistor, Wire Wound, 0R22, 5%, 2WS	MCKNP02SJ022KA10

Part Number Table

Description	Part Number
Resistor, Wire Wound, 0R27, 5%, 2WS	MCKNP02SJ027KA10
Resistor, Wire Wound, 0R33, 5%, 2WS	MCKNP02SJ033KA10
Resistor, Wire Wound, 0R47, 5%, 2WS	MCKNP02SJ047KA10
Resistor, Wire Wound, 0R56, 5%, 2WS	MCKNP02SJ056KA10
Resistor, Wire Wound, 0R82, 5%, 2WS	MCKNP02SJ082KA10
Resistor, Wire Wound, 1R, 5%, 2WS	MCKNP02SJ010JA10
Resistor, Wire Wound, 1R2, 5%, 2WS	MCKNP02SJ012JA10
Resistor, Wire Wound, 1R5, 5%, 2WS	MCKNP02SJ015JA10
Resistor, Wire Wound, 2R2, 5%, 2WS	MCKNP02SJ022JA10
Resistor, Wire Wound, 3R3, 5%, 2WS	MCKNP02SJ033JA10
Resistor, Wire Wound, 3R9, 5%, 2WS	MCKNP02SJ039JA10
Resistor, Wire Wound, 4R7, 5%, 2WS	MCKNP02SJ047JA10
Resistor, Wire Wound, 5R1, 5%, 2WS	MCKNP02SJ051JA10
Resistor, Wire Wound, 6R8, 5%, 2WS	MCKNP02SJ068JA10
Resistor, Wire Wound, 8R2, 5%, 2WS	MCKNP02SJ082JA10
Resistor, Wire Wound, 10R, 5%, 2WS	MCKNP02SJ0100A10
Resistor, Wire Wound, 12R, 5%, 2WS	MCKNP02SJ0120A10
Resistor, Wire Wound, 20R, 5%, 2WS	MCKNP02SJ0200A10
Resistor, Wire Wound, 22R, 5%, 2WS	MCKNP02SJ0220A10
Resistor, Wire Wound, 24R, 5%, 2WS	MCKNP02SJ0240A10
Resistor, Wire Wound, 30R, 5%, 2WS	MCKNP02SJ0300A10
Resistor, Wire Wound, 33R, 5%, 2WS	MCKNP02SJ0330A10
Resistor, Wire Wound, 39R, 5%, 2WS	MCKNP02SJ0390A10
Resistor, Wire Wound, 47R, 5%, 2WS	MCKNP02SJ0470A10
Resistor, Wire Wound, 51R, 5%, 2WS	MCKNP02SJ0510A10
Resistor, Wire Wound, 56R, 5%, 2WS	MCKNP02SJ0560A10
Resistor, Wire Wound, 68R, 5%, 2WS	MCKNP02SJ0680A10
Resistor, Wire Wound, 75R, 5%, 2WS	MCKNP02SJ0750A10
Resistor, Wire Wound, 82R, 5%, 2WS	MCKNP02SJ0820A10
Resistor, Wire Wound, 100R, 5%, 2WS	MCKNP02SJ0101A10
Resistor, Wire Wound, 120R, 5%, 2WS	MCKNP02SJ0121A10
Resistor, Wire Wound, 150R, 5%, 2WS	MCKNP02SJ0151A10
Resistor, Wire Wound, 180R, 5%, 2WS	MCKNP02SJ0181A10
Resistor, Wire Wound, 200R, 5%, 2WS	MCKNP02SJ0201A10

Part Number Table

Description	Part Number
Resistor, Wire Wound, 470R, 5%, 2WS	MCKNP02SJ0471A10
Resistor, Wire Wound, 0R1, 5%, 3W	MCKNP03WJ010KAA9
Resistor, Wire Wound, 0R15, 5%, 3W	MCKNP03WJ015KAA9
Resistor, Wire Wound, 0R22, 5%, 3W	MCKNP03WJ022KAA9
Resistor, Wire Wound, 1R, 5%, 3W	MCKNP03WJ010JAA9
Resistor, Wire Wound, 5R, 5%, 3W	MCKNP03WJ050JAA9
Resistor, Wire Wound, 5R6, 5%, 3W	MCKNP03WJ056JAA9
Resistor, Wire Wound, 6R8, 5%, 3W	MCKNP03WJ068JAA9
Resistor, Wire Wound, 10R, 5%, 3W	MCKNP03WJ0100AA9
Resistor, Wire Wound, 18R, 5%, 3W	MCKNP03WJ0180AA9
Resistor, Wire Wound, 33R, 5%, 3W	MCKNP03WJ0330AA9
Resistor, Wire Wound, 39R, 5%, 3W	MCKNP03WJ0390AA9
Resistor, Wire Wound, 47R, 5%, 3W	MCKNP03WJ0470AA9
Resistor, Wire Wound, 51R, 5%, 3W	MCKNP03WJ0510AA9
Resistor, Wire Wound, 100R, 5%, 3W	MCKNP03WJ0101AA9
Resistor, Wire Wound, 220R, 5%, 3W	MCKNP03WJ0221AA9
Resistor, Wire Wound, 390R, 5%, 3W	MCKNPS3WJ0391AA9
Resistor, Wire Wound, 470R, 5%, 3W	MCKNP03WJ0471AA9
Resistor, Wire Wound, 1K, 5%, 3W	MCKNP03WJ0102AA9
Resistor, Wire Wound, 0.1R, 5%, 3W	MCKNP03UJ010KB00
Resistor, Wire Wound, 0.2R, 5%, 3W	MCKNP03UJ020KB00
Resistor, Wire Wound, 0.5R, 5%, 3W	MCKNP03UJ050KB00
Resistor, Wire Wound, 1R, 5%, 3W	MCKNP03UJ010JB00
Resistor, Wire Wound, 2R, 5%, 3W	MCKNP03UJ020JB00
Resistor, Wire Wound, 5R, 5%, 3W	MCKNP03UJ050JB00
Resistor, Wire Wound, 10R, 5%, 3W	MCKNP03UJ0100B00
Resistor, Wire Wound, 25R, 5%, 3W	MCKNP03UJ0250B00
Resistor, Wire Wound, 40R, 5%, 3W	MCKNP03UJ0400B00
Resistor, Wire Wound, 50R, 5%, 3W	MCKNP03UJ0500B00
Resistor, Wire Wound, 75R, 5%, 3W	MCKNP03UJ0750B00
Resistor, Wire Wound, 100R, 5%, 3W	MCKNP03UJ0101B00
Resistor, Wire Wound, 120R, 5%, 3W	MCKNP03UJ0121B00
Resistor, Wire Wound, 200R, 5%, 3W	MCKNP03UJ0201B00
Resistor, Wire Wound, 220R, 5%, 3W	MCKNP03UJ0221B00

Part Number Table

Description	Part Number
Resistor, Wire Wound, 250R, 5%, 3W	MCKNP03UJ0251B00
Resistor, Wire Wound, 300R, 5%, 3W	MCKNP03UJ0301B00
Resistor, Wire Wound, 330R, 5%, 3W	MCKNP03UJ0331B00
Resistor, Wire Wound, 400R, 5%, 3W	MCKNP03UJ0401B00
Resistor, Wire Wound, 470R, 5%, 3W	MCKNP03UJ0471B00
Resistor, Wire Wound, 500R, 5%, 3W	MCKNP03UJ0501B00
Resistor, Wire Wound, 1K, 5%, 3W	MCKNP03UJ0102B00
Resistor, Wire Wound, 1K2, 5%, 3W	MCKNP03UJ0122B00
Resistor, Wire Wound, 1K5, 5%, 3W	MCKNP03UJ0152B00
Resistor, Wire Wound, 2K, 5%, 3W	MCKNP03UJ0202B00
Resistor, Wire Wound, 3K, 5%, 3W	MCKNP03UJ0302B00
Resistor, Wire Wound, 4K, 5%, 3W	MCKNP03UJ0402B00
Resistor, Wire Wound, 5K, 5%, 3W	MCKNP03UJ0502B00
Resistor, Wire Wound, 0R1, 5%, 3WS	MCKNP03SJ010KA19
Resistor, Wire Wound, 0R14, 5%, 3WS	MCKNP03SJ014KA19
Resistor, Wire Wound, 0R15, 5%, 3WS	MCKNP03SJ015KA19
Resistor, Wire Wound, 0R16, 5%, 3WS	MCKNP03SJ016KA19
Resistor, Wire Wound, 0R18, 5%, 3WS	MCKNP03SJ018KA19
Resistor, Wire Wound, 0R22, 5%, 3WS	MCKNP03SJ022KA19
Resistor, Wire Wound, 0R24, 5%, 3WS	MCKNP03SJ024KA19
Resistor, Wire Wound, 0R27, 5%, 3WS	MCKNP03SJ027KA19
Resistor, Wire Wound, 0R33, 5%, 3WS	MCKNP03SJ033KA19
Resistor, Wire Wound, 0R47, 5%, 3WS	MCKNP03SJ047KA19
Resistor, Wire Wound, 0R56, 5%, 3WS	MCKNP03SJ056KA19
Resistor, Wire Wound, 0R68, 5%, 3WS	MCKNP03SJ068KA19
Resistor, Wire Wound, 1R, 5%, 3WS	MCKNP03SJ010JA19
Resistor, Wire Wound, 1R5, 5%, 3WS	MCKNP03SJ015JA19
Resistor, Wire Wound, 2R2, 5%, 3WS	MCKNP03SJ022JA19
Resistor, Wire Wound, 2R7, 5%, 3WS	MCKNP03SJ027JA19
Resistor, Wire Wound, 3R3, 5%, 3WS	MCKNP03SJ033JA19
Resistor, Wire Wound, 3R9, 5%, 3WS	MCKNP03SJ039JA19
Resistor, Wire Wound, 4R7, 5%, 3WS	MCKNP03SJ047JA19
Resistor, Wire Wound, 10R, 5%, 3WS	MCKNP03SJ0100A19
Resistor, Wire Wound, 15R, 5%, 3WS	MCKNP03SJ0150A19
Resistor, Wire Wound, 22R, 5%, 3WS	MCKNP03SJ0220A19
Resistor, Wire Wound, 27R, 5%, 3WS	MCKNP03SJ0270A19
Resistor, Wire Wound, 30R, 5%, 3WS	MCKNP03SJ0300A19

Part Number Table

Description	Part Number
Resistor, Wire Wound, 33R, 5%, 3WS	MCKNP03SJ0330A19
Resistor, Wire Wound, 39R, 5%, 3WS	MCKNP03SJ0390A19
Resistor, Wire Wound, 47R, 5%, 3WS	MCKNP03SJ0470A19
Resistor, Wire Wound, 56R, 5%, 3WS	MCKNP03SJ0560A19
Resistor, Wire Wound, 68R, 5%, 3WS	MCKNP03SJ0680A19
Resistor, Wire Wound, 100R, 5%, 3WS	MCKNP03SJ0101A19
Resistor, Wire Wound, 200R, 5%, 3WS	MCKNP03SJ0201A19
Resistor, Wire Wound, 220R, 5%, 3WS	MCKNP03SJ0221A19
Resistor, Wire Wound, 330R, 5%, 3WS	MCKNP03SJ0331A19
Resistor, Wire Wound, 0R1, 5%, 5WS	MCKNP05SJ010KAA9
Resistor, Wire Wound, 0R12, 5%, 5WS	MCKNP05SJ012KAA9
Resistor, Wire Wound, 0R15, 5%, 5WS	MCKNP05SJ015KAA9
Resistor, Wire Wound, 0R18, 5%, 5WS	MCKNP05SJ018KAA9
Resistor, Wire Wound, 0R2, 5%, 5WS	MCKNP05SJ020KAA9
Resistor, Wire Wound, 0R22, 5%, 5WS	MCKNP05SJ022KAA9
Resistor, Wire Wound, 0R27, 5%, 5WS	MCKNP05SJ027KAA9
Resistor, Wire Wound, 0R33, 5%, 5WS	MCKNP05SJ033KAA9
Resistor, Wire Wound, 0R39, 5%, 5WS	MCKNP05SJ039KAA9
Resistor, Wire Wound, 0R47, 5%, 5WS	MCKNP05SJ047KAA9
Resistor, Wire Wound, 0R5, 5%, 5WS	MCKNP05SJ050KAA9
Resistor, Wire Wound, 0R56, 5%, 5WS	MCKNP05SJ056KAA9
Resistor, Wire Wound, 0R68, 5%, 5WS	MCKNP05SJ068KAA9
Resistor, Wire Wound, 0R82, 5%, 5WS	MCKNP05SJ082KAA9
Resistor, Wire Wound, 1R, 5%, 5WS	MCKNP05SJ010JAA9
Resistor, Wire Wound, 1R2, 5%, 5WS	MCKNP05SJ012JAA9
Resistor, Wire Wound, 1R5, 5%, 5WS	MCKNP05SJ015JAA9
Resistor, Wire Wound, 1R8, 5%, 5WS	MCKNP05SJ018JAA9
Resistor, Wire Wound, 2R, 5%, 5WS	MCKNP05SJ020JAA9
Resistor, Wire Wound, 2R2, 5%, 5WS	MCKNP05SJ022JAA9
Resistor, Wire Wound, 2R7, 5%, 5WS	MCKNP05SJ027JAA9
Resistor, Wire Wound, 3R3, 5%, 5WS	MCKNP05SJ033JAA9
Resistor, Wire Wound, 3R9, 5%, 5WS	MCKNP05SJ039JAA9
Resistor, Wire Wound, 4R7, 5%, 5WS	MCKNP05SJ047JAA9
Resistor, Wire Wound, 5R6, 5%, 5WS	MCKNP05SJ056JAA9
Resistor, Wire Wound, 6R8, 5%, 5WS	MCKNP05SJ068JAA9
Resistor, Wire Wound, 8R2, 5%, 5WS	MCKNP05SJ082JAA9
Resistor, Wire Wound, 10R, 5%, 5WS	MCKNP05SJ0100AA9

Part Number Table

Description	Part Number
Resistor, Wire Wound, 12R, 5%, 5WS	MCKNP05SJ0120AA9
Resistor, Wire Wound, 15R, 5%, 5WS	MCKNP05SJ0150AA9
Resistor, Wire Wound, 18R, 5%, 5WS	MCKNP05SJ0180AA9
Resistor, Wire Wound, 20R, 5%, 5WS	MCKNP05SJ0200AA9
Resistor, Wire Wound, 22R, 5%, 5WS	MCKNP05SJ0220AA9
Resistor, Wire Wound, 27R, 5%, 5WS	MCKNP05SJ0270AA9
Resistor, Wire Wound, 33R, 5%, 5WS	MCKNP05SJ0330AA9
Resistor, Wire Wound, 39R, 5%, 5WS	MCKNP05SJ0390AA9
Resistor, Wire Wound, 47R, 5%, 5WS	MCKNP05SJ0470AA9
Resistor, Wire Wound, 56R, 5%, 5WS	MCKNP05SJ0560AA9
Resistor, Wire Wound, 68R, 5%, 5WS	MCKNP05SJ0680AA9
Resistor, Wire Wound, 75R, 5%, 5WS	MCKNP05SJ0750AA9
Resistor, Wire Wound, 82R, 5%, 5WS	MCKNP05SJ0820AA9
Resistor, Wire Wound, 100R, 5%, 5WS	MCKNP05SJ0101AA9
Resistor, Wire Wound, 120R, 5%, 5WS	MCKNP05SJ0121AA9
Resistor, Wire Wound, 150R, 5%, 5WS	MCKNP05SJ0151AA9
Resistor, Wire Wound, 180R, 5%, 5WS	MCKNP05SJ0181AA9
Resistor, Wire Wound, 200R, 5%, 5WS	MCKNP05SJ0201AA9
Resistor, Wire Wound, 220R, 5%, 5WS	MCKNP05SJ0221AA9
Resistor, Wire Wound, 270R, 5%, 5WS	MCKNP05SJ0271AA9
Resistor, Wire Wound, 330R, 5%, 5WS	MCKNP05SJ0331AA9
Resistor, Wire Wound, 470R, 5%, 5WS	MCKNP05SJ0471AA9
Resistor, Wire Wound, 1K, 5%, 5WS	MCKNP05SJ0102AA9
Resistor, Wire Wound, 3R3R, 5%, 7WS	MCKNP07SJ033JB00
Resistor, Wire Wound, 5R, 5%, 7WS	MCKNP07SJ050JB00
Resistor, Wire Wound, 10R, 5%, 7WS	MCKNP07SJ0100B00
Resistor, Wire Wound, 27R, 5%, 7WS	MCKNP07SJ0270B00
Resistor, Wire Wound, 33R, 5%, 7WS	MCKNP07SJ0330B00
Resistor, Wire Wound, 100R, 5%, 7WS	MCKNP07SJ0101B00
Resistor, Wire Wound, 150R, 5%, 7WS	MCKNP07SJ0151B00
Resistor, Wire Wound, 1R, 7W, 1%	MCKNP07SF100KB00
Resistor, Wire Wound, 10R, 7W, 1%	MCKNP07SF100JB00
Resistor, Wire Wound, 50R, 7W, 1%	MCKNP07SF500JB00
Resistor, Wire Wound, 100R, 7W, 1%	MCKNP07SF1000B00
Resistor, Wire Wound, 150R, 7W, 1%	MCKNP07SF1500B00
Resistor, Wire Wound, 200R, 7W, 1%	MCKNP07SF2000B00
Resistor, Wire Wound, 250R, 7W, 1%	MCKNP07SF2500B00

Wire Wound Fixed Resistors

Part Number Table

Description	Part Number
Resistor, Wire Wound, 3.3R, 5%, 10WS	MCKNP0ASJ033JB00
Resistor, Wire Wound, 10R, 5%, 10WS	MCKNP0ASJ0100B00
Resistor, Wire Wound, 1R, 1%, 10W	MCKNP0ASF100KB00
Resistor, Wire Wound, 2R, 1%, 10W	MCKNP0ASF200KB00
Resistor, Wire Wound, 10R, 1%, 10W	MCKNP0ASF100JB00
Resistor, Wire Wound, 15R, 1%, 10W	MCKNP0ASF150JB00
Resistor, Wire Wound, 30R, 1%, 10W	MCKNP0ASF300JB00
Resistor, Wire Wound, 100R, 1%, 10W	MCKNP0ASF1000B00

Part Number Explanation:

MCKNP	0	W2	J	025K	A	1	0
Type	Feature	Wattage	Tolerance	Resistance Value	Packing Type	Packing Quantity	Additional Information

Type : MCKNP = MCKNP

Feature : 0 = Standard

Wattage : Normal : W2 = 1/2 W, 1W = 1 W
Small : 1S = 1 W-S, AS = 10 W-S
Extra Small : 3U = 3 W-SS

Tolerance : J = ±5%, F = ±1%

Resistance Value : **E - 24 Series:**
1st digit is “0” 2nd and 3rd digits are the significant figures of the resistance
4th indicates the number of zeros : “J” to 0.1, “K” to 0.01
Ex.: 4.7 Ω to 47 J, 4.7 KΩ to 472

E - 96 Series:
1st to 33rd digits are the significant figures of the resistance and the 4th digit indicates the number of zeros
Ex.: 1.33K = 1331.

Packing Type : A = Tape / Box, B = Bulk / Box.

Packing Quantity : 1 = 1,000 pieces, A = 500 pieces and 0 = Bulk / Box

Additional Information : 0 = PT-52 mm, PT-26 mm, 9 = PT-64 mm.

SAFETY DATA SHEET (SDS)

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Printing Date 09/15/2012 Version number 4 Reviewed on 09/15/2012

*

1 PRODUCT AND COMPANY IDENTIFICATION

***Trade name:* <u>48 Flux Cored Solder</u>**
Relevant identified uses of the substance or mixture and uses advised against *Solder*

Application of the substance / the preparation: Flux cored solder

Details of the supplier of the safety data sheet
This Safety Data Sheet has been updated in accordance with the Globally Harmonized System (GHS).
Manufacturer/Supplier:
Kester
800 West Throndale Ave.
Itasca, IL 60143
Tel (630) 616-4000
Fax (630) 616-4044

Kester Components Pte Ltd
500 Chai Chee Lane
Singapore 469024
Tel: 65-64491133

Information department: *SDS Coordinator (630) 616-6844*
Emergency telephone number:
CHEMTREC 24-Hour Emergency Response Telephone Number : (800) 424-9300
CHEMTREC 24-Hour Emergency Response (Outside US & Canada) Telephone Number : (703) 527-3887

*

2 HAZARDS IDENTIFICATION

Classification of the substance or mixture
Classification according to Regulation (EC) No 1272/2008


GHS08 Health hazard

Repr. 2 H361 Suspected of damaging fertility or the unborn child.
STOT RE 2 H373 May cause damage to organs through prolonged or repeated exposure.


GHS07

Acute Tox. 4 H332 Harmful if inhaled.
Skin Sens. 1 H317 May cause an allergic skin reaction.

Label elements
Labelling according to Regulation (EC) No 1272/2008
The product is classified and labelled according to the CLP regulation.
Hazard pictograms



GHS07 GHS08

Signal word Warning

Hazard-determining components of labelling:
lead
Rosin
Hazard statements
H332 Harmful if inhaled.
H317 May cause an allergic skin reaction.

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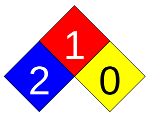
H361 Suspected of damaging fertility or the unborn child.
H373 May cause damage to organs through prolonged or repeated exposure.
Precautionary statements
P285 In case of inadequate ventilation wear respiratory protection.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P362 Take off contaminated clothing and wash before reuse.
P304+P340 IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P405 Store locked up.
P501 Dispose of contents/container in accordance with local/regional/national/international regulations.

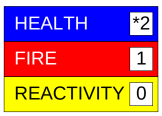
Classification system:

NFPA ratings (scale 0 - 4)



Health = 2
Fire = 1
Reactivity = 0

HMIS-ratings (scale 0 - 4)



*Health = *2*
Fire = 1
Reactivity = 0

Other hazards

Results of PBT and vPvB assessment

PBT: Not applicable.
vPvB: Not applicable.

*

3 COMPOSITION OF MIXTURE

Chemical characterization: Mixtures

Description: *This product contains the substance(s) listed below:*

CAS No.	*Description*		*% Range*
CAS: 7440-31-5 *EINECS: 231-141-8*	*tin*		*50-100%*
CAS: 7439-92-1 *EINECS: 231-100-4*	*lead*	*Acute Tox. 3, H301* *Repr. 2, H361; STOT RE 2, H373* *Acute Tox. 4, H332*	*25-50%*
CAS: 8050-09-7 *EINECS: 232-475-7*	*Rosin*	*Acute Tox. 1, H300* *Skin Sens. 1, H317*	*2.5-10%*

Additional information:

This solder product does not contain any Substance of Very High Concern (SVHC) on the European Chemicals Agency (ECHA) candidate list.
Composition and weight percent of solder alloys varies widely and can be determined by product label.
Flux in core is typically 1-3% by weight.

*

4 FIRST AID MEASURES

Description of first aid measures

After inhalation: *Supply fresh air; consult doctor in case of complaints.*
After skin contact: *Immediately wash with water and soap and rinse thoroughly.*
After eye contact: *Rinse opened eye for several minutes under running water.*
After swallowing: *Seek immediate medical advice.*
Information for doctor:
Most important symptoms and effects, both acute and delayed No further relevant information available.
Indication of any immediate medical attention and special treatment needed No further relevant information available.

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5 FIREFIGHTING MEASURES

Extinguishing media
Suitable extinguishing agents:
CO_2, extinguishing powder or water spray. Fight larger fires with water spray or alcohol resistant foam.
Special hazards arising from the substance or mixture
Melted solder above 1000°F will liberate toxic lead fumes.
In case of fire, the following can be released:
Carbon monoxide (CO)
Carbon dioxide (CO_2)
Aliphatic aldehydes
Advice for firefighters
Protective equipment: *Wear self-contained respiratory protective device.*
Additional information *Flux in cored solder may ignite when the solder melts in a fire.*

*

6 ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures *Ensure adequate ventilation*
Environmental precautions: *Do not allow to enter sewers/ surface or ground water.*
Methods and material for containment and cleaning up:
Dispose contaminated material as waste according to item 13.
Ensure adequate ventilation.
Melted solder will solidify on cooling and can be scraped up. Use caution to avoid breathing fumes if a gas torch is used to cut up large pieces.
Reference to other sections
See Section 7 for information on safe handling.
See Section 8 for information on personal protection equipment.
See Section 13 for disposal information.

*

7 HANDLING AND STORAGE

Handling:
Precautions for safe handling *Thorough dedusting.*
Information about protection against explosions and fires: *No special measures required.*

Conditions for safe storage, including any incompatibilities
Storage:
Requirements to be met by storerooms and receptacles: Store in a cool location.
Information about storage in one common storage facility: Not required.
Further information about storage conditions:
Keep receptacle tightly sealed.
Store in dry conditions.
Exposure to sulfur or to high humidity will tarnish solder surface.
Specific end use(s) *No further relevant information available.*

*

8 EXPOSURE CONTROLS / PERSONAL PROTECTION

Additional information about design of technical systems: *No further data; see item 7.*

Control parameters

Components with limit values that require monitoring at the workplace:	
7440-31-5 tin	
PEL	*2 mg/m³* *metal*
REL	*2 mg/m³*

(Contd. on page 4)

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(Contd. of page 3)

TLV	*2 mg/m³* *metal*
7439-92-1 lead	
PEL	*0.05* mg/m³* **see 29 CFR 1910.1025*
REL	*0.05 mg/m³* *excluding lead arsenate; See Pocket Guide App. C*
TLV	*0.05* mg/m³* **and inorganic compounds, as Pb; BEI*
8050-09-7 Rosin	
TLV	*SEN; L*

Additional information:
PEL = Permissible Exposure Limit (OSHA)
TLV= Threshold Limit Value (ACGIH)
OSHA= Occupational Safety and Health Administration
ACGIH= American Conference of Governmental Industrial Hygienists

Exposure controls
Personal protective equipment:
General protective and hygienic measures:
The usual precautionary measures for handling chemicals should be followed.
Keep away from foodstuffs, beverages and feed.
Immediately remove all soiled and contaminated clothing.
Wash hands before breaks and at the end of work.
Breathing equipment:
Exposure Controls: Use appropriate engineering control such as process enclosures, local exhaust ventilation to control airborne levels below recommended exposure limits.
When ventilation is not sufficient to remove airborne levels from the breathing zone, a NIOSH safety approved respirator or self-contained breathing apparatus should be worn. Consult with local procedures for selection, training, inspection and maintenance of the personal protective equipment.
Protection of hands:

Protective gloves

Material of gloves:
Cloth gloves
Nitrile rubber, NBR
Natural rubber, NR
Penetration time of glove material:
The exact break through time has to be found out by the manufacturer of the protective gloves and has to be observed.
Eye protection: Safety Glasses with Sideshields

*
9 PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties
General Information
Appearance:

Form:	*Solid material*
Color:	*Silver grey*
Odor:	*Mild*
pH-value:	*Not applicable.*
Change in condition	
Melting point/Melting range:	*> 100°C (> 212 °F)* *Undetermined.*
Boiling point/Boiling range:	*1740°C (3164 °F)*

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SAFETY DATA SHEET (SDS)

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Trade name: 48 Flux Cored Solder

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Flash point: *Undetermined.*

Flammability (solid, gaseous): *Not determined.*

Auto igniting: *Product is not selfigniting.*

Danger of explosion: *Product does not present an explosion hazard.*

Vapor pressure: *Not applicable.*

Density at 20°C (68 °F): *7 g/cm³ (58.415 lbs/gal)*
Vapour density *Not applicable.*

Solubility in / Miscibility with
Water: *Insoluble.*

*
10 STABILITY AND REACTIVITY

Reactivity
Chemical stability
Thermal decomposition / conditions to be avoided: No decomposition if used according to specifications.
Possibility of hazardous reactions *No dangerous reactions known.*
Conditions to avoid *No further relevant information available.*
Incompatible materials: *Strong acids, strong oxidizers.*
Hazardous decomposition products:
Carbon monoxide and carbon dioxide
When heated to soldering temperatures, the solvents are evaporated and rosin may be thermally degraded to liberate aliphatic aldehydes and acids.

*
11 TOXICOLOGICAL INFORMATION

Information on toxicological effects
Acute toxicity:
Primary irritant effect:
on the skin:
Irritant to skin and mucous membranes.
Possible local irritation by contact with flux or fumes.
on the eye:
Irritating effect.
Smoke during soldering can cause eye irritation.
through inhalation:
Flux fumes during soldering may cause irritation and damage of mucous membranes and respiratory system.
Additional toxicological information:
The product shows the following dangers according to internally approved calculation methods for preparations:
Harmful
Irritant

Carcinogenic categories

IARC (International Agency for Research on Cancer)		
7439-92-1	*lead*	*2B*

NTP (National Toxicology Program)		
7439-92-1	*lead*	*R*

*
12 ECOLOGICAL INFORMATION

Toxicity
Aquatic toxicity: *No further relevant information available.*

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SAFETY DATA SHEET (SDS)

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Trade name: 48 Flux Cored Solder

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Additional ecological information:
General notes:
Do not allow undiluted product or large quantities of it to reach ground water, water course or sewage system.
Danger to drinking water if even small quantities leak into the ground.
Results of PBT and vPvB assessment
PBT: *Not applicable.*
vPvB: *Not applicable.*

*
13 DISPOSAL CONSIDERATIONS

Waste treatment methods
Recommendation:
Must not be disposed of together with household garbage. Do not allow product to reach sewage system.
Disposal must be made according to official regulations.

Uncleaned packagings:
Recommendation: *Disposal must be made according to official regulations.*

*
14 TRANSPORT INFORMATION

UN-Number	*Not regulated*
DOT, ADN, IMDG, IATA	*Not applicable*
ADR	*Not applicable*
	Not regulated
UN proper shipping name	
DOT, ADR, ADN	*Not applicable*
IMDG, IATA	*Not regulated*
Transport hazard class(es)	
DOT, IMDG	
Class	*Not applicable*
	Not regulated.
ADR, ADN, IATA	
Class	*Not applicable*
Packing group	
DOT, ADR, IMDG, IATA	*Not applicable*
Environmental hazards:	
Marine pollutant:	*No*
Special precautions for user	*Not applicable.*
Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code	*Not applicable.*
Transport/Additional information:	*Not dangerous according to the above specifications.*

*
15 REGULATORY INFORMATION

Safety, health and environmental regulations/legislation specific for the substance or mixture

USA The following information relates to product regulation specific to the USA.

SARA (Superfund Amendments and Reauthorization Act)

Section 355 (extremely hazardous substances):
None of the ingredient is listed.

Section 313 (Specific toxic chemical listings):	
7439-92-1	*lead*

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TSCA (Toxic Substances Control Act): Kester certifies that all components listed below for the subject finished product are on the TSCA Inventory of Chemical Substances and are not subject to any chemical specific regulation under TSCA Section 12(b) export notification requirements delineated at 40 CFR part 707, subpart D.
All ingredients are listed or exempt from listing.

California Proposition 65
Chemicals known to cause cancer:
WARNING: This product contains a chemical(s) known to the State of California to cause cancer.

lead

Chemicals known to cause reproductive toxicity:
WARNING: This product contains a chemical(s) known to the State of California to cause birth defects and/or other reproductive harm.

lead

Carcinogenic categories

EPA (Environmental Protection Agency)		
7439-92-1	*lead*	*B2*

NIOSH-Ca (National Institute for Occupational Safety and Health)
None of the ingredients is listed.

OSHA-Ca (Occupational Safety & Health Administration)
None of the ingredients is listed.

CANADA: Not classified.
Labelling according to Regulation (EC) No 1272/2008
The product is classified and labelled according to the CLP regulation.
Hazard pictograms

GHS07 GHS08

Signal word Warning

Hazard-determining components of labelling:
lead
Rosin
Hazard statements
H332 Harmful if inhaled.
H317 May cause an allergic skin reaction.
H361 Suspected of damaging fertility or the unborn child.
H373 May cause damage to organs through prolonged or repeated exposure.
Precautionary statements
P285 In case of inadequate ventilation wear respiratory protection.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P362 Take off contaminated clothing and wash before reuse.
P304+P340 IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P405 Store locked up.
P501 Dispose of contents/container in accordance with local/regional/national/international regulations.
Chemical safety assessment: *A Chemical Safety Assessment has not been carried out.*

16 OTHER INFORMATION

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The information contained herein is based on data considered accurate and is offered solely for information, consideration and investigation. Kester extends no warranties, makes no representations and assumes no responsibilty as to the accuracy, completeness or suitability of this data for any purchaser's use. The data on this Material Safety Data Sheet relates only to this product and does not relate to use with any other material or in any process. All chemical products should be used only by, or under the direction of, technically qualified personnel who are aware of the hazards involved and the necessity for reasonable care in handling. Hazard communication regulations require that employees must be trained on how to use a Material Safety Data Sheet as a source for hazard information.

Abbreviations and acronyms:

ADR: Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road)
IMDG: International Maritime Code for Dangerous Goods
DOT: US Department of Transportation
IATA: International Air Transport Association
GHS: Globally Harmonized System of Classification and Labelling of Chemicals
NFPA: National Fire Protection Association (USA)
HMIS: Hazardous Materials Identification System (USA)

**** Data compared to the previous version altered.***

USA

APPENDIX D

Finances

Group	Subsystem	Cost in SEK	All components bought	
Mechanics	Outer Structure	15575.08	Yes	
Mechanics	Inner Structure	583.36	Yes	
Mechanics	Attachments	1739.366	Yes	
Electronics	Power Distribution	15800.23	Yes	
Electronics	Components	2300.86	Yes	
Software	OBDH - OnBoard Data Handling	499	Yes	
Outreach	Outreach	6962.5	Yes	
Team	Miscellaneous	28631	No	
TOTAL		**72091.396**		
FUNDING				
Patron	**Status**	**Funds in SEK**	**Spent in SEK**	**Remaining funds in SEK**
Department of Computer Science, Electrical and Space Engineering	Sponsorship recieved	20000	20000	0
Department of Computer Science, Electrical and Space Engineering	Sponsorship recieved	20000		
LKAB	Sponsorship recieved	14700		
Tribotec	Sponsorship for silicone adhesive recieved	1600	1600	0
Nybergs mek. & verkstad	Sponsorship recieved: reduced price	4577.5	4577.5	0
Tätring AB	Sponsorship recieved	894.08	894.08	0
Department of Computer Science, Electrical and Space Engineering	Sponsorship recieved (t-shirts)	2231.25	2231.25	0
SNSB	Sponsorship recieved	30000		
Department of Computer Science, Electrical and Space Engineering (studentrekryteringen)	Sponsorship recieved	2500	2500	0
TOTAL		**96502.83**	6177.5	
BALANCE		**24411.434**		

Subsystem	Component	Component name	Price per unit	Number of units	Cost in SEK	Retailer	Bought
Outer Structure	Silicone adhesive	TSE397	800	2	1600	Tribotec	Yes
Outer Structure	Hat Vacuum (Aluminium)	Hat Vacuum	2288.75	1	2288.75	Nybergs Mekaniska Verkstad	Yes
Outer Structure	Hat Pressurized (Aluminium)	Hat Pressurized	2288.75	1	2288.75	Nybergs Mekaniska Verkstad	Yes
Outer Structure	Base (aluminium)	Base	2288.75	2	4577.5	Nybergs Mekaniska Verkstad	Yes
Outer Structure	Electronics box (aluminium)	Hammond 26908PSLA	120	2	240	Elfa Distrilec	Yes
Outer Structure	O-ring	80641343000	24.44	8	195.52	Tätringen AB	Yes
Outer Structure	Batterypack housing with attachment (aluminium)	Batterypack housing with attachment	70	2	140	SRT	Yes
Outer Structure	Vacuum grease	80647025000	788.56	1	788.56	Tätringen AB	Yes
Outer Structure	Module to attach the experiment to the shaker and bulkhead for tests	Module to attach the experiment to the shaker and bulkhead for tests	3456	1	3456	IRF	Yes
Inner Structure	PCB experiment	PCB experiment	40	7	280	SRT	Yes
Inner Structure	PCB sensors	PCB sensors	40	3	120	SRT	Yes
Inner Structure	PCB electronics box	PCB electronics box	80	2	160	SRT	Yes
Inner Structure	Solder	Sn63/Pb37	23.36	1	23.36	SRT	Yes
Attachments	Screw M2x8	BN 610 M2X8	0.519	80	41.52	Elfa Distrilec	Yes
Attachments	Screw M3x12	BN 610 M3X12MM	0.798	77	61.446	Elfa Distrilec	Yes
Attachments	Screw M3x12 countersunk	BN 3803 M3X12MM	0.86	26	22.36	Elfa Distrilec	Yes
Attachments	Screw M3x20	BN 610 M3X20MM	1.02	13	13.26	Elfa Distrilec	Yes
Attachments	Screw M3x50	N/A	3.3	16	52.8	Verktygshuset i Kiruna	Yes
Attachments	Screw M4x8	BN 610 M4X8MM	0.863	79	68.177	Elfa Distrilec	Yes
Attachments	Screw M4x12 countersunk	BN 3803 M4X12MM	1.68	51	85.68	Elfa Distrilec	Yes
Attachments	Screw M4x30	M4x30	0.99	64	63.36	Verktygshuset i Kiruna	Yes

Attachments	Screw M3x5	48-493-70	1.14	35	39.9	Elfa Distrilec	Yes
Attachments	Screw M3x8	48-493-72	1.77	5	8.85	Elfa Distrilec	Yes
Attachments	Nut M2	BN 628 M2	0.47	80	37.6	Elfa Distrilec	Yes
Attachments	Lock nut M3	48-426-70	0.771	86	66.306	Elfa Distrilec	Yes
Attachments	Lock nut M4	48-426-71	0.832	58	48.256	Elfa Distrilec	Yes
Attachments	Helicoil M3	M3x4.5	1.42	20	28.4	IRF	Yes
Attachments	Helicoil M4	M4x4	1.22	40	48.8	IRF	Yes
Attachments	Loctite	Loctite 270 10ml	167	1	167	Elfa Distrilec	Yes
Attachments	Loctite	Loctite 243 10 ml	167	2	334	Elfa Distrilec	Yes
Attachments	Washer M2	BN 670 M2	0.159	80	12.72	Elfa Distrilec	Yes
Attachments	Spring washer M3	BN 672 M3	0.302	110	33.22	Elfa Distrilec	Yes
Attachments	Spring washer M4	BN 672 M4	0.504	110	55.44	Elfa Distrilec	Yes
Attachments	Spring washer M3	48-000-42	0.077	63	4.851	Elfa Distrilec	Yes
Attachments	Spring washer M5	48-000-44	0.15	22	3.3	Elfa Distrilec	Yes
Attachments	Spacer M3 5mm	DISTIN3060NY-05	3.63	20	72.6	Elfa Distrilec	Yes
Attachments	Spacer M3 5 mm	48-916-02	1.49	12	17.88	Elfa Distrilec	Yes
Attachments	Spacer M3 10mm	DISTIN3060NY-10	3.63	21	76.23	Elfa Distrilec	Yes
Attachments	Spacer M3 10mm	48-916-28	2.72	7	19.04	Elfa Distrilec	Yes
Attachments	Spacer M3 25mm	DISTIN3060NY-25	8.93	14	125.02	Elfa Distrilec	Yes
Attachments	Spacer bolt M3x5	48-012-17	1.73	11	19.03	Elfa Distrilec	Yes
Attachments	Zip ties	RG231	5.26	12	63.12	Elfa Distrilec	Yes
Attachments	Insex screw M3x8	48-872-71	0.585	4	2.34	Elfa Distrilec	Yes
Attachments	Insex screw M5x16	48-872-84	0.685	28	19.18	Elfa Distrilec	Yes
Attachments	Insex screw M3x50	N/A	N/A	15	N/A	Verktygshuset i Kiruna	Yes
Attachments	UNC-440x5	48-006-92	1.73	16	27.68	Elfa Distrilec	Yes
Power Distribution	Switch	IPU039N03L G	7.67	17	130.39	Digikey	Yes
Power Distribution	DC/DC converter	TSR 1-2450	95.7	2	191.4	Elfa Distrilec	Yes
Power Distribution	DC/DC converter	TSR 1-2433	95.7	2	191.4	Elfa Distrilec	Yes
Power Distribution	DC/DC converter	TSR 1-24120	78.66	2	157.32	Farnell	Yes
Power Distribution	Wires	E 1219	0	1	0	Amgab	Yes
Power Distribution	Wires	ET 2419	0	1	0	Amgab	Yes
Power Distribution	Socket header	215297-6	11.6	5	58	Elfa	Yes
Power Distribution	Socket header	323-13-120-41-001101	45.6	2	91.2	Elfa	Yes
Power Distribution	Pin header	PST 1,3/6-5,0	5.49	6	32.94	Elfa	Yes
Power Distribution	Battery pack (NiMh pack)	NHS 4200 SCH	753.75	3	2261.25	Celltech	Yes
Power Distribution	Additonal Battery pack (NiMh pack)	NHS 4200 SCH	753.75	3	2261.25	Celltech	Yes

Power Distribution	Battery pack (NiMh pack)	Ordering cost	500	1	500	Celltech	Yes
Power Distribution	Additional Battery pack (NiMh pack)	Ordering cost	500	1	500	Celltech	Yes
Power Distribution	D-SUB 15 connector	09 68 253 7613	37.7	2	75.4	Elfa Distrilec	Yes
Power Distribution	D-SUB 15P connector	09 67 015 4715	48.9	2	97.8	Elfa Distrilec	Yes
Power Distribution	Capacitor	790D-106X0040C2	114	4	456	Elfa Distrilec	Yes
Power Distribution	Capacitor	790D-226X0040C2	114	4	456	Elfa Distrilec	Yes
Power Distribution	Capacitor	T350F226M016AT	15.3	10	153	Elfa Distrilec	Yes
Power Distribution	Capacitor	T350E106M016AT	12.7	8	101.6	Elfa Distrilec	Yes
Power Distribution	Pin header	801-87-036-10-001101	39.5	4	158	Elfa	Yes
Power Distribution	Socket header	SL1-036-S184/01-99	21.6	4	86.4	Elfa	Yes
Power Distribution	Power resistor	MCKNP05SJ012JA	2.12	10	21.2	Farnell	Yes
Power Distribution	Power resistor	45J1R0E	26.71	6	160.26	Farnell	Yes
Power Distribution	Op amp	LM201AN	18.14	4	72.56	Farnell	Yes
Power Distribution	Switchregulator 5 VDC 1A	TSR 1-2450	95.7	2	191.4	Elfa Distrilec	Yes
Power Distribution	Switchregulator 3.3 VDC 1000 mA	TSR 1-2433	95.7	2	191.4	Elfa Distrilec	Yes
Power Distribution	Filter - Bourns	SRF0905-251Y	10.58	6	63.48	Fernell	Yes
Power Distribution	MOSFET	IPU039N03LGIN-ND	9.12	4	36.48	Digikey Corp.	Yes
Power Distribution	Optocoupler	IL300	31.97	2	63.94	Farnell	Yes
Power Distribution	Optocoupler	PC3H7J00000F	5.98	2	11.96	Farnell	Yes
Power Distribution	Power resistor	MCKNP07SJ0101B	4.04	6	24.24	Farnell	Yes
Power Distribution	Power resistor	MP915-1.00-1%	37.81	4	151.24	Farnell	Yes
Power Distribution	Main PCBs	N/A	1250	4	5000	Multicad	Yes
Power Distribution	D-sub 15	09 67 015 5615	43.2	2	86.4	Elfa Distrilec	Yes
Power Distribution	D-sub 15	09 67 015 4715	48.9	1	48.9	Elfa Distrilec	Yes
Power Distribution	Hybrid D-subs	FM 9W4P-K120	36.2	4	144.8	Elfa Distrilec	Yes
Power Distribution	Hybrid D-subs	FM9W4S-K121	41.7	4	166.8	Elfa Distrilec	Yes
Power Distribution	Hybrid D-subs	FM 5W5P-K120	18.5	4	74	Elfa Distrilec	Yes
Power Distribution	Hybrid D-subs	FM5W5S-K121	18.5	2	37	Elfa Distrilec	Yes
Power Distribution	Power pins	FMP006S103	22.2	20	444	Elfa Distrilec	Yes
Power Distribution	Power pins	FMP006P103	17.2	16	275.2	Elfa Distrilec	Yes
Power Distribution	Tantalum	T350A104M035AT	11.9	3	35.7	Elfa Distrilec	Yes
Power Distribution	Inductor	HM50-100KLF	11.5	5	55.9	Elfa Distrilec	Yes

Power Distribution	Capacitor	592D158X06R3R2T	62.15	2	124.3	Farnell	Yes
Power Distribution	Resistor	MCKNP05SJ015JA	2.16	10	21.6	Farnell	Yes
Power Distribution	Resistor	MCKNP05SJ018JA	2.16	10	21.6	Farnell	Yes
Power Distribution	Resistor	MCKNP05SJ020JA	2.16	10	21.6	Farnell	Yes
Power Distribution	Resistor	MCKNP05SJ022JA	2.16	10	21.6	Farnell	Yes
Power Distribution	Jack post	C9994-1232FWI0	10.9	5	54.5	Elfa Distrilec	Yes
Power Distribution	Jack post	C9994-232FWI00	7.17	1	7.17	Elfa Distrilec	Yes
Power Distribution	Screws	1857211-2	26	4	104	Elfa Distrilec	Yes
Power Distribution	Screws	BN 3 M3X8MM	0.585	20	11.7	Elfa Distrilec	Yes
Power Distribution	Screws	MC6S M3X6H	1.085	20	21.7	Elfa Distrilec	Yes
Power Distribution	Spacer bolts	99130-50050 / DSM3050X5 DI	2.97	25	74.25	Elfa Distrilec	Yes
Components	Pressure sensor	XFPM-200KPGR (H)	352	2	704	Elfa Distrilec	Yes
Components	Nichrome wire	Nichrome wire 0.2 mm	35	6	210	Alega	Yes
Components	Temperature sensor DO-24	KTY84-150	15.9	8	127.2	Elfa Distrilec	Yes
Components	Micro sd card	SFSD1024N1BN1T	282.86	2	565.72	Farnell	Yes
Components	Signal transciever	MAX488EESA	75.72	1	75.72	Farnell	Yes
Components	Micro sd card holder	2908-05WB-MG	20.4	4	81.6	Elfa Distrilec	Yes
Components	Level converter bidirectional	MAX3378EEUD	62.63	1	62.63	Farnell	Yes
Components	Pressure sensor	HSCDANN015PAA	349.43	1	349.43	Digikey	Yes
Components	Atmega 328	ATMEGA328-PU	30.73	2	61.46	Farnell	Yes
Components	Pressure sensor	SPD100G	63.1	1	63.1	Elfa Distrilec	Yes
OBDH	MCU	Atmega328	100	4	400	SRT	Yes(2)
OBDH	Micro SD USB reader	Micro SDHC Card Reader	99	1	99	Clas Ohlson	Yes
Outreach	Posters	Posters	250	10	2500	LTU	Yes
Outreach	Team t-shirts	T-shirts	318.75	14	4462.5	Falks tryckeri och brodyr i Kiruna AB	Yes
Miscellaneous	Transportation STW	Fuel	460	1	460	Statoil	Yes
Miscellaneous	Transportation Selection Workshop	Plane tickets			13384.32	NEX	Yes
Miscellaneous	Accomodation Selection Workshop	Hotel	6615.68	1	6615.68		Yes
Miscellaneous	Food STW	Lunch, dinner for 2 members, 5 days	103	20	2060	Esrange SSC	Yes

Miscellaneous	Shipping fee for components	Shipping fee Elfa	39	1	39	Elfa Distrilec	Yes
Miscellaneous	Shipping fee for components	Shipping fee Alega Skolmaterial AB	72	1	72	Alega	Yes
Miscellaneous	Shipping fee for components	Shipping fee Farnell	200	1	200	Farnell	Yes
Miscellaneous	Fuel Launch campaign	Fuel	500	1	500		No
Miscellaneous	Transportation to Oulu, Finland	Rental car	1800	1	1800		No
Miscellaneous	Transportation to Oulu, Finland	Fuel	1500	1	1500		No
Miscellaneous	Accomodation Oulu, Finland	Hotel/Hostel	500	4	2000		No
TOTAL					**72091.396**		

Component	Component name	Price per unit	Number of units	Cost in SEK	Retailer	Comment	Bought	Date of purchase	Purchase expense (occured by team member)
Silicone adhesive	TSE397	800	2	1600	Tribotec		Yes	2012-05-25	
Hat Vacuum (Aluminium)	Hat Vacuum	2288.75	1	2288.75	Nybergs Mekaniska Verkstad		Yes	2012-08-29	
Hat Pressurized (Aluminium)	Hat Pressurized	2288.75	1	2288.75	Nybergs Mekaniska Verkstad		Yes	2012-08-29	
Base (aluminium)	Base	2288.75	2	4577.5	Nybergs Mekaniska Verkstad		Yes	2012-08-29	
Electronics box (aluminium)	Hammond 26908PSLA	120	2	240	Elfa Distrilec		Yes	2012-09-03	
O-ring	80641343000	24.44	8	195.52	Tätringen AB		Yes	2012-08-17	
Batterypack housing with attachment (aluminium)	Batterypack housing with attachment	70	2	140	SRT		Yes	2012-09-24	
Vacuum grease	80647025000	788.56	1	788.56	Tätringen AB		Yes	2012-08-23	
Module to attach the experiment to the shaker and bulkhead for tests	Module to attach the experiment to the shaker and bulkhead for tests	3456	1	3456	IRF		Yes	2012-09-26	
Total				**15575.08**					

Component	Component name	Price per unit	Number of units	Cost in SEK	Retailer	Comment	Bought	Date of purchase	Purchase expense (occured by team member)
PCB experiment	PCB experiment	40	7	280	SRT		Yes	2012-06-04	
PCB sensors	PCB sensors	40	3	120	SRT		Yes	2012-09-13	
PCB electronics box	PCB electronics box	80	2	160	SRT		Yes	2012-10-05	
Solder	Sn63/Pb37	23.36	1	23.36	SRT		Yes	2012-06-04	
Total				**583.36**					

Component	Component name	Price/unit (SEK)	Number of units	Cost in SEK	Retailer	Comment	Bought	Date of purchase	Purchase expense (occured by team member)
Screw M2x8	BN 610 M2X8	0.519	80	41.52	Elfa Distrilec		Yes	2012-09-03	
Screw M3x12	BN 610 M3X12MM	0.798	77	61.446	Elfa Distrilec		Yes	2012-09-03	
Screw M3x12 countersunk	BN 3803 M3X12MM	0.86	26	22.36	Elfa Distrilec		Yes	2012-09-03	
Screw M3x20	BN 610 M3X20MM	1.02	13	13.26	Elfa Distrilec		Yes	2012-09-03	
Screw M3x50	N/A	3.3	16	52.8	Verktygshuset i Kiruna		No		
Screw M4x8	BN 610 M4X8MM	0.863	79	68.177	Elfa Distrilec		Yes	2012-09-03	
Screw M4x12 countersunk	BN 3803 M4X12MM	1.68	51	85.68	Elfa Distrilec		Yes	2012-09-03	
Screw M4x30	M4x30	0.99	64	63.36	Verktygshuset i Kiruna		Yes	2012-09-03	
Screw M3x5	48-493-70	1.14	35	39.9	Elfa Distrilec		Yes	2013-01-16	
Screw M3x8	48-493-72	1.77	5	8.85	Elfa Distrilec		Yes	2013-01-16	
Nut M2	BN 628 M2	0.47	80	37.6	Elfa Distrilec		Yes	2012-09-03	
Lock nut M3	48-426-70	0.771	86	66.306	Elfa Distrilec		Yes	2012-09-03	
Lock nut M4	48-426-71	0.832	58	48.256	Elfa Distrilec		Yes	2012-09-03	
Helicoil M3	M3x4.5	1.42	20	28.4	IRF		Yes	2012-09-03	
Helicoil M4	M4x4	1.22	40	48.8	IRF		Yes	2012-09-03	
Loctite	Loctite 270 10ml	167	1	167	Elfa Distrilec		Yes	2012-09-03	
Loctite	Loctite 243 10 ml	167	2	334	Elfa Distrilec		Yes	2012-09-03	
Washer M2	BN 670 M2	0.159	80	12.72	Elfa Distrilec		Yes	2012-09-03	
Spring washer M3	BN 672 M3	0.302	110	33.22	Elfa Distrilec		Yes	2012-09-03	
Spring washer M4	BN 672 M4	0.504	110	55.44	Elfa Distrilec		Yes	2012-09-03	
Spring washer M3	48-000-42	0.077	63	4.851	Elfa Distrilec		Yes	2013-01-16	
Spring washer M5	48-000-44	0.15	22	3.3	Elfa Distrilec		Yes	2013-01-16	
Spacer M3 5mm	DISTIN3060NY-05	3.63	20	72.6	Elfa Distrilec		Yes	2012-09-03	
Spacer M3 5 mm	48-916-02	1.49	12	17.88	Elfa Distrilec		Yes	2013-01-16	
Spacer M3 10mm	DISTIN3060NY-10	3.63	21	76.23	Elfa Distrilec		Yes	2012-09-03	
Spacer M3 10mm	48-916-28	2.72	7	19.04	Elfa Distrilec		Yes	2013-01-16	
Spacer M3 25mm	DISTIN3060NY-25	8.93	14	125.02	Elfa Distrilec		Yes	2012-09-03	
Spacer bolt M3x5	48-012-17	1.73	11	19.03	Elfa Distrilec		Yes	2013-01-16	
Zip ties	RG231	5.26	12	63.12	Elfa Distrilec		Yes	2012-11-05	
Insex screw M3x8	48-872-71	0.585	4	2.34	Elfa Distrilec		Yes	2013-01-16	
Insex screw M5x16	48-872-84	0.685	28	19.18	Elfa Distrilec		Yes	2013-01-16	
Insex screw M3x50	N/A	N/A	15	N/A	Verktygshuset i Kiruna		Yes	2013-01-16	
UNC-440x5	48-006-92	1.73	16	27.68	Elfa Distrilec		Yes	2013-01-16	
Total				**1739.366**					

Component	Component name	Price per unit	Number of units	Cost in SEK	Retailer	Comment	Bought	Date of purchase	Purchase expense (occured by team member)
Switch	IPU039N03L G	7.67	17	130.39	Digikey	Plus shipping	Yes	2012-08-10 and 2013-04-09	Björn Sjödahl both times
DC/DC converter	TSR 1-2450	95.7	2	191.4	Elfa Distrilec		Yes	2012-09-03	
DC/DC converter	TSR 1-2433	95.7	2	191.4	Elfa Distrilec		Yes	2012-08-31	
DC/DC converter	TSR 1-24120	78.66	2	157.32	Farnell		Yes	2012-10-25	
Wires	E 1219	0	1	0	Amgab		Yes	2012-09-03	
Wires	ET 2419	0	1	0	Amgab		Yes	2012-09-03	
Socket header	215297-6	11.6	5	58	Elfa		Yes	2012-11-05	
Socket header	323-13-120-41-001101	45.6	2	91.2	Elfa		Yes	2012-11-05	
Pin header	PST 1,3/6-5,0	5.49	6	32.94	Elfa		Yes	2012-11-05	
Battery pack (NiMh pack)	NHS 4200 SCH	753.75	3	2261.25	Celltech		Yes	2012-05-29	
Additonal Battery pack (NiMh pack)	NHS 4200 SCH	753.75	3	2261.25	Celltech		Yes	2012-10-26	
Battery pack (NiMh pack)	Ordering cost	500	1	500	Celltech		Yes	2012-05-29	
Additional Battery pack (NiMh pack)	Ordering cost	500	1	500	Celltech		Yes	2012-10-26	
D-SUB 15 connector	09 68 253 7613	37.7	2	75.4	Elfa Distrilec		Yes	2012-05-13	
D-SUB 15P connector	09 67 015 4715	48.9	2	97.8	Elfa Distrilec		Yes	2012-09-03	
Capacitor	790D-106X0040C2	114	4	456	Elfa Distrilec		Yes	2012-09-08 and 2013-04-09	
Capacitor	790D-226X0040C2	114	4	456	Elfa Distrilec		Yes	2012-09-08 and 2013-04-09	
Capacitor	T350F226M016AT	15.3	10	153	Elfa Distrilec		Yes	2012-09-08 and 2013-04-09	
Capacitor	T350E106M016AT	12.7	8	101.6	Elfa Distrilec		Yes	2012-09-08 and 2013-04-09	
Pin header	801-87-036-10-001101	39.5	4	158	Elfa		Yes	2013-04-09	
Socket header	SL1-036-S184/01-99	21.6	4	86.4	Elfa		Yes	2013-04-09	
Power resistor	MCKNP05SJ012JAA9	2.12	10	21.2	Farnell		Yes	2012-09-08	
Power resistor	45J1R0E	26.71	6	160.26	Farnell		Yes	2012-09-22	
Op amp	LM201AN	18.14	4	72.56	Farnell		Yes	2012-09-08	
Switchregulator 5 VDC 1A	TSR 1-2450	95.7	2	191.4	Elfa Distrilec		Yes	2012-05-13	
Switchregulator 3.3 VDC 1000 mA	TSR 1-2433	95.7	2	191.4	Elfa Distrilec		Yes	2012-09-03	
Filter - Bourns	SRF0905-251Y	10.58	6	63.48	Fernell		Yes	2012-05-13	
MOSFET	IPU039N03LGIN-ND	9.12	4	36.48	Digikey Corp.		Yes	2012-05-13	
Optocoupler	IL300	31.97	2	63.94	Farnell		Yes	2012-09-08	
Optocoupler	PC3H7J00000F	5.98	2	11.96	Farnell		Yes	2012-09-03	
Power resistor	MCKNP07SJ0101B00	4.04	6	24.24	Farnell		Yes	2012-10-25	
Power resistor	MP915-1.00-1%	37.81	4	151.24	Farnell		Yes	2012-10-25	
Main PCBs	N/A	1250	4	5000	Multicad		Yes	2012-10-19	
D-sub 15	09 67 015 5615	43.2	2	86.4	Elfa Distrilec		Yes	2012-10-04	
D-sub 15	09 67 015 4715	48.9	1	48.9	Elfa Distrilec		Yes	2012-10-25	
Hybrid D-subs	FM 9W4P-K120	36.2	4	144.8	Elfa Distrilec		Yes	2012-10-04	
Hybrid D-subs	FM9W4S-K121	41.7	4	166.8	Elfa Distrilec		Yes	2012-10-04	
Hybrid D-subs	FM 5W5P-K120	18.5	4	74	Elfa Distrilec		Yes	2012-10-04 and 2013-04-09	
Hybrid D-subs	FM5W5S-K121	18.5	2	37	Elfa Distrilec		Yes	2012-10-04	
Power pins	FMP006S103	22.2	20	444	Elfa Distrilec		Yes	2012-10-04	

Power pins	FMP006P103	17.2	16	275.2	Elfa Distrilec		Yes	2012-10-04		
Tantalum	T350A104M035AT	11.9	3	35.7	Elfa Distrilec		Yes	2012-10-04		
Inductor	HM50-100KLF	11.5	5	55.9	Elfa Distrilec		Yes	2012-10-04 and 2013-04-09		
Capacitor	592D158X06R3R2T20	62.15	2	124.3	Farnell		Yes	2012-10-04		
Resistor	MCKNP05SJ015JAA9	2.16	10	21.6	Farnell		Yes	2012-10-04		
Resistor	MCKNP05SJ018JAA9	2.16	10	21.6	Farnell		Yes	2012-10-04		
Resistor	MCKNP05SJ020JAA9	2.16	10	21.6	Farnell		Yes	2012-10-04		
Resistor	MCKNP05SJ022JAA9	2.16	10	21.6	Farnell		Yes	2012-10-04		
Jack post	C9994-1232FWI0	10.9	5	54.5	Elfa Distrilec		Yes	2012-10-04		
Jack post	C9994-232FWI00	7.17	1	7.17	Elfa Distrilec		Yes	2012-10-04		
Screws	1857211-2	26	4	104	Elfa Distrilec		Yes	2012-10-04		
Screws	BN 3 M3X8MM	0.585	20	11.7	Elfa Distrilec		Yes	2012-10-04		
Screws	MC6S M3X6H	1.085	20	21.7	Elfa Distrilec		Yes	2012-10-04		
Spacer bolts	99130-50050 / DSM3050X5 DI	2.97	25	74.25	Elfa Distrilec		Yes	2012-11-05		
Total				**15800.23**						

Component	Component name	Price per unit	Number of units	Cost in SEK	Retailer	Comment	Bought	Date of purchase	Purchase expense (occured by team member)
Pressure sensor	XFPM-200KPGR (H)	352	2	704	Elfa Distrilec		Yes	2012-05-13 and 2012-09-08	
Nichrome wire	Nichrome wire 0.2 mm	35	6	210	Alega		Yes	2012-04-25	Björn Sjödahl
Temperature sensor DO-24	KTY84-150	15.9	8	127.2	Elfa Distrilec		Yes	2012-05-13	
Micro sd card	SFSD1024N1BN1T	282.86	2	565.72	Farnell		Yes	2012-10-25	
Signal transciever	MAX488EESA	75.72	1	75.72	Farnell		Yes	2012-09-03	
Micro sd card holder	2908-05WB-MG	20.4	4	81.6	Elfa Distrilec		Yes	2012-09-03 and 2013-04-09	
Level converter bidirectional	MAX3378EEUD	62.63	1	62.63	Farnell		Yes	2012-09-03	
Pressure sensor	HSCDANN015PAA	349.43	1	349.43	Digikey		Yes	2013-04-09	Björn Sjödahl
Atmega 328	ATMEGA328-PU	30.73	2	61.46	Farnell		Yes	2013-04-09	
Pressure sensor	SPD100G	63.1	1	63.1	Elfa Distrilec		Yes	2012-10-04	
Total				**2300.86**					

Component	Component name	Price per unit	Number of units	Cost in SEK	Retailer	Comment	Bought	Date of purchase	Purchase expense (occured by team member)
MCU	Atmega328	100	4	400	SRT	2 bought (200 SEK)	Yes	2012-05-25	
Micro SD USB reader	Micro SDHC Card Reader	99	1	99	Clas Ohlson		Yes	2012-10-13	Hamoon Shahbazi
Total				**499**					

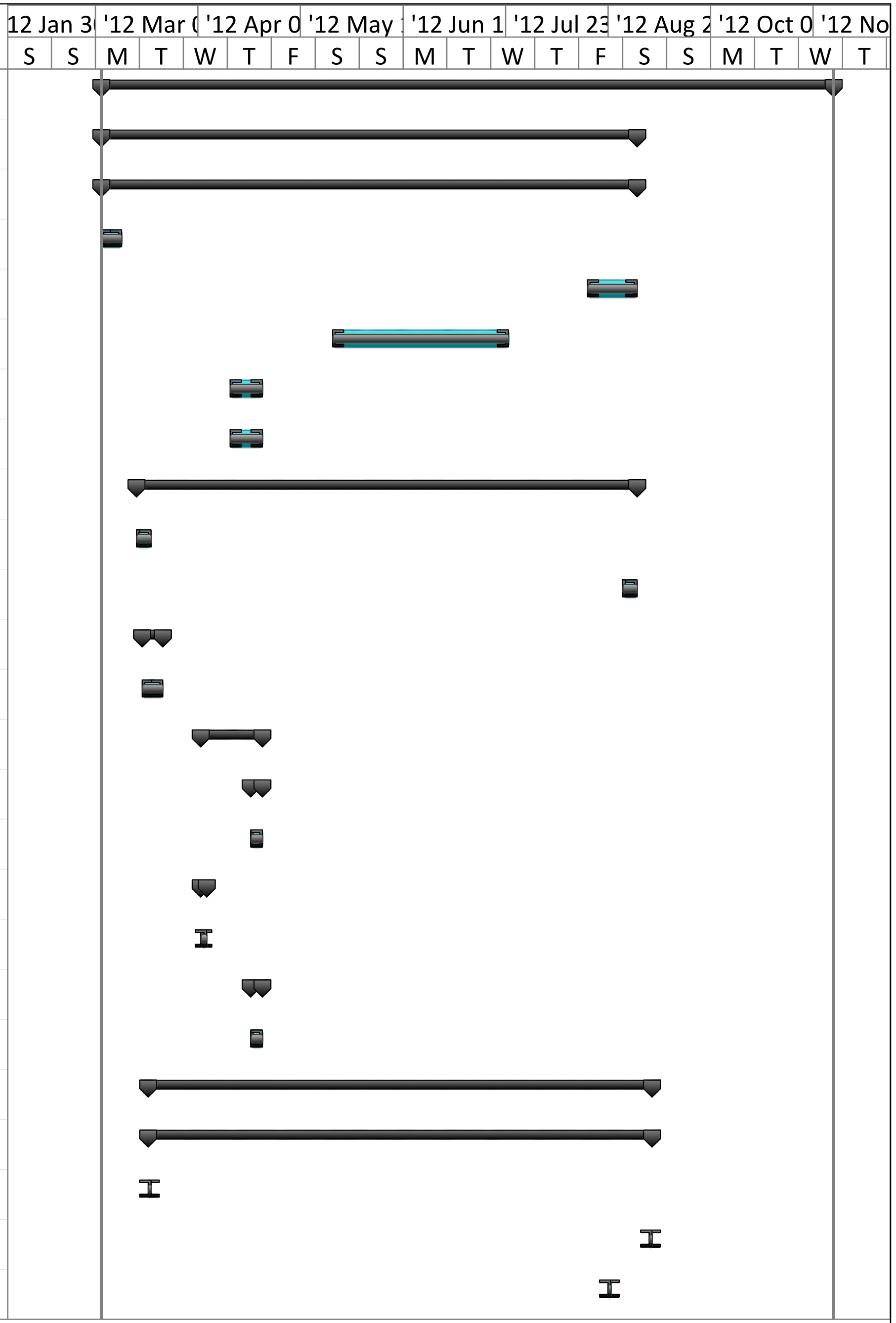
Component	Component name	Price per unit	Number of units	Cost in SEK	Retailer	Comment	Bought	Date of purchase	Purchase expense (occured by team member)
Posters	Posters	250	10	2500	LTU		Yes	2012-11-13	
Team t-shirts	T-shirts	318.75	14	4462.5	Falks tryckeri och brodyr i Kiruna AB		Yes	2012-10-03	
Total				**6962.5**					

Component	Component name	Price per unit	Number of units	Cost in SEK	Retailer	Comment	Bought	Date of purchase	Purchase expense (occured by team member)
Transportation STW	Fuel	460	1	460	Statoil		Yes	2012-02-27 - 2012-03-02	Björn Sjödahl
Transportation Selection Workshop	Plane tickets			13384.32	NEX		Yes	2011-11-06	
Accomodation Selection Workshop	Hotel	6615.68	1	6615.68			Yes	2011-11-06	Anders Svedevall
Food STW	Lunch, dinner for 2 members, 5 days	103	20	2060	Esrange SSC		Yes	2012-02-27 - 2012-03-02	Robert Lindberg
Shipping fee for components	Shipping fee Elfa	39	1	39	Elfa Distrilec		Yes	2012-05-13	
Shipping fee for components	Shipping fee Alega Skolmaterial AB	72	1	72	Alega		Yes	2012-05-13	
Shipping fee for components	Shipping fee Farnell	200	1	200	Farnell		Yes	2012-05-13	
Fuel Launch campaign	Fuel	500	1	500			No		
Transportation to Oulu, Finland	Rental car	1800	1	1800			No		
Transportation to Oulu, Finland	Fuel	1500	1	1500			No		
Accomodation Oulu, Finland	Hotel/Hostel	500	4	2000			No		
Total				**28631**					

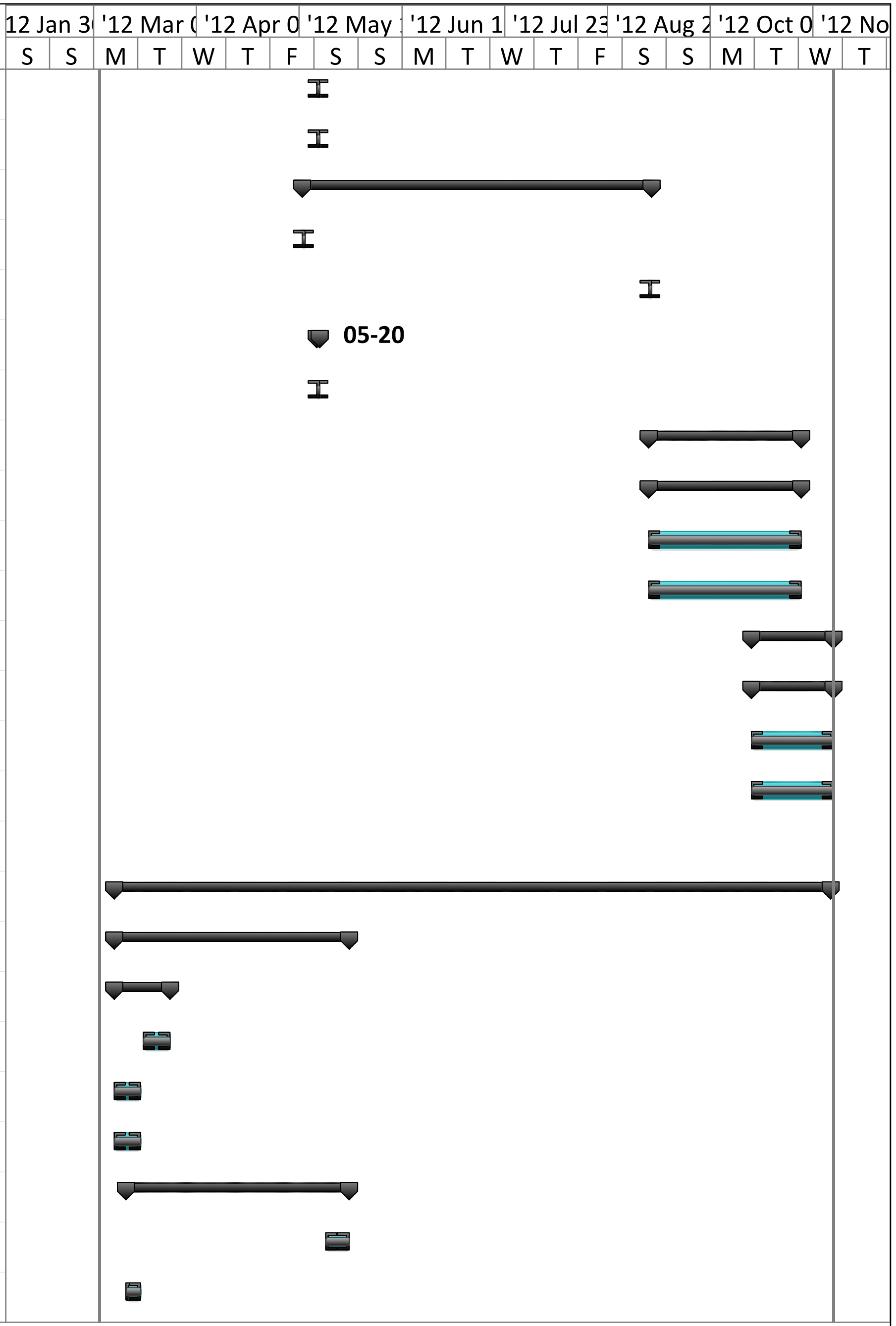
APPENDIX E

Work Breakdown Structure and Gantt Charts

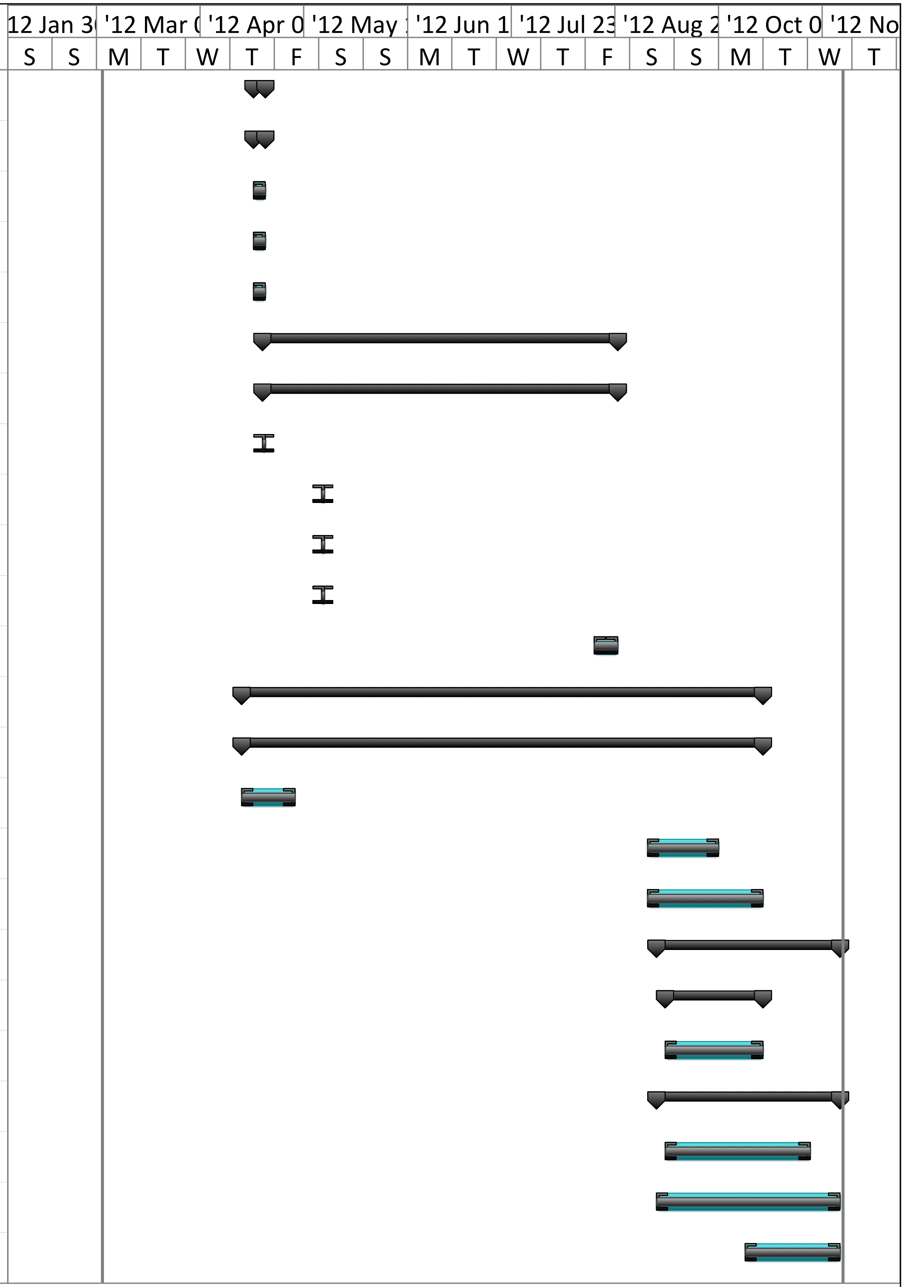
ID		Task Name	Duration	Start	Finish
1	✓	1 PDS	**178 days**	**12-03-07**	**12-11-11**
2	✓	1.1 Design	**131 days**	**12-03-07**	**12-09-05**
3	✓	1.1.1 Interface	**131 days**	**12-03-07**	**12-09-05**
4	✓	1.1.1.1 Cables	5 days	12-03-07	12-03-13
5	✓	1.1.1.2 Connectors	13 days	12-08-20	12-09-05
6	✓	1.1.1.3 Optocoupler	42 days	12-05-25	12-07-23
7	✓	1.1.1.4 Safety system	7 days	12-04-20	12-04-30
8	✓	1.1.1.5 Filters	7 days	12-04-20	12-04-30
9	✓	1.1.2 Power supply	**123 days**	**12-03-19**	**12-09-05**
10	✓	1.1.2.1 Batteries	5 days	12-03-19	12-03-23
11	✓	1.1.2.2 Cs, Ls, Rs and Ds	4 days	12-09-01	12-09-05
12	✓	1.1.3 Voltage regulating	**5 days**	**12-03-21**	**12-03-27**
13	✓	1.1.3.1 Power cicuits	5 days	12-03-21	12-03-27
14	✓	1.2 Simulation	**15 days**	**12-04-10**	**12-04-30**
15	✓	1.2.1 Interface	**2 days**	**12-04-27**	**12-04-30**
16	✓	1.2.1.1 Safety system	2 days	12-04-27	12-04-30
17	✓	1.2.2 Batteries	**2 days**	**12-04-10**	**12-04-11**
18	✓	1.2.2.1 Connection	2 days	12-04-10	12-04-11
19	✓	1.2.3 Voltage regulating	**2 days**	**12-04-27**	**12-04-30**
20	✓	1.2.3.1 Power cicuits	2 days	12-04-27	12-04-30
21	✓	1.3 Order	**122 days**	**12-03-23**	**12-09-10**
22	✓	1.3.1 Interface	**122 days**	**12-03-23**	**12-09-10**
23	✓	1.3.1.1 Cables	1 day	12-03-23	12-03-23
24	✓	1.3.1.2 Connectors	1 day	12-09-10	12-09-10
25	✓	1.3.1.3 Optocoupler	1 day	12-08-27	12-08-27



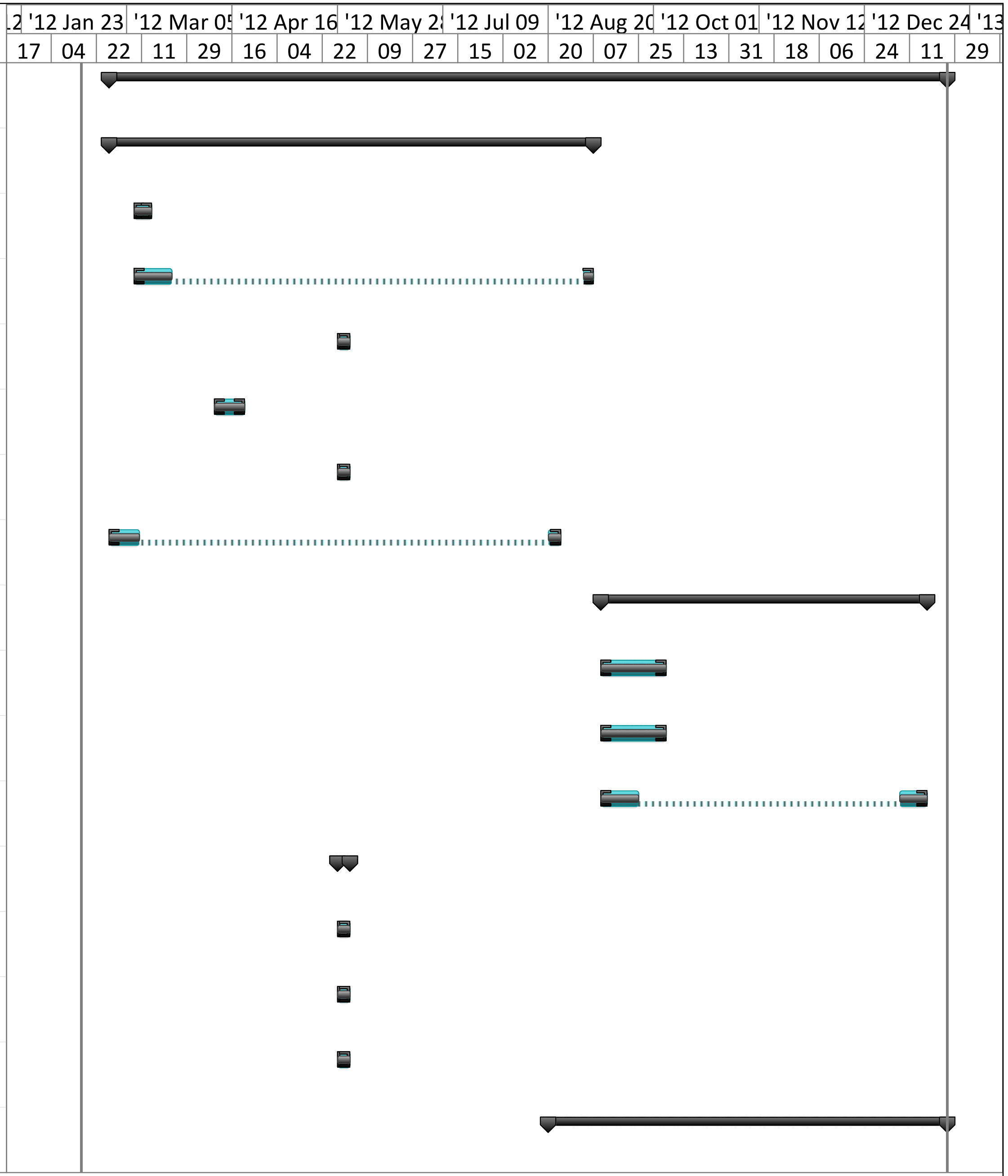
ID		Task Name	Duration	Start	Finish
26	✓	1.3.1.4 Safety system	1 day	12-05-20	12-05-20
27	✓	1.3.1.5 Filters	1 day	12-05-20	12-05-20
28	✓	**1.3.2 Batteries**	**85 days**	**12-05-15**	**12-09-10**
29	✓	1.3.2.1 Batteries	1 day	12-05-15	12-05-15
30	✓	1.3.2.2 Cs, Ls, Rs and Ds	1 day	12-09-10	12-09-10
31	✓	**1.3.3 Voltage regulator**	**0 days**	**12-05-20**	**12-05-20**
32	✓	1.3.3.1 Power cicuits	1 day	12-05-20	12-05-20
33	✓	**1.4 Construction**	**38 days**	**12-09-10**	**12-10-31**
34	✓	**1.4.1 Power distribution system**	**38 days**	**12-09-10**	**12-10-31**
35	✓	1.4.1.1 Service module	38 days	12-09-10	12-10-31
36	✓	1.4.1.2 Batteries	38 days	12-09-10	12-10-31
37	✓	**1.5 Testing**	**20 days**	**12-10-15**	**12-11-11**
38	✓	**1.5.1 Power distribution system**	**20 days**	**12-10-15**	**12-11-11**
39	✓	1.5.1.1 Service module	21 days	12-10-15	12-11-11
40	✓	1.5.1.2 Batteries	21 days	12-10-15	12-11-11
41					
42	✓	**2 CPS**	**175 days**	**12-03-12**	**12-11-10**
43	✓	**2.1 Design**	**58 days**	**12-03-12**	**12-05-30**
44	✓	**2.1.1 Chamber components**	**15 days**	**12-03-12**	**12-03-30**
45	✓	2.1.1.1 Resistance wires	7 days	12-03-22	12-03-30
46	✓	2.1.1.2 Temperature sensor	7 days	12-03-12	12-03-20
47	✓	2.1.1.3 Pressure sensor	7 days	12-03-12	12-03-20
48	✓	**2.1.2 Components**	**54 days**	**12-03-16**	**12-05-30**
49	✓	2.1.2.1 Telemetry and data	6 days	12-05-23	12-05-30
50	✓	2.1.2.2 Microcontroller	3 days	12-03-16	12-03-20



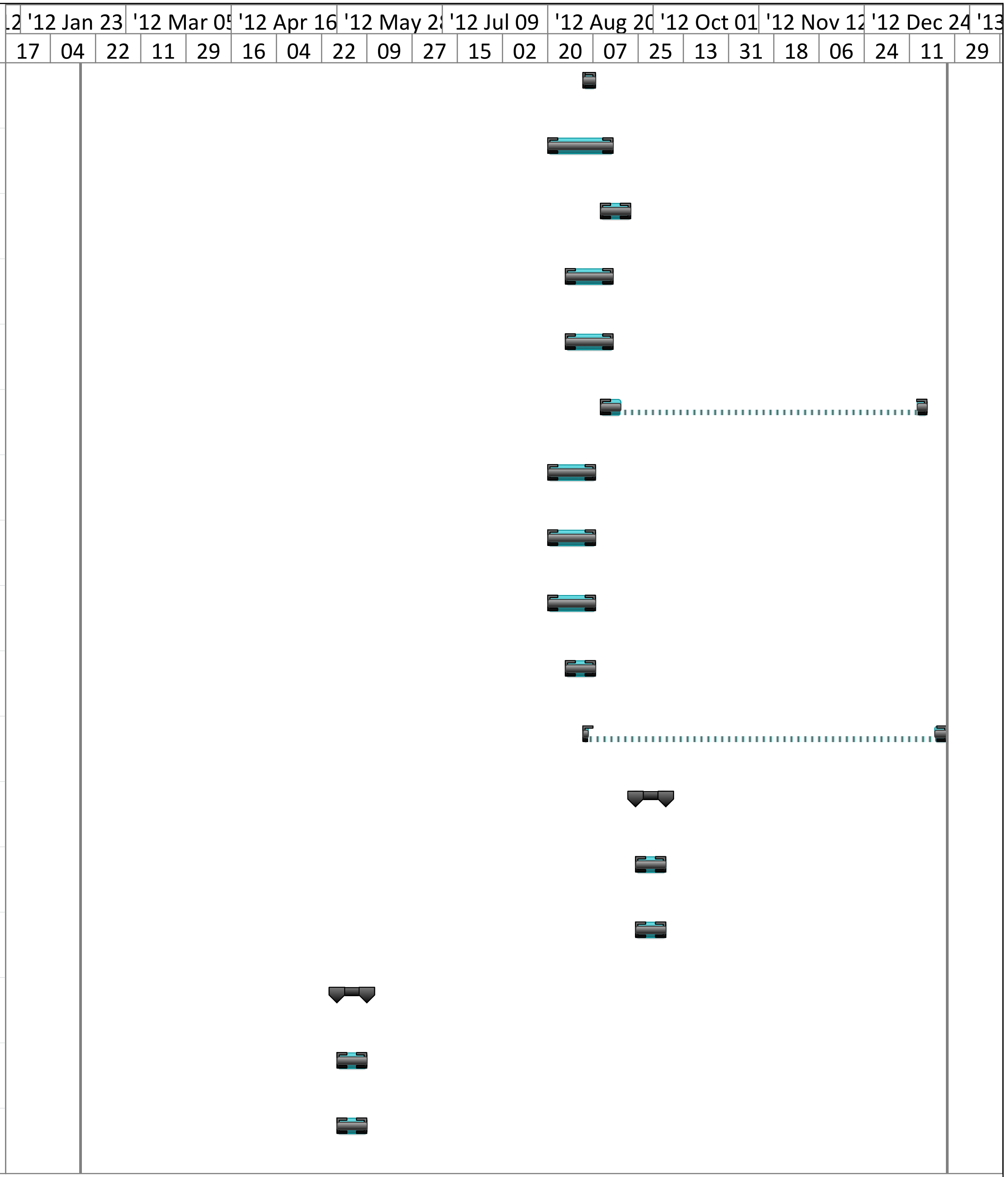
ID		Task Name	Duration	Start	Finish
51	✓	2.2 Simulation	**2 days**	**12-04-27**	**12-04-30**
52	✓	2.2.1 Breadboard	**2 days**	**12-04-27**	**12-04-30**
53	✓	2.2.1.1 Temperature sensor	2 days	12-04-27	12-04-30
54	✓	2.2.1.2 Pressure sensor	2 days	12-04-27	12-04-30
55	✓	2.2.1.3 Microcontroller	2 days	12-04-27	12-04-30
56	✓	2.3 Order	**86 days**	**12-04-30**	**12-08-27**
57	✓	2.3.1 Components	**86 days**	**12-04-30**	**12-08-27**
58	✓	2.3.1.1 Resistance wires	1 day	12-04-30	12-04-30
59	✓	2.3.1.2 Temperature sensor	1 day	12-05-20	12-05-20
60	✓	2.3.1.3 Pressure sensor	1 day	12-05-20	12-05-20
61	✓	2.3.1.4 Microcontroller	1 day	12-05-20	12-05-20
62	✓	2.3.1.5 Telemetry and data components	6 days	12-08-20	12-08-27
63	✓	2.4 Testing	**126 days**	**12-04-23**	**12-10-15**
64	✓	2.4.1 Components	**126 days**	**12-04-23**	**12-10-15**
65	✓	2.4.1.1 Resistance wires	14 days	12-04-23	12-05-10
66	✓	2.4.1.2 Performance test - All components	17 days	12-09-07	12-09-30
67	✓	2.4.1.3 Breadboarding system	27 days	12-09-07	12-10-15
68	✓	2.5 Integration	**45 days**	**12-09-10**	**12-11-10**
69	✓	2.5.1 Batteries	**23 days**	**12-09-13**	**12-10-15**
70	✓	2.5.1.1 Resistance wires	23 days	12-09-13	12-10-15
71	✓	2.5.2 Service module	**45 days**	**12-09-10**	**12-11-10**
72	✓	2.5.2.1 Chamber components	35 days	12-09-13	12-10-31
73	✓	2.5.2.2 Telemetry and data components	46 days	12-09-10	12-11-10
74	✓	2.5.2.3 Microcontroller	24 days	12-10-10	12-11-10



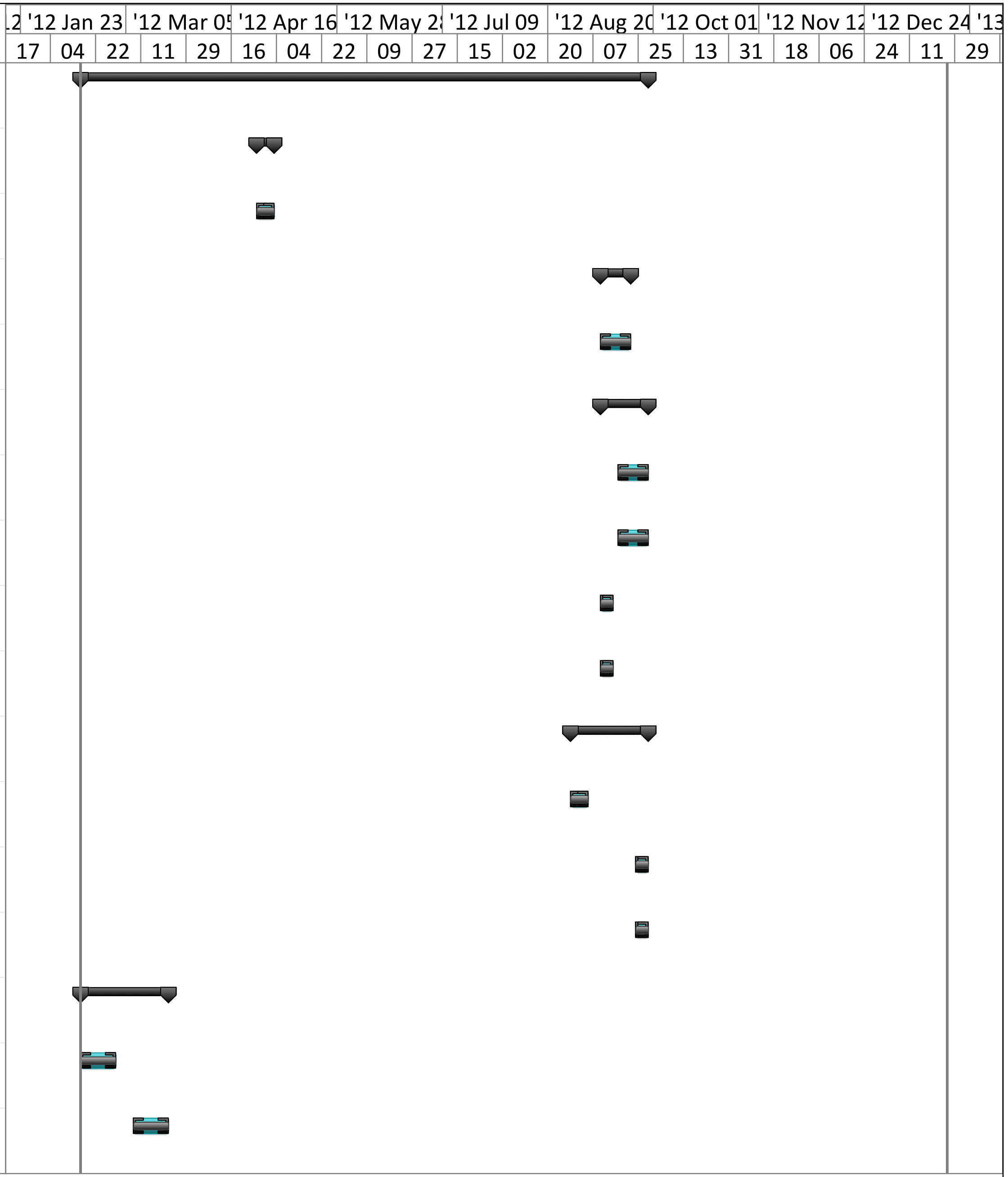
ID		Task Name	Duration	Start
1	✓	**1 On-Board Data Handling**	**48 wks**	**12-02-27**
2	✓	**1.1 Design**	**27,8 wks**	**12-02-27**
3	✓	1.1.1 Top down structure of data flow	1 wk	12-03-08
4	✓	1.1.2 Connectors to what pins	3 wks	12-03-08
5	✓	1.1.3 Telemetry	1 wk	12-05-28
6	✓	1.1.4 Stages	2 wks	12-04-09
7	✓	1.1.5 Bandwidth	1 wk	12-05-28
8	✓	1.1.6 Software flow	3 wks	12-02-27
9	✓	**1.2 Simulation**	**18,8 wks**	**12-09-10**
10	✓	1.2.1 Temp sensor simulator	4 wks	12-09-10
11	✓	1.2.2 Pressure sensor simulator	4 wks	12-09-10
12	✓	1.2.3 Saving to SD card	4 wks	12-09-10
13	✓	**1.3 Order**	**1 wk**	**12-05-28**
14	✓	1.3.1 Order headerboard	1 wk	12-05-28
15	✓	1.3.2 Order programmer	1 wk	12-05-28
16	✓	1.3.3 Order SD card	1 wk	12-05-28
17	✓	**1.4 Coding**	**23 wks**	**12-08-20**



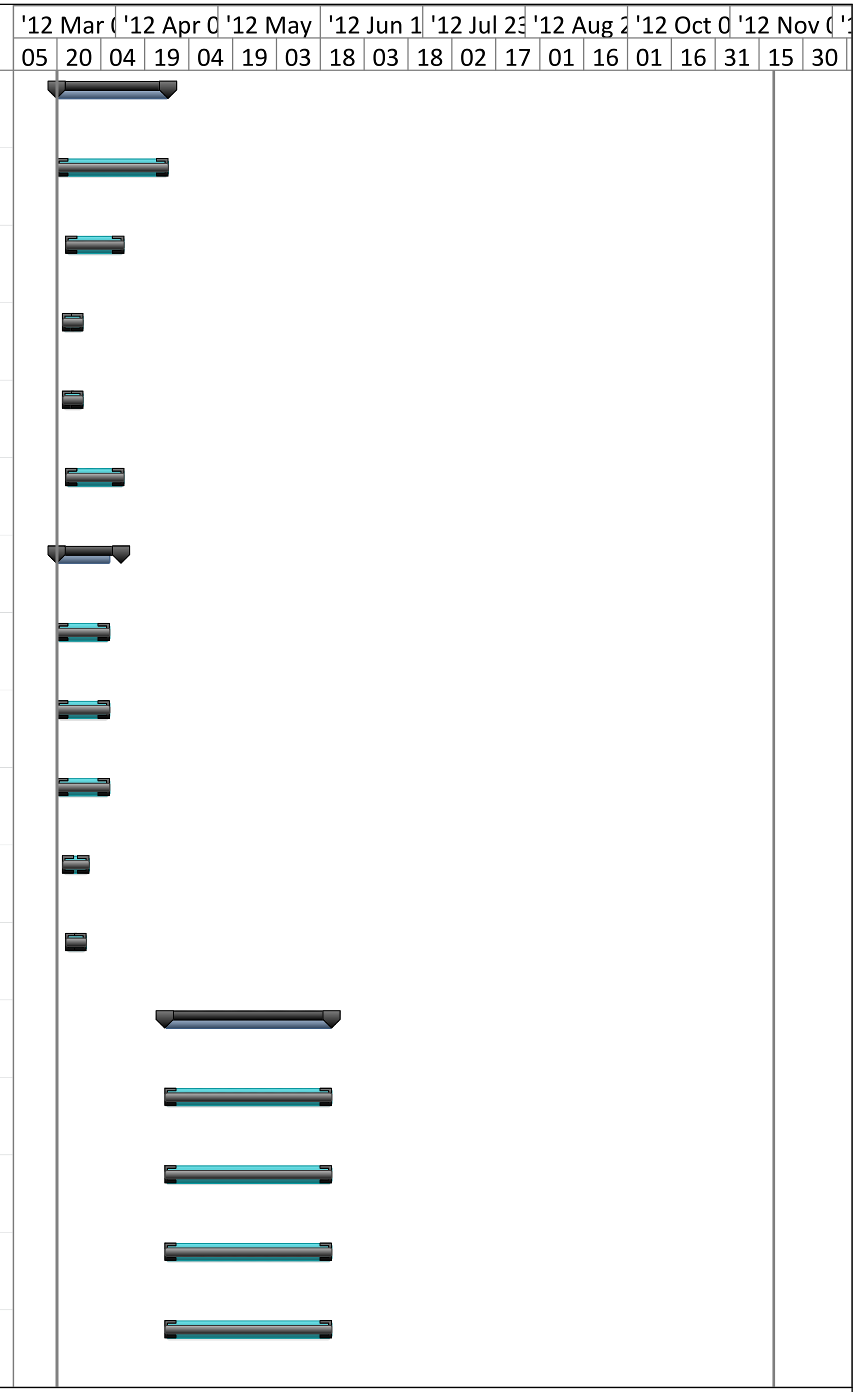
ID		Task Name	Duration	Start
18	✓	1.4.1 Main loop	1 wk	12-09-03
19	✓	1.4.2 Timeline/Statemachine	4 wks	12-08-20
20	✓	1.4.3 Resistance wires	2 wks	12-09-10
21	✓	1.4.4 Temperature sensor	3 wks	12-08-27
22	✓	1.4.5 Pressure sensor	3 wks	12-08-27
23	✓	1.4.6 SD card	2 wks	12-09-10
24	✓	1.4.7 Protocols	3 wks	12-08-20
25	✓	1.4.8 Downlink	3 wks	12-08-20
26	✓	1.4.9 Uplink	3 wks	12-08-20
27	✓	1.4.10 LO	2 wks	12-08-27
28	✓	1.4.11 Emergency system/Watchdog	1,4 wks	12-09-03
29	✓	**1.5 Test**	**2 wks**	**12-09-24**
30	✓	1.5.1 Temperature sensor	2 wks	12-09-24
31	✓	1.5.2 Pressure sensor	2 wks	12-09-24
32	✓	**1.6 General**	**2 wks**	**12-05-28**
33	✓	1.6.1 IDE	2 wks	12-05-28
34	✓	1.6.2 Source control	2 wks	12-05-28



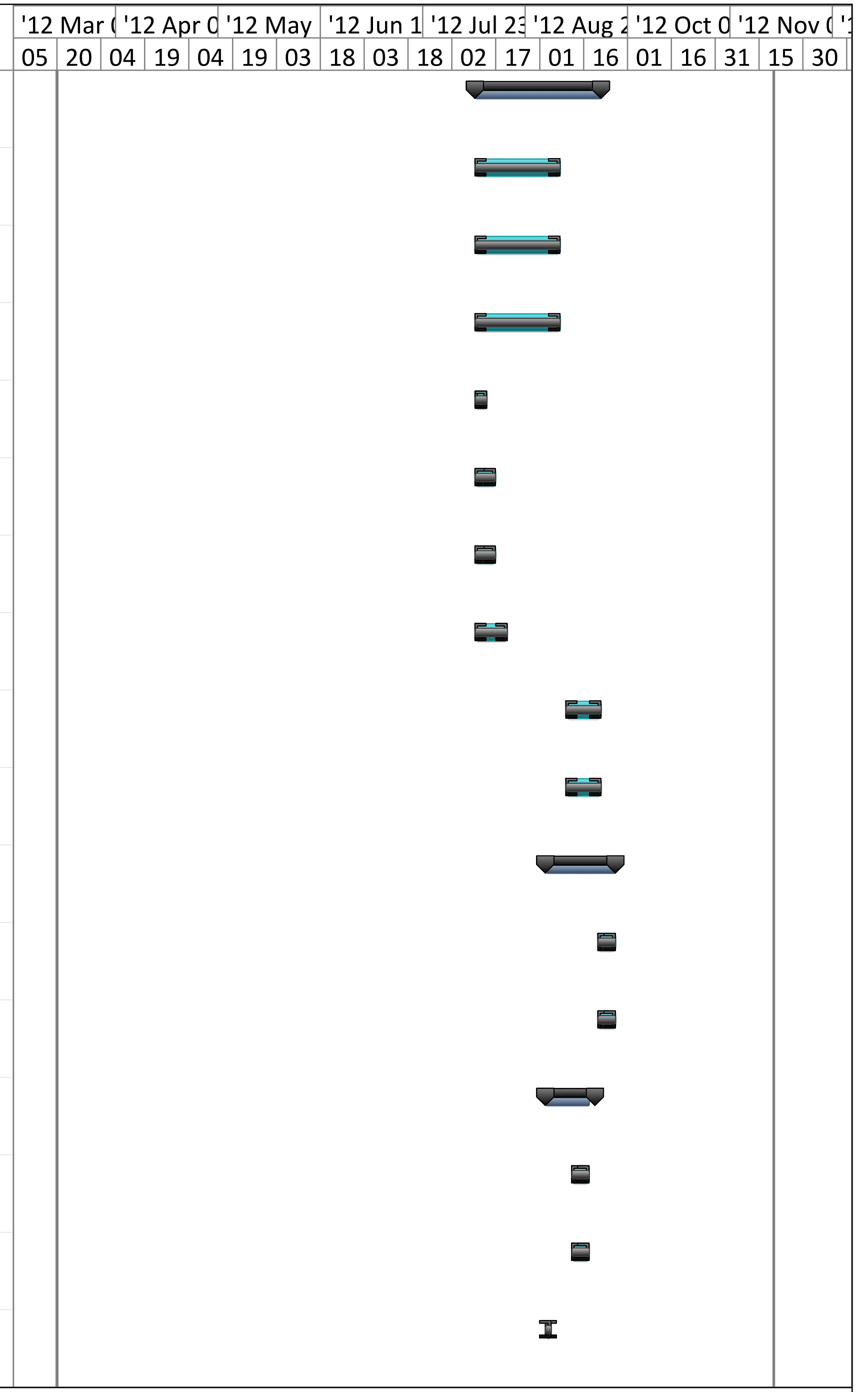
ID		Task Name	Duration	Start
35	✓	**2 SOLAR Ground Station**	**32,4 wks**	**12-02-16**
36	✓	**2.1 Design**	**1 wk**	**12-04-26**
37	✓	2.1.1 Overview	1 wk	12-04-26
38	✓	**2.2 Simulation**	**2 wks**	**12-09-10**
39	✓	2.2.1 Data logging	2 wks	12-09-10
40	✓	**2.3 Coding**	**3 wks**	**12-09-10**
41	✓	2.3.1 Data logging	2 wks	12-09-17
42	✓	2.3.2 Visualization	2 wks	12-09-17
43	✓	2.3.3 Downlink	1 wk	12-09-10
44	✓	2.3.4 Uplink	1 wk	12-09-10
45	✓	**2.4 Test**	**4,6 wks**	**12-08-29**
46	✓	2.4.1 Recieving data	1 wk	12-08-29
47	✓	2.4.2 Monitor data	1 wk	12-09-24
48	✓	2.4.3 Store data	1 wk	12-09-24
49	✓	**2.5 General**	**5 wks**	**12-02-16**
50	✓	2.5.1 IDE	2 wks	12-02-16
51	✓	2.5.2 Source control	2 wks	12-03-08



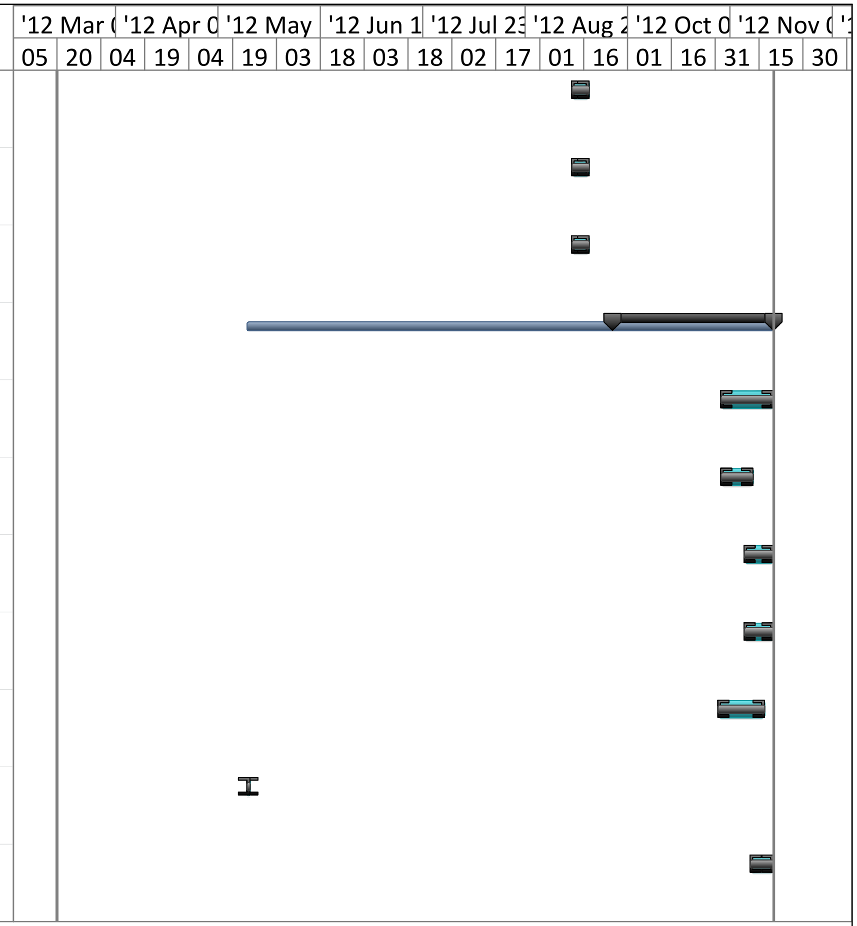
ID		Task Name	Duration	Start	Finish
1	✓	**1 Design**	**28 days**	**12-03-20**	**12-04-26**
2	✓	1.1 CAD	28 days	12-03-20	12-04-26
3	✓	1.2 Layout	14 days	12-03-23	12-04-11
4	✓	1.3 Batterypack housing	5 days	12-03-22	12-03-28
5	✓	1.4 shaker plate	5 days	12-03-22	12-03-28
6	✓	1.5 Electronics box	14 days	12-03-23	12-04-11
7	✓	**1.6 Chambers**	**16 days**	**12-03-20**	**12-04-10**
8	✓	1.6.1 PCB layout and attachment	14 days	12-03-20	12-04-06
9	✓	1.6.2 Base	14 days	12-03-20	12-04-06
10	✓	1.6.3 Hat	14 days	12-03-20	12-04-06
11	✓	1.6.4 Sealing	7 days	12-03-22	12-03-30
12	✓	1.6.5 Screws and bolts	5 days	12-03-23	12-03-29
13	✓	**2 Simulations**	**42 days**	**12-04-26**	**12-06-21**
14	✓	2.1 FEM	42 days	12-04-26	12-06-21
15	✓	2.2 Modal	42 days	12-04-26	12-06-21
16	✓	2.3 Thermal	42 days	12-04-26	12-06-21
17	✓	2.4 vacuum	42 days	12-04-26	12-06-21



ID		Task Name	Duration	Start	Finish
18	✓	**3 Order**	**31 days**	**12-08-10**	**12-09-21**
19	✓	3.1 Base	21 days	12-08-10	12-09-07
20	✓	3.2 Hat	21 days	12-08-10	12-09-07
21	✓	3.3 PCB and attachments	21 days	12-08-10	12-09-07
22	✓	3.4 Solder Sn63Pb37	2 days	12-08-10	12-08-13
23	✓	3.5 Screws and bolts	5 days	12-08-10	12-08-16
24	✓	3.6 Electronics box	5 days	12-08-10	12-08-16
25	✓	3.7 Sealing	7 days	12-08-10	12-08-20
26	✓	3.8 Batterypack housing	10 days	12-09-10	12-09-21
27	✓	3.9 Shaker plate	10 days	12-09-10	12-09-21
28	✓	**4 Construction**	**18 days**	**12-09-03**	**12-09-26**
29	✓	4.1 Mount electronics box	4 days	12-09-21	12-09-26
30	✓	4.2 Mount battery package	4 days	12-09-21	12-09-26
31	✓	**4.3 Assemble chambers**	**13 days**	**12-09-03**	**12-09-19**
32	✓	4.3.1 Base	4 days	12-09-12	12-09-17
33	✓	4.3.2 Hat	4 days	12-09-12	12-09-17
34	✓	4.3.3 PCB and mounting	2 days	12-09-03	12-09-04

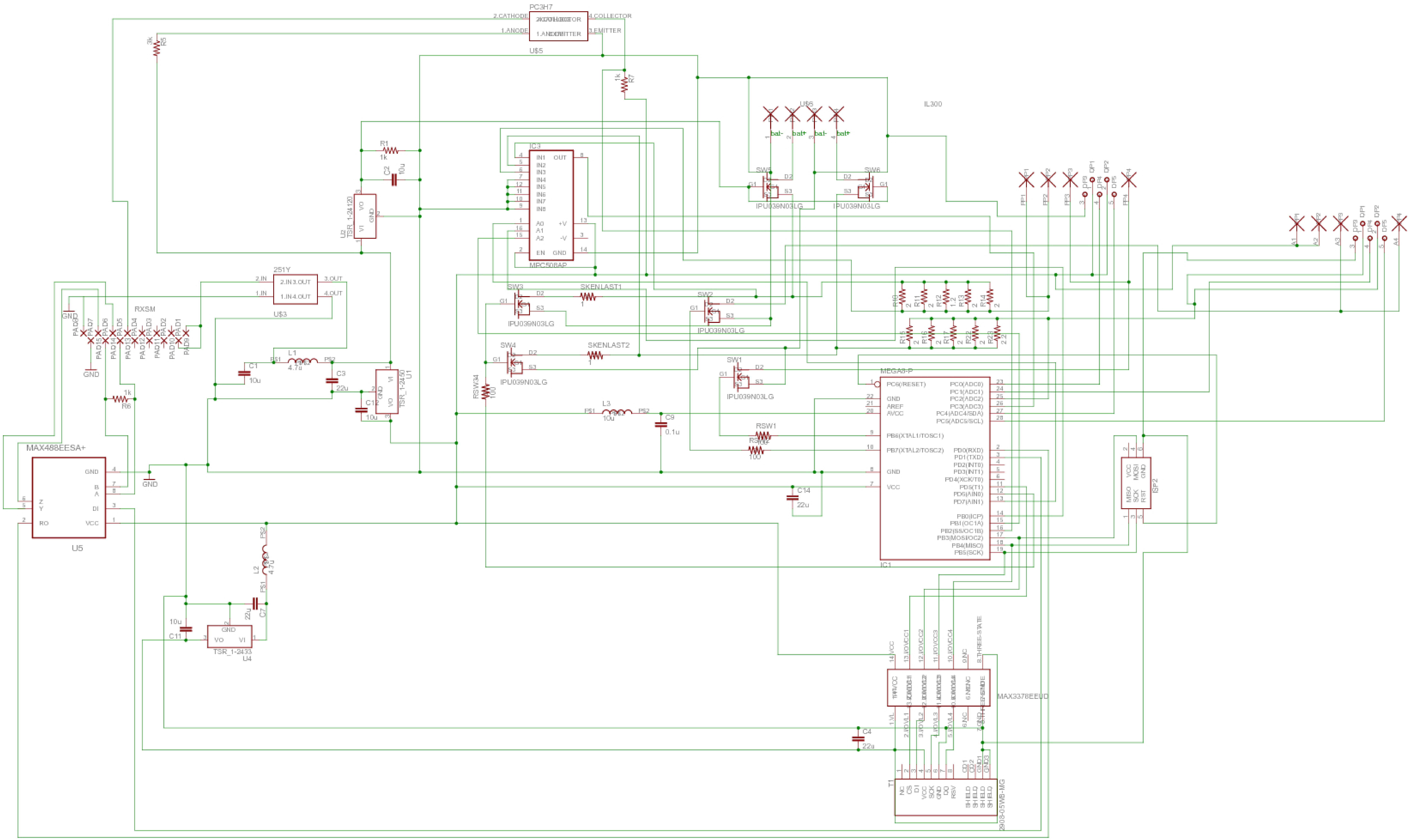


ID		Task Name	Duration	Start	Finish
35	✓	4.3.4 Sealing	4 days	12-09-12	12-09-17
36	✓	4.3.5 Insulation	4 days	12-09-12	12-09-17
37	✓	4.3.6 Screws and bolts	4 days	12-09-12	12-09-17
38	✓	**5 Test**	**39 days**	**12-09-26**	**12-11-19**
39	✓	5.1 Shake test of experiment OST.1	12 days	12-11-02	12-11-19
40	✓	5.2 Vacuum & performance test OST.2	7 days	12-11-02	12-11-12
41	✓	5.3 Thermal test OST.3	7 days	12-11-10	12-11-19
42	✓	5.4 Thermal test of heat spread OST.4	7 days	12-11-10	12-11-19
43	✓	5.5 Weigh the experiment OST.5	12 days	12-11-01	12-11-16
44	✓	5.6 Performance test of solder IST.1	1 day	12-05-24	12-05-24
45	✓	5.7 Complementary tests	6 days	12-11-12	12-11-19

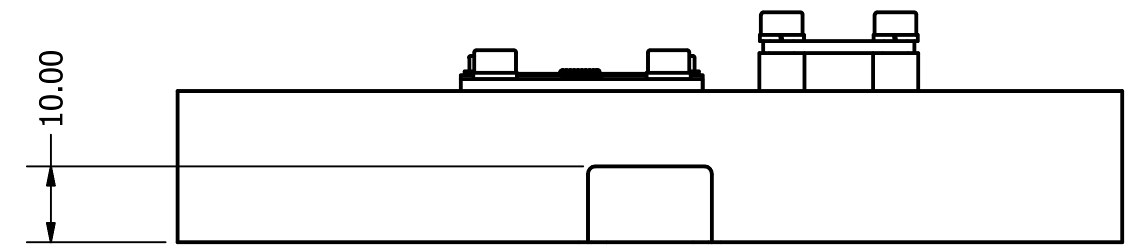


APPENDIX F

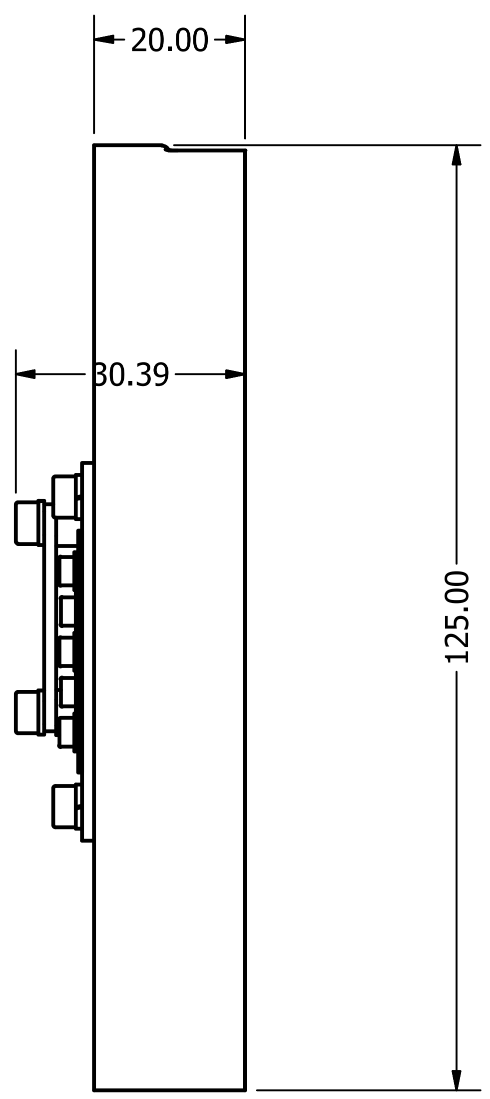
Drawings



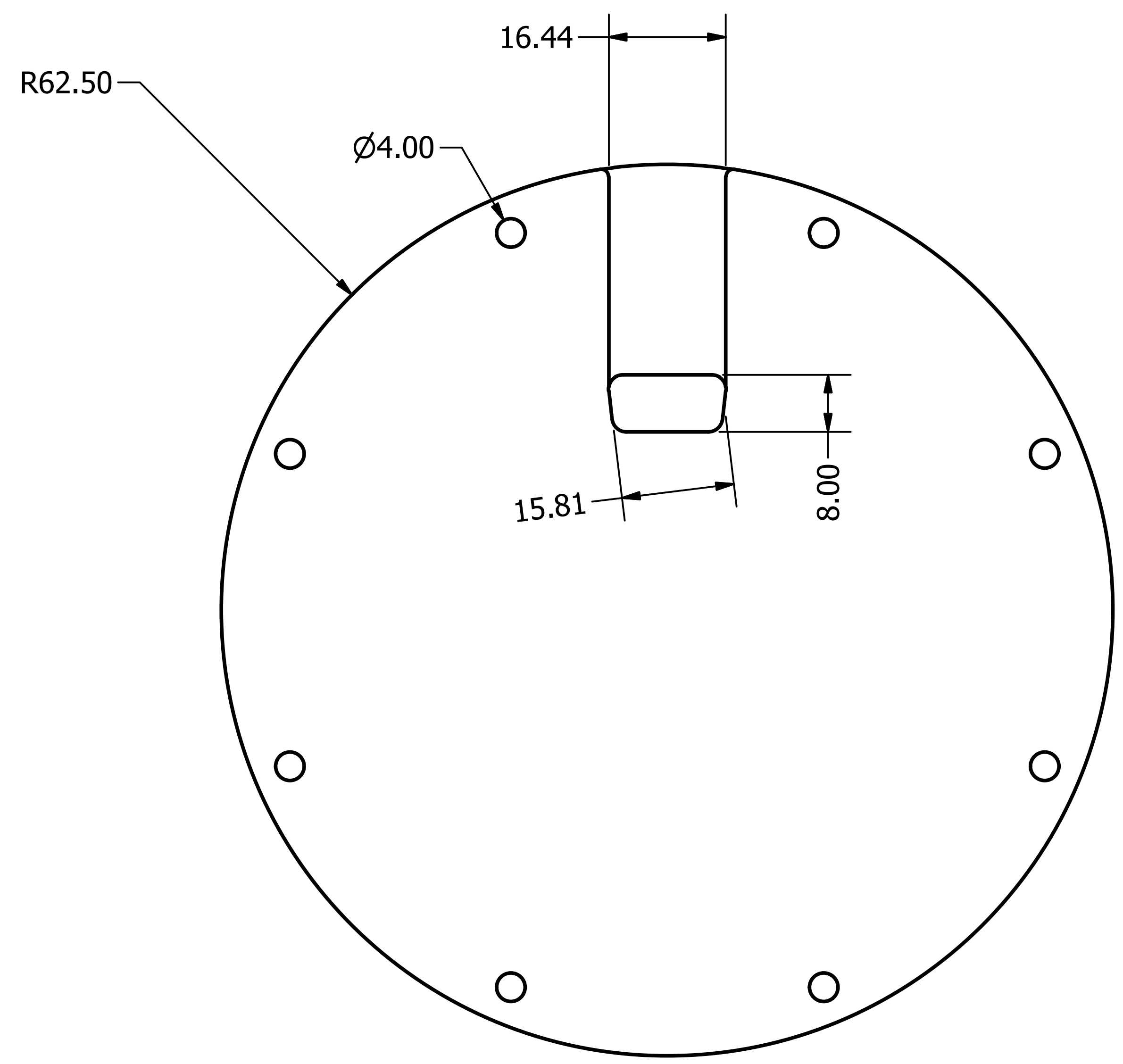
PC3H7
U$5
IL300
U$6
IC3
MPC508AP
R1
1k
C2
10u
U2
TSR_1-24120
251Y
U$3
RXSM
GND
L1
4.7u
C1
10u
C3
22u
C12
10u
U1
TSR_1-2450
SW1
SW2
SW3
SW4
SW5
SW6
IPU039N03LG
SKENLAST1
SKENLAST2
RSW34
100
RSW1
L3
10u
C9
0.1u
C14
22u
MEGA8-P
IC1
MAX488EESA+
U5
R5
3k
R6
1k
R7
1k
L2
4.7u
C7
22u
C11
10u
TSR_1-2433
U4
MAX3378EEUD
C4
22u
T1
2908-05WB-MG
ISP2



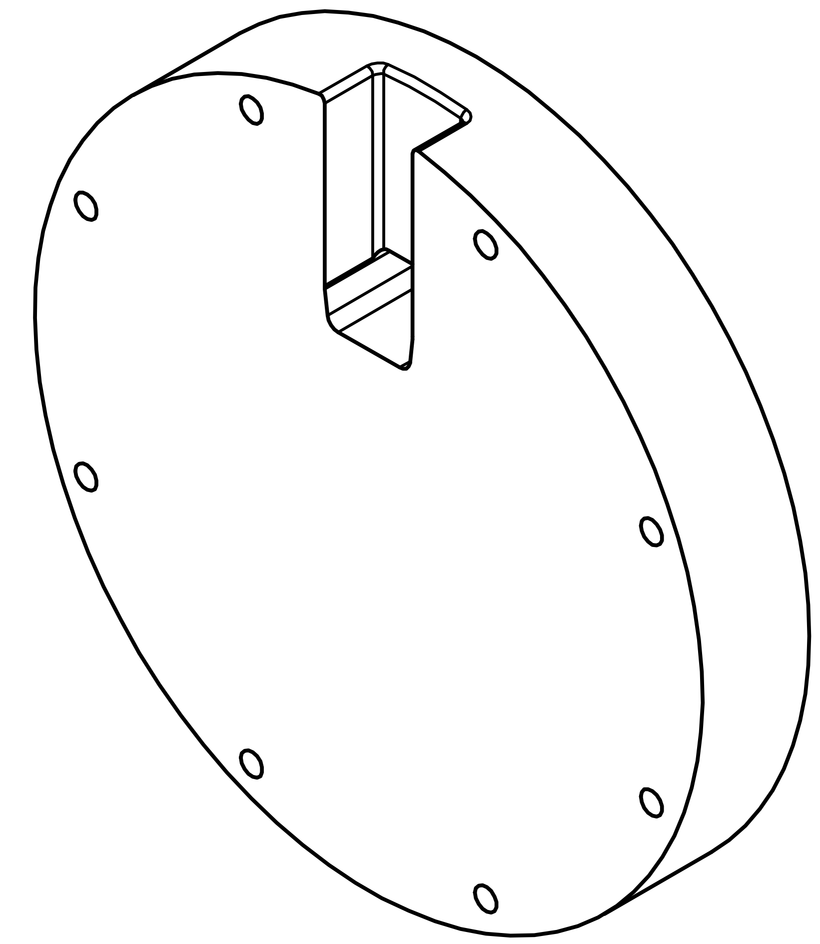
Side view

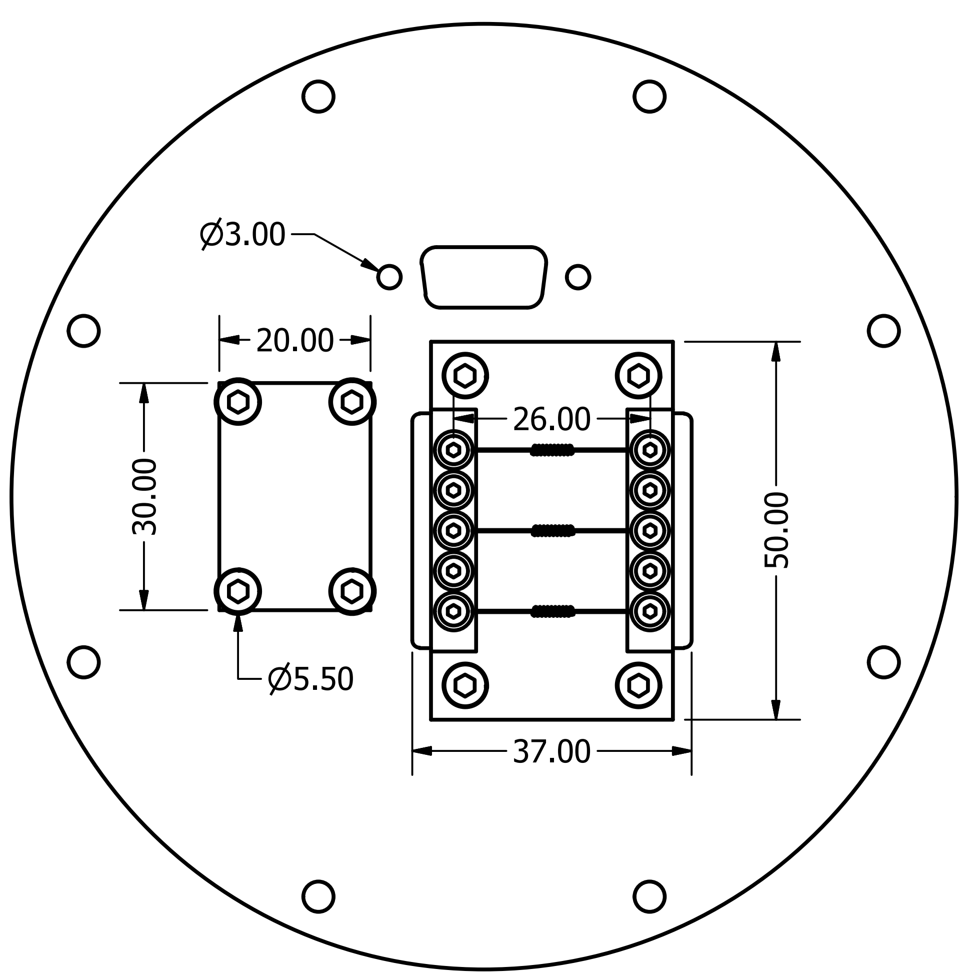


Side view



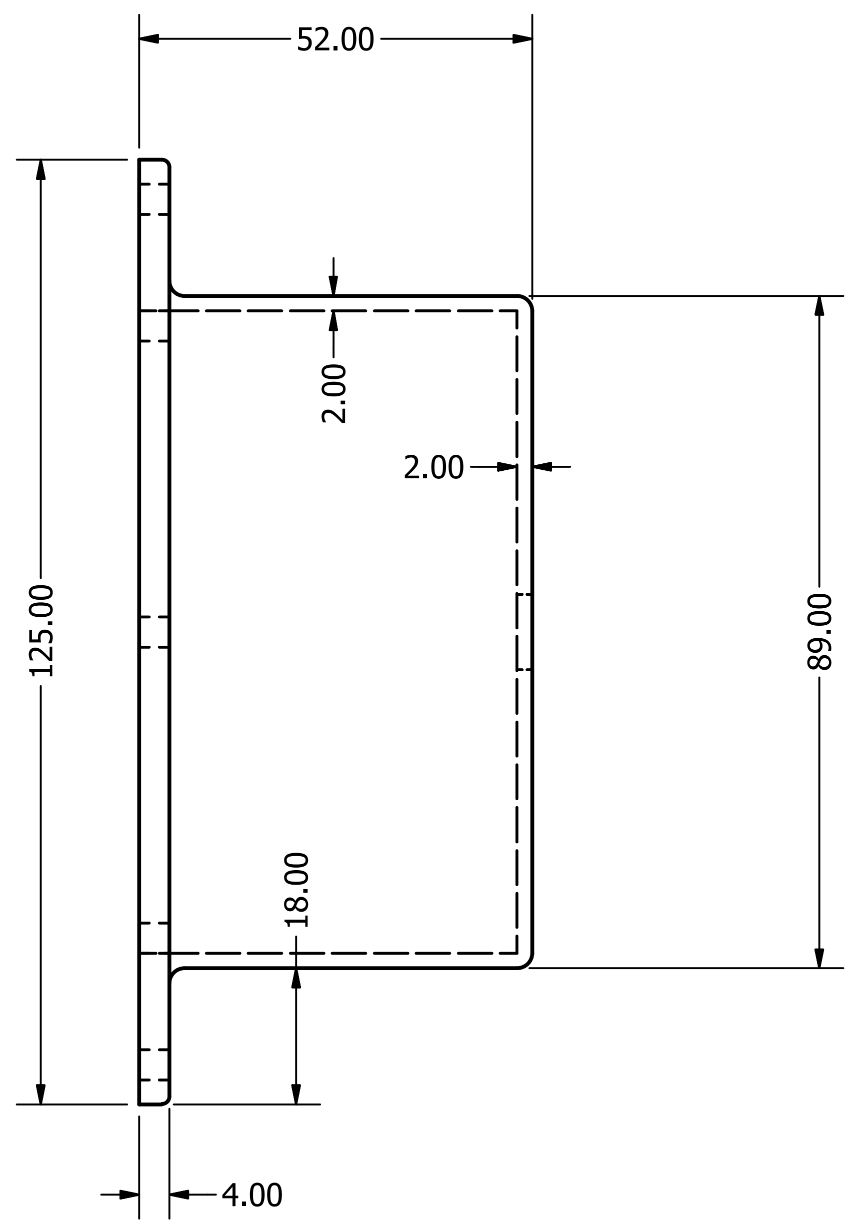
Bottom view



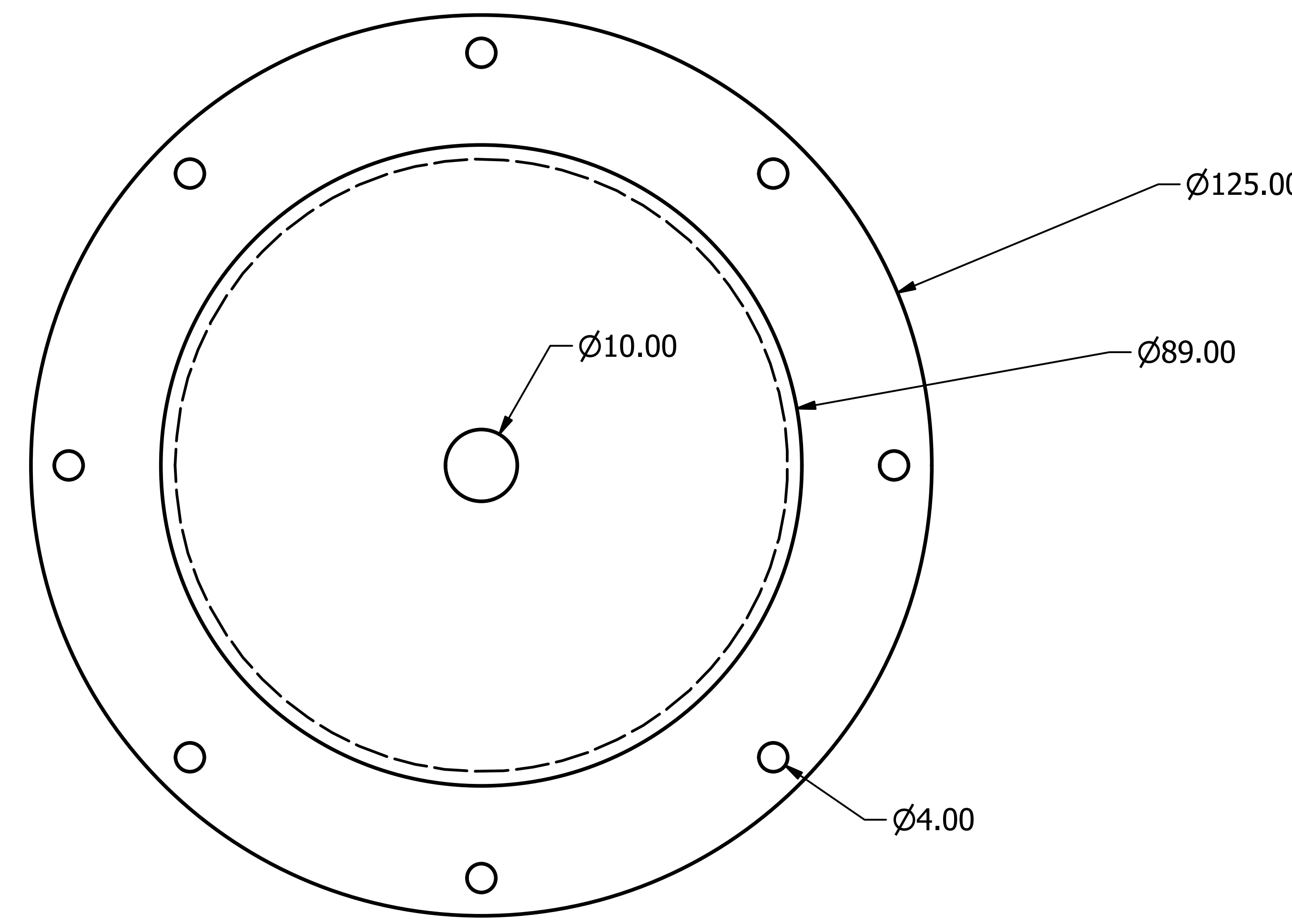


Top view with soldering setup

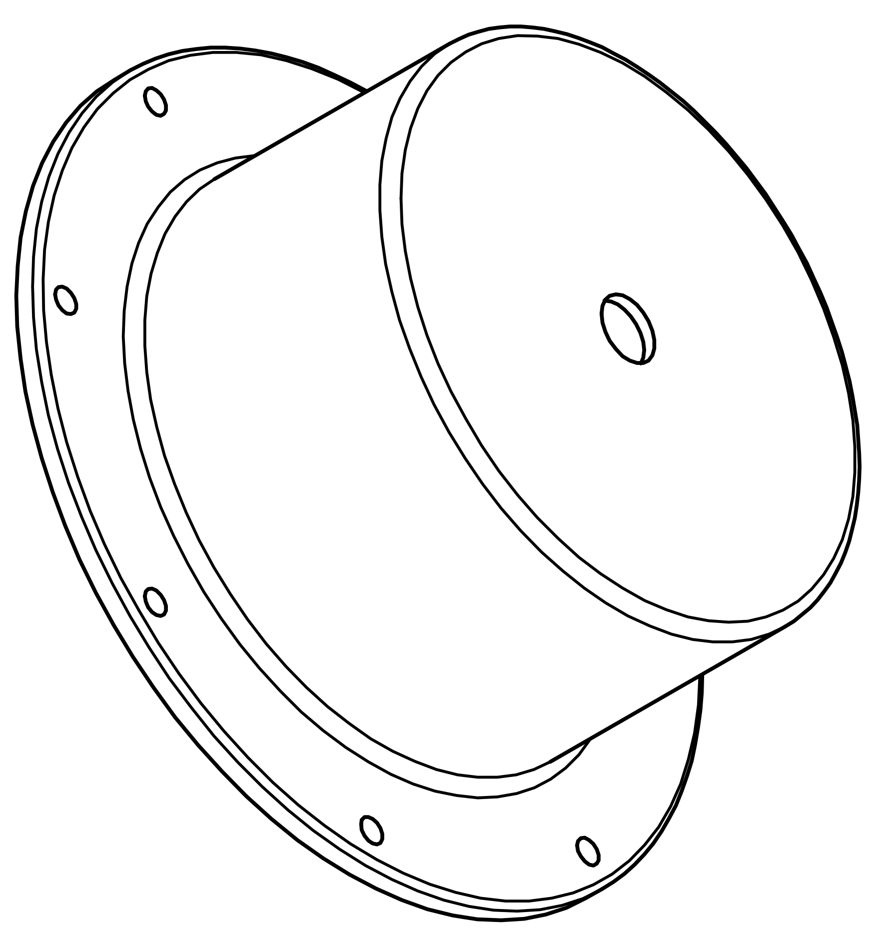
DRAWN SOLAR	2012-08-02	
CHECKED		TITLE Base for both vacuum and pressurised chamber
QA		
MFG		Unit: mm
APPROVED		SIZE C / DWG NO chamber base1 / REV
		SCALE / SHEET 1 OF 1



Side view

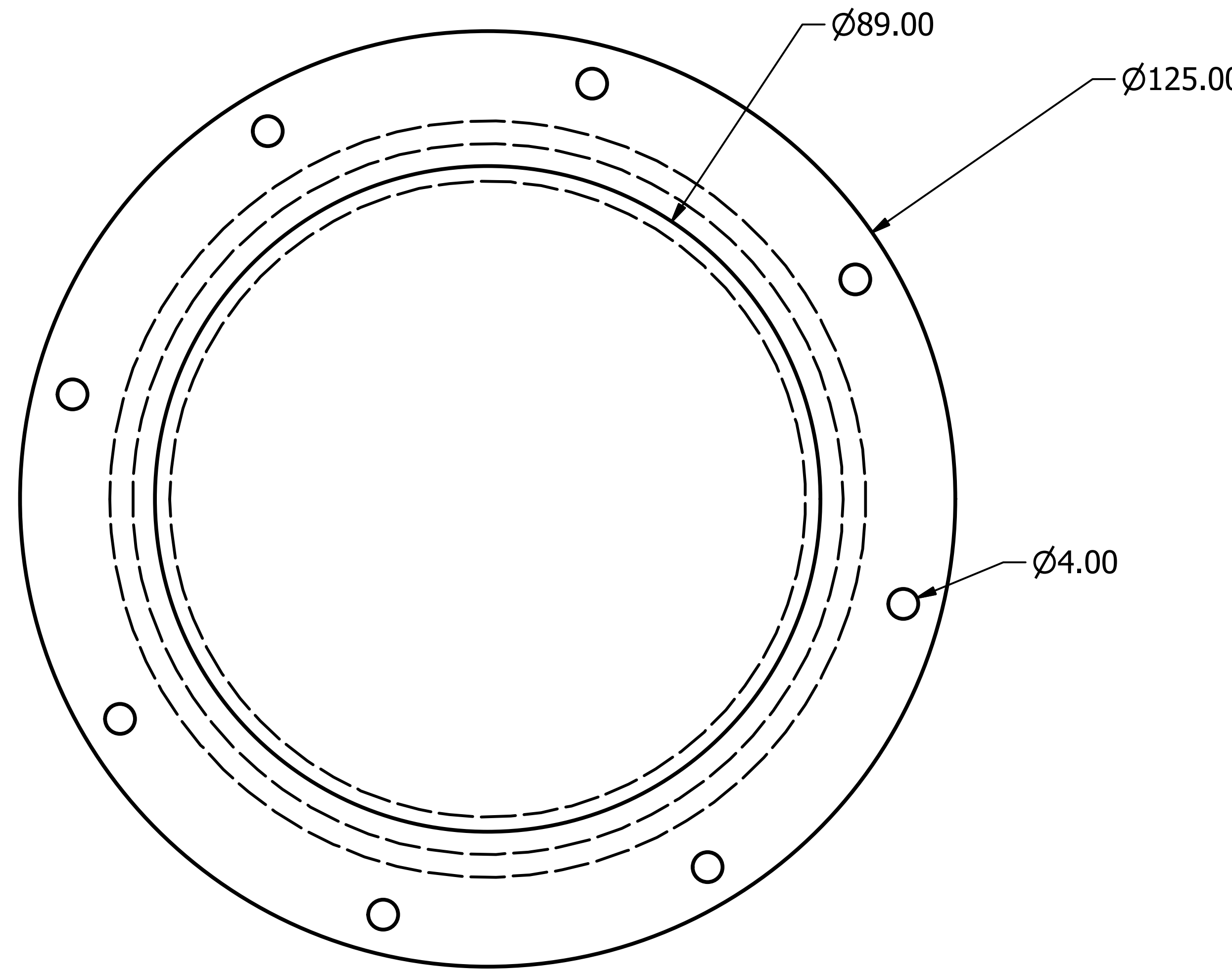


Top view

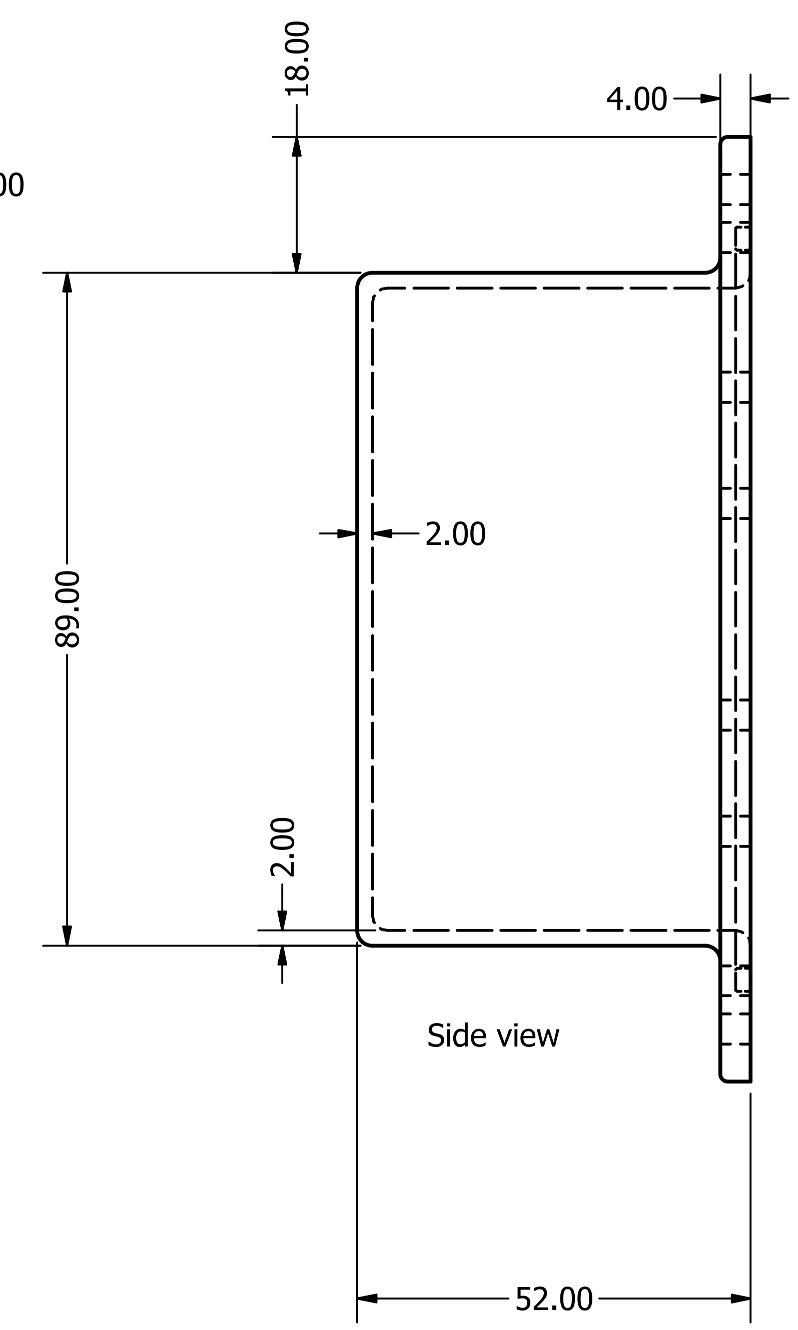


DRAWN SOLAR	2012-08-02	
CHECKED		TITLE Vacuum chamber, hat
QA		
MFG		Unit: mm
APPROVED		SIZE C — DWG NO hat vacuum1 — REV
		SCALE — SHEET 1 OF 1

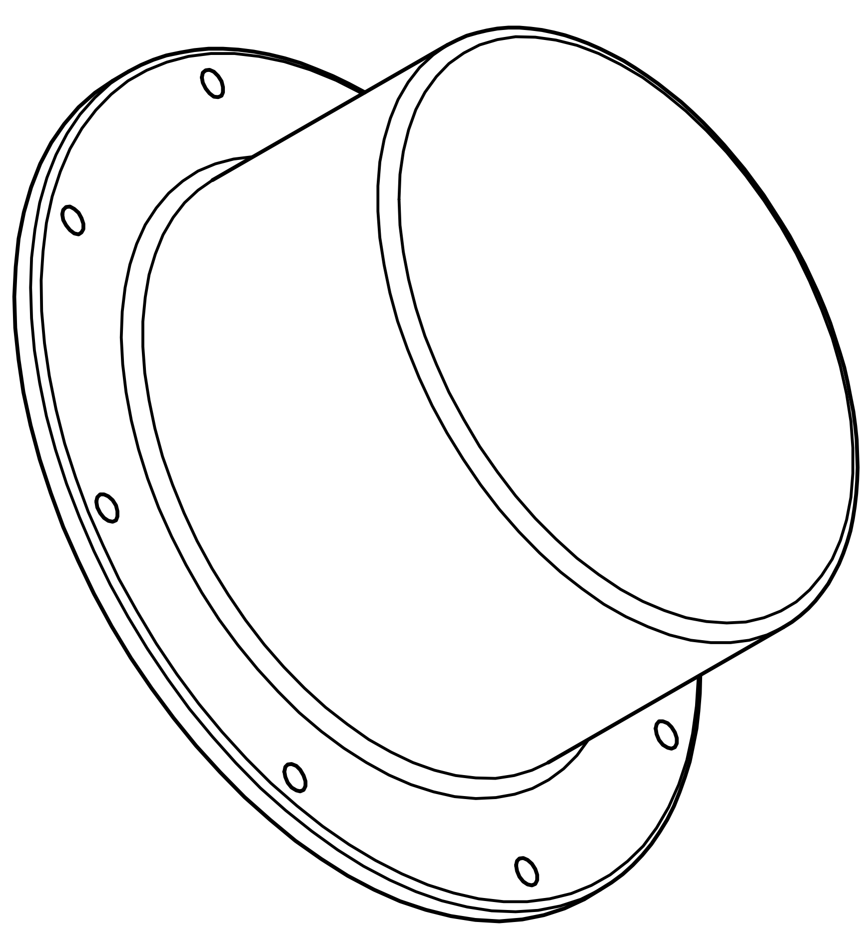
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT



Top view



Side view



DRAWN SOLAR	2012-08-02			
CHECKED		TITLE Pressurized chamber, hat		
QA				
MFG				
APPROVED		Unit: mm		
		SIZE C	DWG NO hat pressurized1	REV
		SCALE		SHEET 1 OF 1

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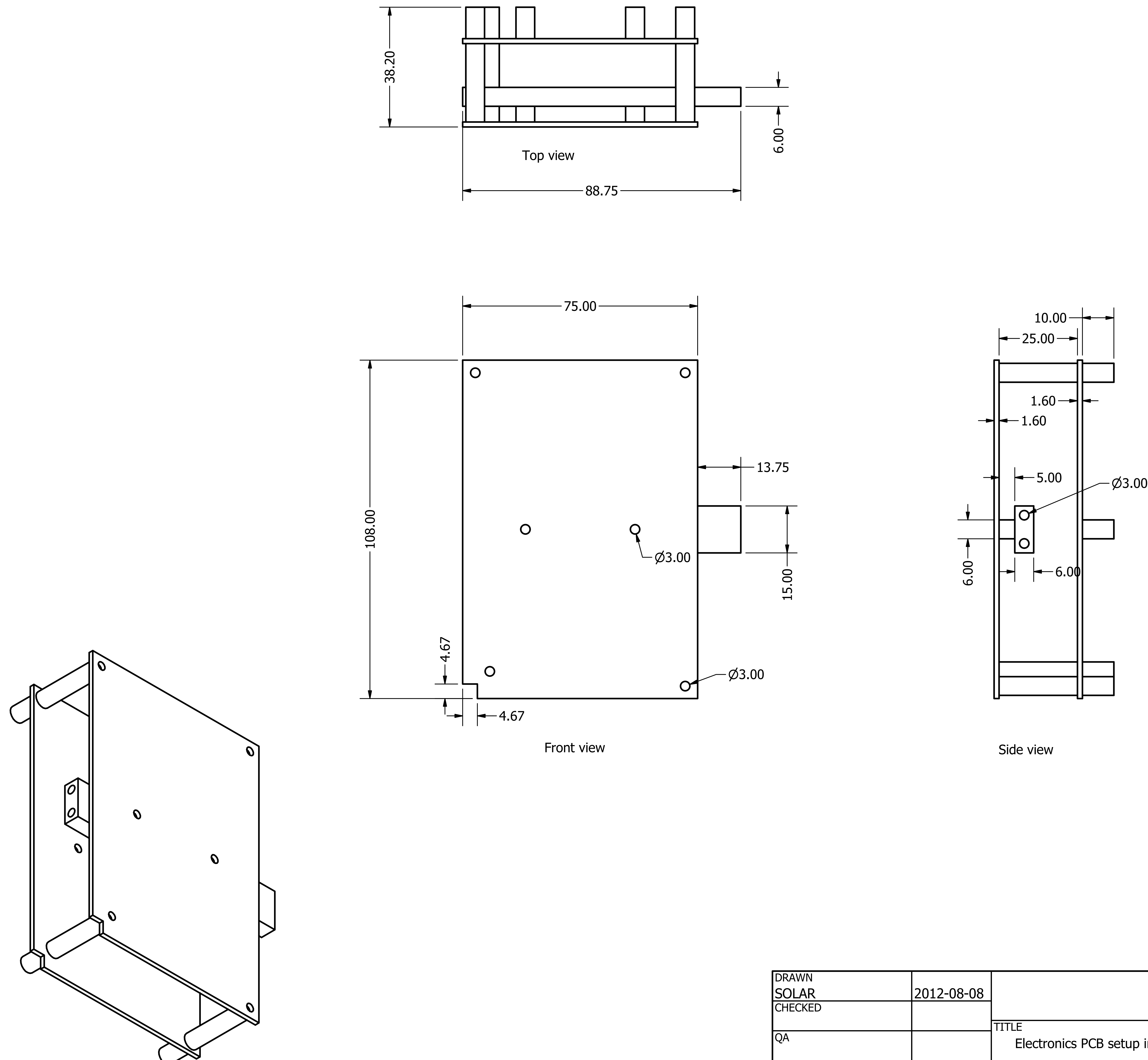
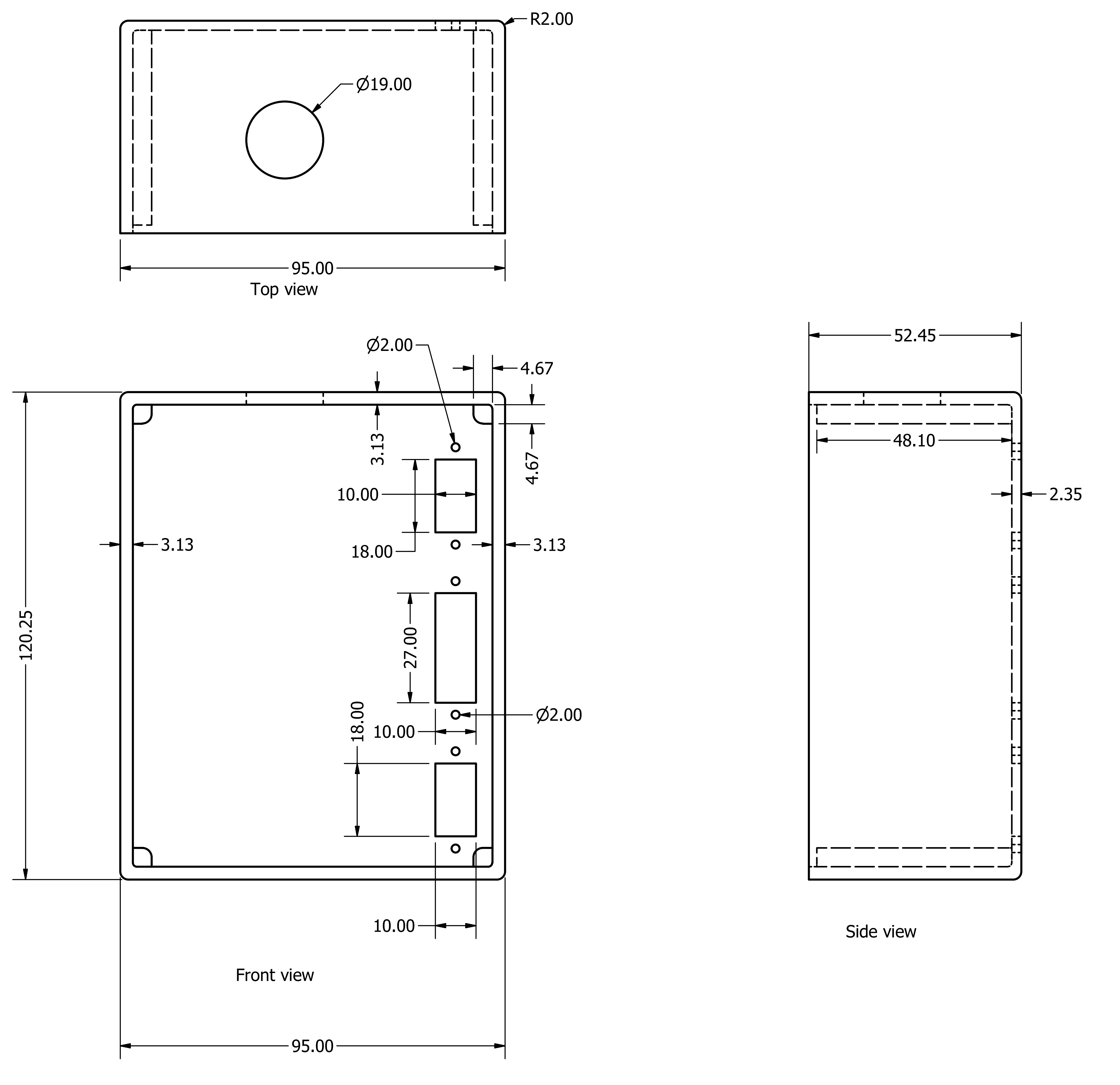
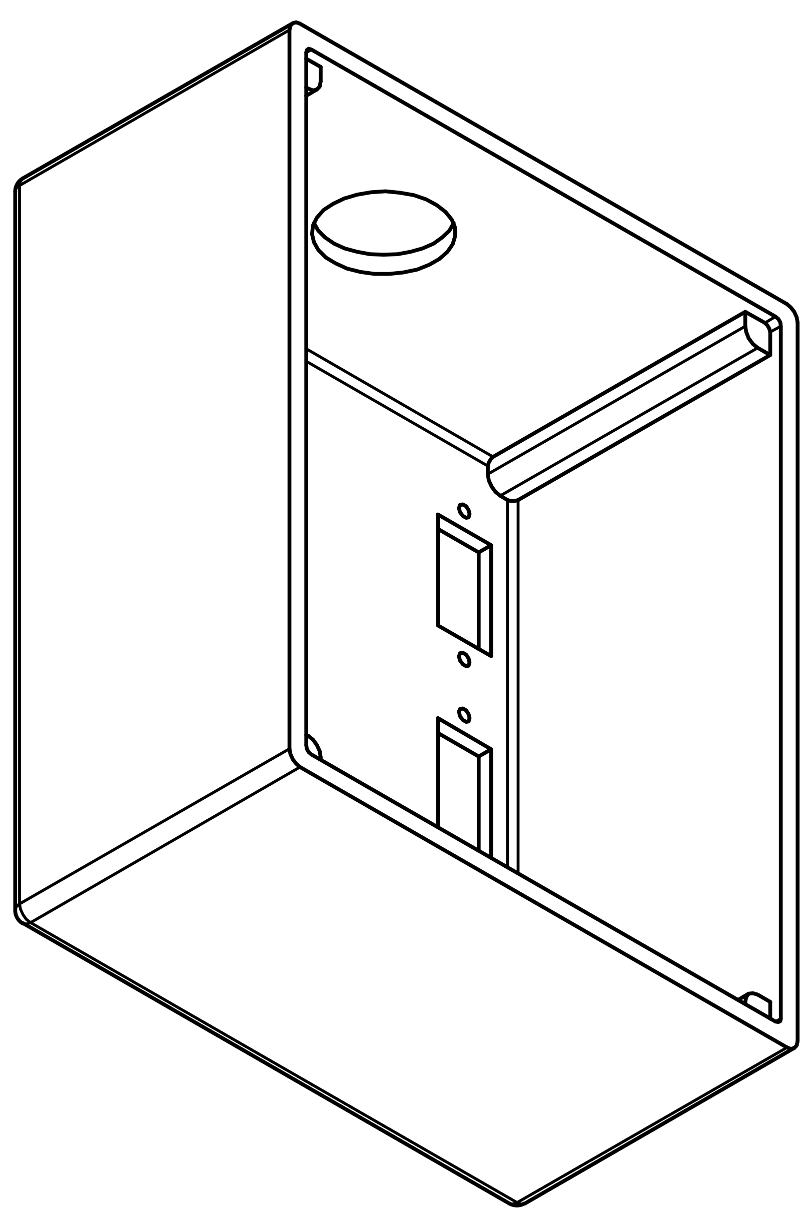
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT



DRAWN SOLAR	2012-08-08	
CHECKED		TITLE Electronics PCB setup inside the box
QA		
MFG		Unit: mm
APPROVED		
		SIZE C · DWG NO electronic pcb2 · REV
		SCALE · SHEET 1 OF 1

PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT





DRAWN SOLAR	2012-08-08	
CHECKED		TITLE Electronic box without lid
QA		
MFG		Unit: mm
APPROVED		
		SIZE C / DWG NO electronic box2 / REV
		SCALE / SHEET 1 OF 1

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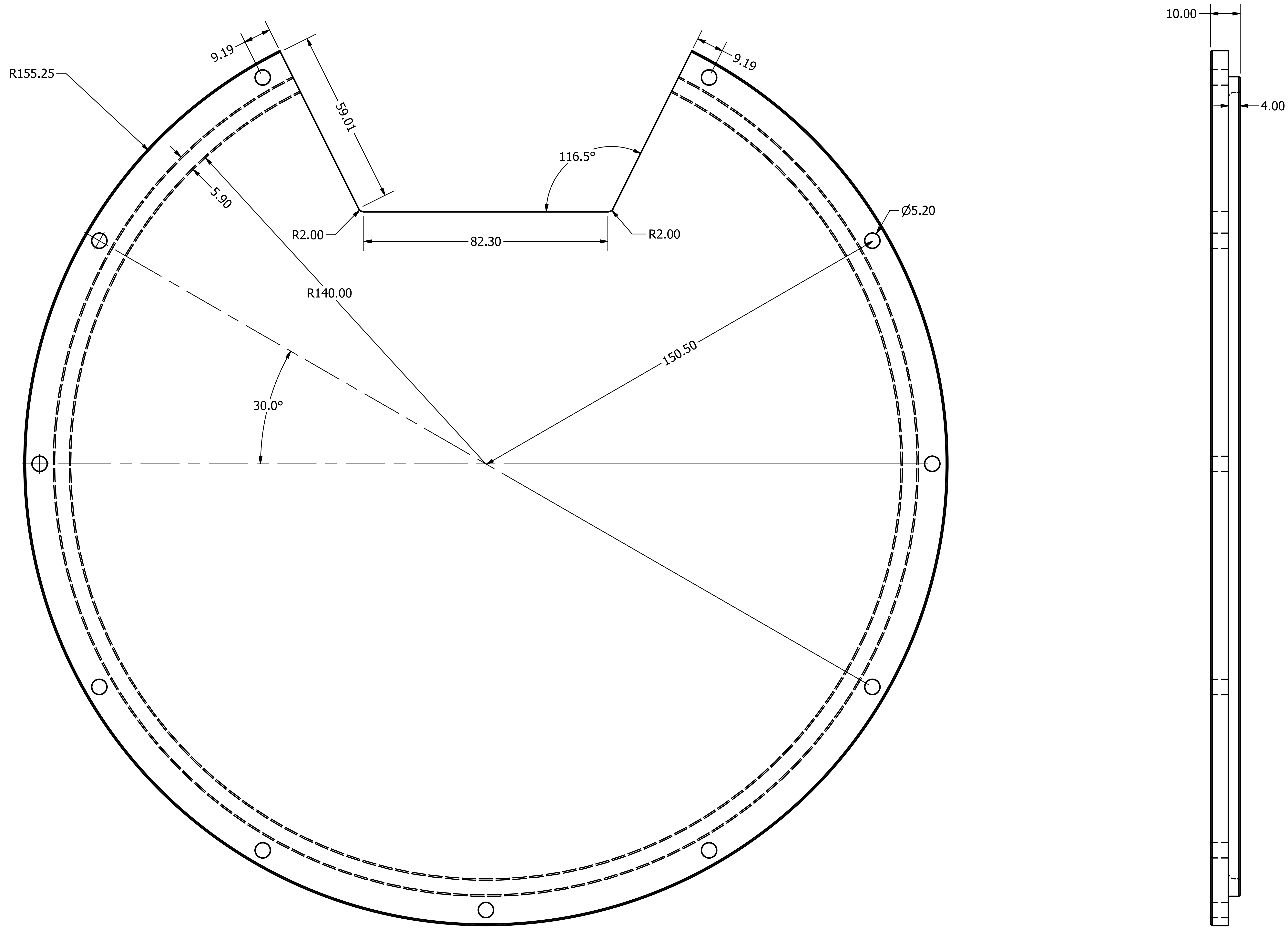

DRAWN SOLAR	2012-09-10				
CHECKED		TITLE	BULKHEAD		
QA			Unit: mm		
MFG					
APPROVED					
		SIZE C		DWG NO bulkhead_dlr	REV
		SCALE		SHEET 1 OF 1	

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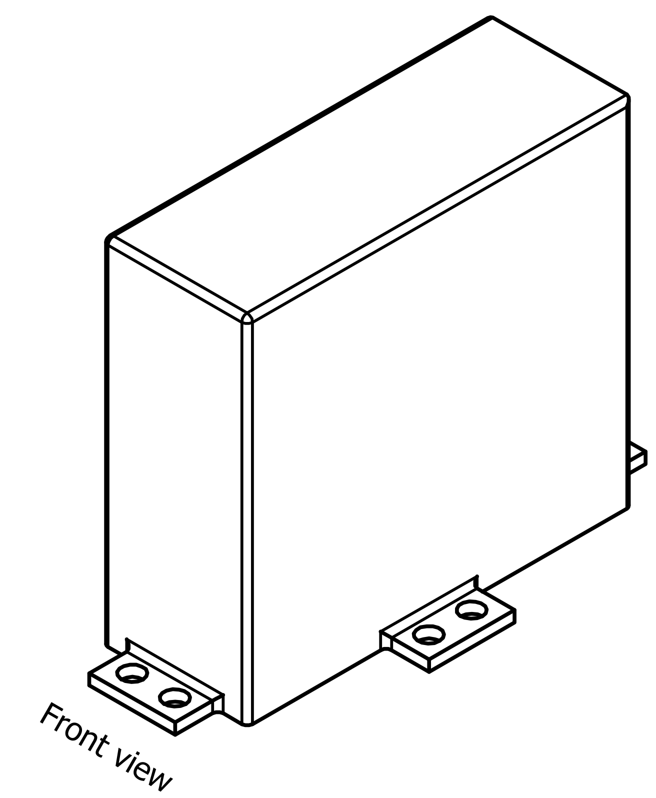
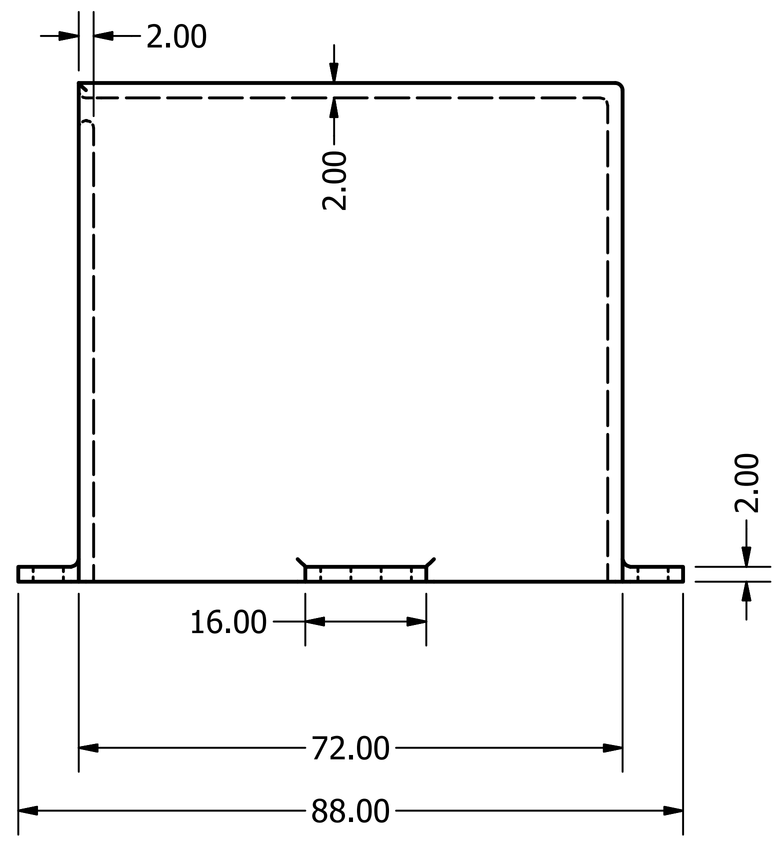
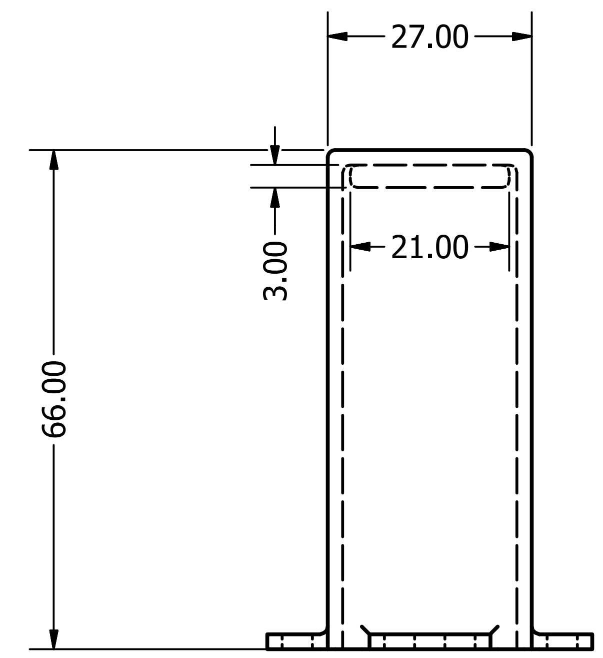
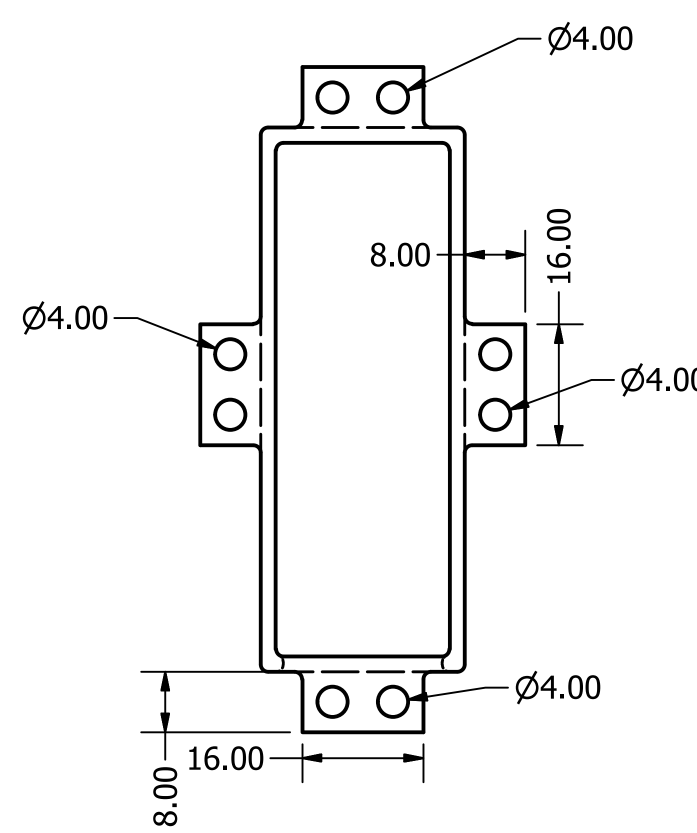




Side view



Front view



Bottom view

DRAWN SOLAR	2012-08-08			
CHECKED		TITLE Protection box for the batteries		
QA				
MFG		Unit: mm		
APPROVED				
		SIZE C	DWG NO battery case2	REV
		SCALE	SHEET 1 OF 1	

PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT
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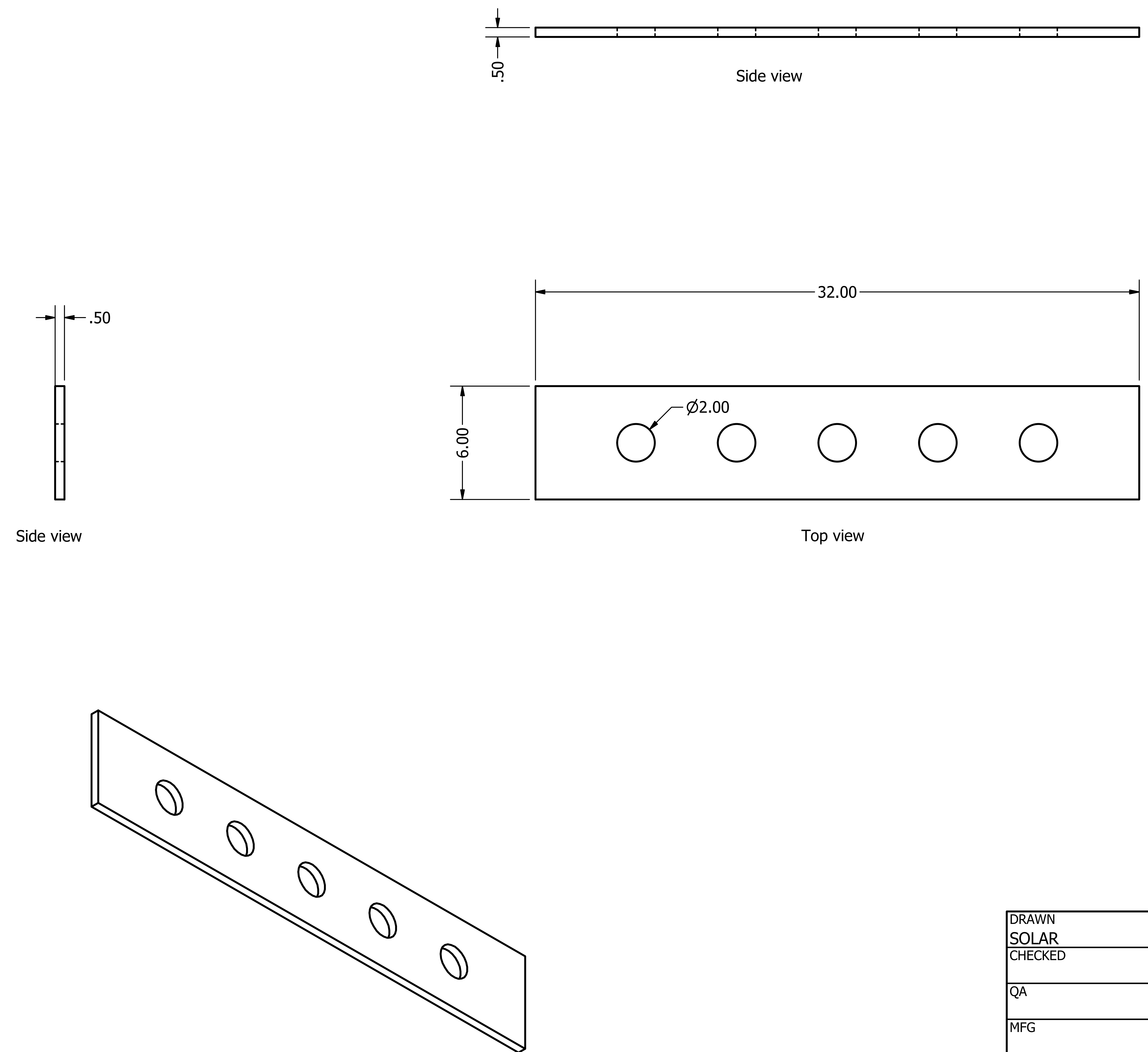
PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT



DRAWN SOLAR	2012-08-02	
CHECKED		
QA		TITLE Copper plate in the chambers
MFG		Unit: mm
APPROVED		
		SIZE C · DWG NO copper plate1 · REV
		SCALE · SHEET 1 OF 1

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APPENDIX G

Procedures and Checklists

Procedure no: S_1 Experiment Test

Experiment Test
Description: Run a full experiment test with RXSM simulator including:

- Start up procedure.
- Data sampling via UART.
- Arm/disarm commands.

Experiment phase: Launch campaign
Responsible project members (s): Robert Lindberg
Equipment: Computer
UART Serial Converter
MAX232+MAX488 circuit
SD-card
SD-card reader

Startup procedure

1. Start up procedure.
    a. Start SGS.
    b. Control values returned.
    c. In case of value = error:
        i. Check physical connections.
        ii. Check code.

MCU

2. Check operating voltage.
3. Verify experiment data.
4. In case of MCU failure:
    a. Test in smaller scale to narrow down possible failure area.
    b. Check voltage levels on pins.
    c. Check physical connections.

SGS

5. Make sure SGS is showing the correct values.
6. Make sure SGS saves received data.
7. If SGS does not save data:
    a. Check code.
8. If wrong values are shown.
    a. Check voltage levels between the sensors and MCU.
    b. Check the voltage before and after the level converters.
    c. Test a different UART Converter.

Test SD Card

9. Read the SD card on a computer via converter.
10. Compare the values written to the SD card with the values received via UART.
11. In case of no/wrong values:

   a. Test a different SD card.
   b. Check voltage levels on circuit.
   c. Test with different micro SD to USB converter.

Redundancy

1. Repeat the **Experiment Test** with the backup computer.
2. Test a warm redundant switch over during a test.

Procedure no: S_2 Pre flight setup

Pre flight setup

Item: Two computers shall be up and running at all times. One computer is operational and one computer is warm redundant incase the first one fails during the experiment. Both computers have SGS software running and are used to verify everything is working as intended.

Experiment phase: Pre flight
Responsible project members (s): Björn Paulström
Equipment: Computer
Mouse
UART Serial Converter
Power strip

Set up SGS

1. Start the computers
2. Make sure power saving mode is disabled
3. Connect cable to primary computer
4. Start SGS

Check MCU functionality

5. In case of no/wrong answer.
    a. Verify the hardware we have access to (level converters, computer).
    b. Verify SGS is working as intended.
    c. Change hardware.

ARM Experiment

6. Send arm command to experiment.
7. Check that the arm command was received by the MCU.

Procedure no: S_3 Computer crash

Pre flight setup
Item: In case of a computer crash or any other problem that cause the SGS software to malfunction.

Experiment phase: During flight
Responsible project members (s): Björn Paulström
Equipment: Computer
Mouse
UART Serial Converter
Power strip

1. Restart program.
2. Switch computer if restart does not work.

Procedure no: S_4 Computer crash

Post flight procedure

Description: Procedure to carry out post flight.

Experiment phase: Post flight

Responsible project members (s): Hamoon Shahbazi

Equipment:
- Computer
- Mouse
- UART Serial Converter
- SD Card
- Power strip
- Micro SD card converter

1. Backup data from SGS.
2. Backup SD Card data.
3. Read SD card via computer.
4. Compare SGS and SD card data.
5. Summarize and present the data.

Procedure

Item: Soldering samples
Experiment phase: Preparation
Responsible project member(s): Jens Kanje Nordberg

Location: The solder samples are best manufactured sitting down at a stable, clean table

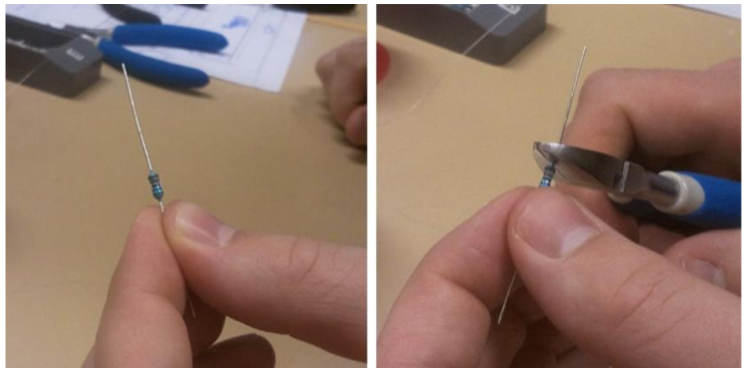
Tools: 1 wire cutter
1 needle-nose plier

Material: 5cm Solder wire ($Sn_{63}PB_{37}$, d=0.5mm)
15cm Nichrome wire (33Ω/m, d = 0.2mm),
1 resistor

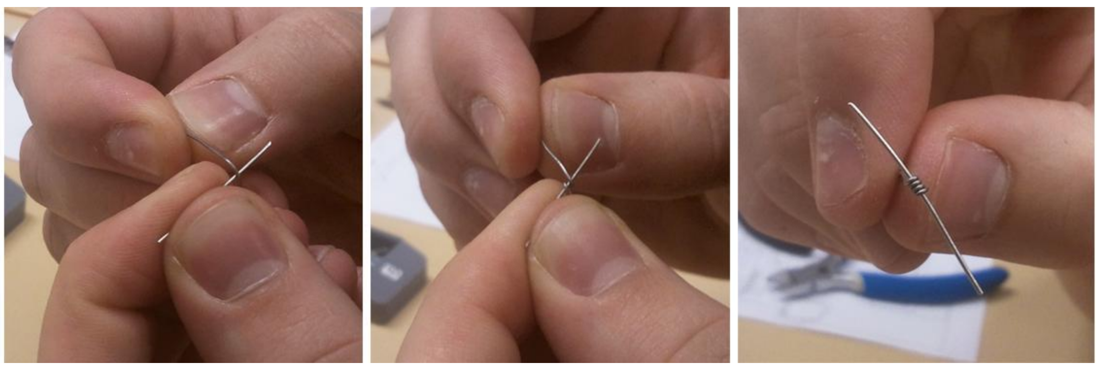
Procedure: The procedure is divided into six steps.

1. Take a resistor in your left hand between the thumb and forefinger. Use the wire cutter to cut 2 cm of the component leg. Put away the remaining part of the resistor.
2. Take 5 cm of the solder wire and wrap four turns tightly around the center of the component leg.
3. Use the wire cutter to cut away the redundant solder wire.
4. Use the needle-nose plier to bend the ends inwards.
5. a) Take 15 cm of the nichrome wire and wrap three turns tightly before the solder wire.
   b) Hold the two wires together between your forefinger and thumb and wrap four turns on top of the solder wire.
   c) Wrap three turns tightly after the solder wire onto the component leg.
6. Use the wire cutter to cut away the redundant parts of the component leg. Leave 3mm margin to the solder wire on both sides.

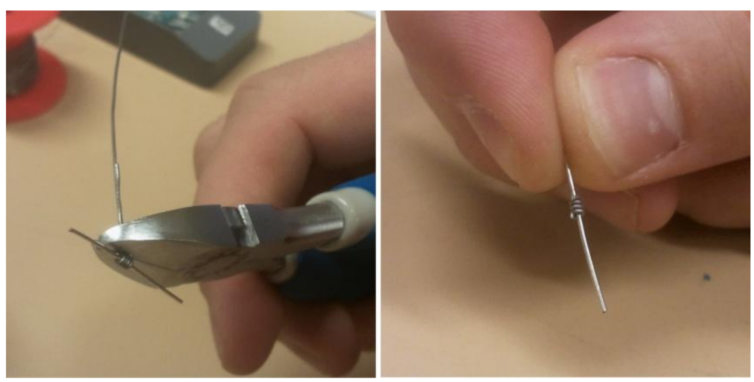
Procedure no: E_1 Preparation of soldering samples



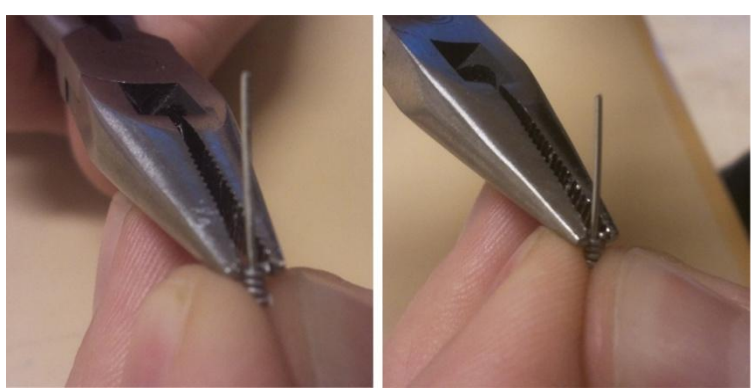
Step 1



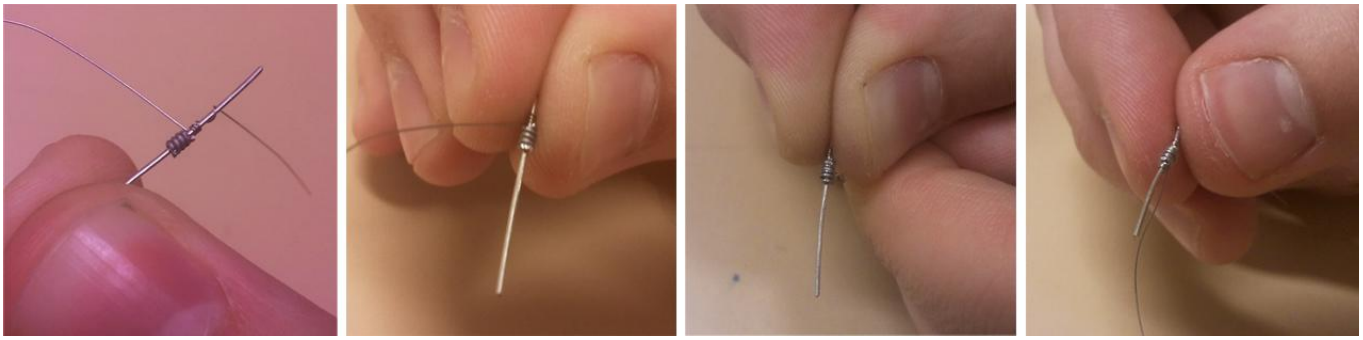
Step 2



Step 3

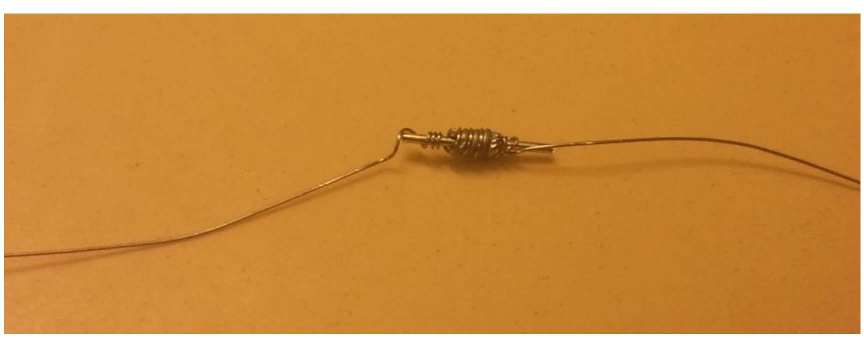


Step 4



Step 5

Step 6



Finished solder sample

Procedure no: E_1 Preparation of soldering samples

Solder wire ($Sn_{63}PB_{37}$, d=0.5mm) Nichrome wire (33Ω/m, d = 0.2mm)

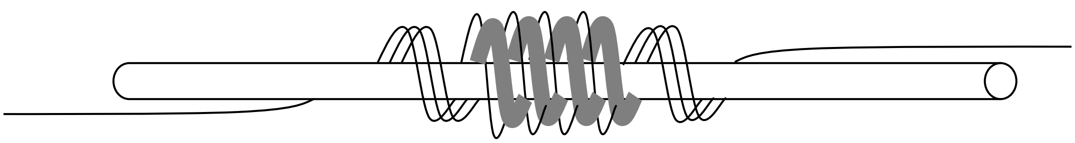


Illustration of solder sample

Procedure

Item: Soldering PCB
Experiment phase: Preparations
Responsible project member(s): Johanna Åstrand

Locations: The soldering PCBs are manufactured in a workshop equipped with a fume-hood and a stationary drill.

Tools:
1mm drill
3 mm drill
3.2mm drill
2 pliers
2 acid containers
1 measuring tube
1 scale
1 protective glasses
1 protective coat
1 base
1 template for copperplate
1 template for copper coating on overhead paper
1 UV exposure-box
1 black ink-pencil

Material:
32x50mm PCB with copper coating
800ml water
200ml hydrogen peroxide
100ml hydrochloric
5 grams of developer for positive (20) photoresist

Procedure: The procedure is divided into 28 steps:

Illumination on the PCB:
1. Take the PCB with copper coating and put it in the UV exposure-box.
2. Put the overhead paper over the PCB so the sides are aligning.
3. Close the lid on the exposure-box and select top-side lighting, set the timer on 230 seconds and press start.
4. When the timer reach zero open the box and remove the PCB.

First acid bath:
5. Put on the protective coat and glasses.
6. Weigh 5 grams of the developer for photoresist and put it in one container.
7. Use the measuring tube and fill it with 500ml lukewarm water from the tap.
8. Pour the water in the same container as the developer and use a plier to stir the mix.
9. Use the plier too gently Put the PCB in the container.
10. Stir frequently until the photo lacquer has totally disappeared.
11. Remove the PCB from the container with the plier and wash it with the tap

water.

Second acid bath:
12. Use the measuring tube and fill it with 300ml tap water and pour it in a new container.
13. Use the measuring tube and fill it with 200ml hydrogen peroxide and pour it in the same container as the water.
14. Wash the measuring tube with tab water.
15. Use the measuring tube and fill it with 100ml hydrochloric and pour it gently in the same container as the water and hydrogen peroxide.
16. Use a new plier and Put the PCB in the container.
17. Stir frequently with the plier until the copper coating has totally disappeared on the areas where it is not supposed to be.
18 Remove it from the container and wash it with tap water.

Cleaning of the tools:
19. The content in the two different containers can be poured out in the sink.
20. Use tap water to clean all the tools that has been in contact with either of the mixtures.

Drilling the holes:
21. Put the PCB on the Base and use a ink-pencil to mark the center of the four holes that is for the attachment screws.
22. Place the template for the copperplate so it aligns with the long-side of the PCB and so the hole in the middle is 25 mm from the side.
23. Mark the center of the holes with the ink-pencil.
24. Do the same at the other long-side.
25. Assemble the stationary drill with the 1 mm drill.
26. Drill all the holes that you marked out on the PCB.
27. Change to the 3.2 mm drill and drill the 4 holes that are for the attachment screws.
28. Change to the 3 mm drill and do the remaining holes.

Procedure no: M_2 Preparations of bulk head (pre-flight)

Procedure

Item: Assemble/disassemble all experiment housings on/from the bulk head
Experiment phase: Pre-flight
Responsible project member(s): Adrian Lindqvist

Tools: Torque wrench
Socket wrench extension >100mm
Insex bit for M4 Allen screws
Socket wrench insert, hexagon head suiting the torque wrench
Allen screws:
16 M4x30
21 M4x8, A2
Spring washer:
37 M4,A2

Housings: 1 battery box
1 electronics box
2 chambers
1 D-SUB contact holder

Procedure: To assemble all of the housings <u>on</u> the bulk head, preferably proceed in the following order:

1. Battery box
    a. Attach the long sides first to enable a correct position for the shorter sides.
    b. Screws: 8 M4x8,A2; spring washers: 8 M4,A2
    c. Estimated time: 5 min
2. Electronics box
    a. Attach 1 screw loosely on each short side at first and 1-2 screws on the long side to enable a correct position for the entire box.
    b. Screws: 9 M4x8,A2; spring washers: 9 M4,A2
    c. Estimated time: 7 min
3. D-SUB contact holder
    a. Screws: 4 M4x8, A2; spring washers: 4 M4,A2
    b. Estimated time: 2 min

4. Chamber(s)
    a. One at a time, does not matter which one is mounted first.
    b. Screws: 2x8 M4x30; spring washers: 2x8 M4,A2
    c. Estimated time: 1 min/ chamber

To disassembly all of the housings <u>from</u> bulk head, preferably proceed in the following order:

1. Chamber(s)
    a. Does not matter which one is removed first
    b. Estimated time: 1 min/chamber
2. D-SUB contact holder
    a. Estimated time: 1 min
3. Electronics box
    a. Estimated time: 3 min

4. Battery box
    a. Estimated time: 1 -2 min

Procedure no: M_3 Switching soldering PCB´s

Procedure

Item: Soldering PCB´s
Experiment phase: Test
Responsible project member(s): Björn Sjödahl

Tools: Torque wrench
Socket wrench extension >100mm
Insex bit M4 screws
Socket wrench insert, hexagon head suiting the torque wrench
Allen key: M3 and M2
Allen screws:
8 M4x30
4 M3x12, A2
4 M2x8,A2

Procedure: Switching a used soldering PCB to a new one:

1. Remove all screws from the chamber.
   a. 8 M4x30
2. Remove the hat.
3. Unscrew the solder PCB from the base (corner screws).
   a. 4 M3x12,A2
4. Unscrew the end screws on the copper plates and remove the blade terminals.
   a. 4 M2x12,A2
5. Swop to new and fully prepared solder PCB.
6. Orient the new solder PCB according to the markings on the PCB/base.
7. Reattach the blade terminals on the new PSC and tighten the end screws on the copper plates.
8. Attach the corner screws to the base.
   a. 4 M3x12,A2
9. Remount the hat.
10. Reassembly the chamber on the bulk head.
    a. 8 M4x30

Estimated time: One entire swop - ca. 15 min

Procedure no: M_4 manufacture copper plates

Procedure

Item: Copper plate
Experiment phase: Preparations
Responsible project member(s): Maja Nylén

Tools: Copper plates (big one)
Template (5 holes)
Drill
Shears

Procedure:

1. Attach the template to the big copper plate.
2. Follow the template and drill all five holes.
3. Use centre of each hole to measure 6mm across; each hole in the middle
4. Use centre of each hole to measure 32mm along; end holes symmetrically from each end.
5. Cut according to the 32x6mm measurements.

Procedure

Item: Sensor PCB
Experiment phase: Preparations
Responsible project member(s): Adrian Lindqvist

Locations: The sensor PCBs are manufactured in a workshop equipped with a fume-hood and a stationary drill.

Tools:
1mm drill
2 pliers
2 acid containers
1 measuring tube
1 scale
1 protective glasses
1 protective coat
1 template for sensor layout on overhead paper
1 UV exposure-box
1 black ink-pencil

Material:
26x54 mm PCB with copper coating
800ml water
200ml hydrogen peroxide
100ml hydrochloric
5 grams of developer for positive (20) photoresist

Procedure: The procedure is divided into 28 steps:

Illumination on the PCB:
1. Take the PCB with copper coating and put it in the UV exposure-box.
2. Put the overhead paper over the PCB so the sides are aligning.
3. Close the lid on the exposure-box and select top-side lighting, set the timer on 230 seconds and press start.
4. When the timer reach zero open the box and remove the PCB.

First acid bath:
5. Put on the protective coat and glasses.
6. Weigh 5 grams of the developer for photoresist and put it in one container.
7. Use the measuring tube and fill it with lukewarm water from the tap.
8. Pour the water in the same container as the developer and use a plier to stir the mix.
9. Use the plier too gently put the PCB in the container.
10. Stir frequently until the photo lacquer has totally disappeared.
11. Remove the PCB from the container with the plier and wash it with the tap water.

Second acid bath:
12. Use the measuring tube and fill it with 300ml tap water and pour it in a new container.
13. Use the measuring tube and fill it with 200ml hydrogen peroxide and pour it in the same container as the water.
14. Wash the measuring tube with tab water.
15. Use the measuring tube and fill it with 100ml hydrochloric and pour it gently in the same container as the water and hydrogen peroxide.
16. Use a new plier and put the PCB in the container.

17. Stir frequently with the plier until the copper coating has totally disappeared on the areas where it is not supposed to be.
18 Remove it from the container and wash it with tap water.

Cleaning of the tools:
19. The content in the two different containers can be poured out in the sink.
20. Use tap water to clean all the tools that has been in contact with either of the mixtures.

Drilling the holes:
21. Assemble the stationary drill with the 1 mm drill.
22. Drill all the holes where the copper pads are for the components on the PCB.

Procedure

Item: Battery housing
Experiment phase: Preparation
Responsible project member(s): Johanna Åstrand

Locations: At a *workbench*

Tools:
1 knife
1 ruler
1 template for the small insulation plates (60x60mm)
1 template for the large insulation plates (60x65mm)

Material:
Armaflex (insulation)
2 tie straps
1 battery-box
2 batteries
Tape

Procedure: The procedure are divided into two parts, first manufacturing of the insulations plates then the assembly of the insulations plates, battery and the box.

Manufacturing the insulations plates:
1. Take the insulation, the templates for both plates and the knife and put it on a workbench, if needed use something to protect bench's surface so the knife does not damage it .
2. Both the small and the large insulations plates are 4 mm thick. Cut out 3 of the small and 4 of the large template.

Assembly of the insulation, battery and the box:
3. The small plates are placed on each side and one between the two batteries. See Figure 1.
4. The large plates are placed on the other sides. See Figure 1.
5. Use the tape to hold the plates together. See Figure 2.
6. Thread the cables through the two holes in the battery box and then gently pull the cables until the batteries are inside. See Figure 2.
7. Use the two tie straps to attach the batteries to the top of the box. See Figure 3.

For instruction how to attach the battery-box on the bulkhead see [G.M.2] Assembly of bulkhead.pdf.

Procedure no: M_6 Battery insulation and assembly

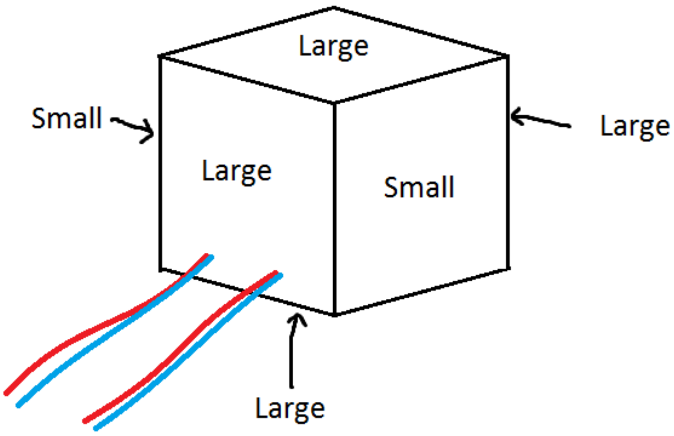


Figure 1- Shows where the insulation plates are placed around the batteries.

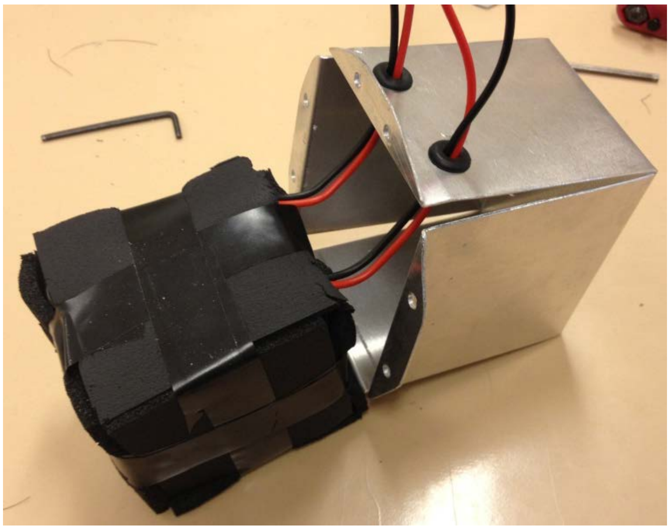


Figure 2- Shows the insulation, tape and the cables through the holes in the box.

Figure 3- Shows how the tie straps are used.

Procedure no: M_7 Assembly of the vacuum chamber (pre-flight)

Procedure

Item: **Assemble the vacuum chamber to flight readiness**
Experiment phase: **Pre-flight**
Responsible project member(s): **Johan Strandgren**

Tools: **Torque wrench**
Insex bit for M3 Allen screw
Allen screws:
7 M3x12, A2
Spring washers:
7 M3, A2
Spacers:
3 M3x5

Parts: **1 Vacuum base**
1 Vacuum hat
1 Soldering PCB
1 Sensor PCB

Procedure: **The procedure is divided into 4 steps.**

1. **Attach the soldering PCB according to the procedure *M_3 Switching soldering PCB´s.***
2. **Attach the sensor PCB to the base, next to the soldering PCB with a torque of 1.2 Nm**
    a. **Allen screws: 3 M3x12, A2**
    b. **spring washers: 3 M3, A2**
    c. **spacers: 3 M3x5.**
3. **Solder the small wires to the sensor PCB.**
4. **Put the vacuum hat on the base so the holes correspond to each other.**

Procedure no: M_8 Assembly of the pressurized chamber (pre-flight)

Procedure

Item: **Assemble the pressurized chamber to flight readiness**
Experiment phase: **Pre-flight**
Responsible project member(s): **Johan Strandgren**

Tools: **Torque wrench**
Insex bit for M3 Allen screw
Allen screws:
7 M3x12, A2
Spring washers:
7 M3, A2
Spacers:
3 M3x5
O-ring:
1 47.46x2.62
Vacuum grease

Parts: **1 Pressurized base**
1 Pressurized hat
1 Soldering PCB
1 Sensor PCB

Procedure: **The procedure is divided into 6 steps.**

1. **Attach the soldering PCB according to the procedure *M_3 Switching soldering PCB´s.***
2. **Attach the sensor PCB to the base, next to the soldering PCB with a torque of 1.2 Nm**
   a. **Allen screws: 3 M3x12, A2**
   b. **spring washers: 3 M3, A2**
   c. **spacers: 3 M3x5.**
3. **Solder the small wires to the sensor PCB.**
4. **Lubricate the O-ring with a smooth layer of vacuum grease.**
5. **Put the O-ring gently in the track, in the pressurized hat.**
6. **Put the pressurized hat on the base so the holes correspond to each other.**

Procedure no: M_9 Assembly of a complete soldering PCB with all fixings (preparation)

Procedure

Item: **Assemble of a complete soldering PCB with all fixings to flight readiness**
Experiment phase: **Preparation**
Responsible project member(s): **Jens Kanje Nordberg**

Tools: **Torque wrench**
Insex bit for M2 Allen screw
Adjustable wrench
Allen screws:
6 M2x8, A2
Washers:
12 M2, A2
Nuts:
6 M2

Parts: **3 soldering samples**
1 Soldering PCB
2 copper plates

Procedure: **The procedure is divided into 4 steps.**

1. **Attach the copper plates loosely on each side of the soldering PCB using the three holes in the middle. The order of all parts, seen from above shall be: screw head, washer, copperplate, soldering PCB, washer and finally the nut.**
    a. **Allen screws: 6 23x18, A2**
    b. **washers: 12 M2, A2**
    c. **nuts: 6 M2.**
2. **Put each solder sample right in the middle of the soldering PCB, between the screw pairs.**
3. **Wrap the resistance wires 1.5 revs around the screws on each side, between the upper washer and the copper plate.**
4. **Fasten all screws with a torque of 0.35 Nm.**

Procedure no: M_10 Attachment of electronic contacts (pre-flight)

Procedure

Item: **Attachment of electronic contacts**
Experiment phase: **Pre-flight**
Responsible project member(s): **Sara Widbom**

Tools: **Torque wrench**
Insex bit for M3 Allen screw
Lock nuts:
8 M3
Spring washers:
16 M3
Spacer bolts:
6 M3
Jack posts:
2 M3

Parts: **1 Vacuum chamber**
1 Pressurized chamber
1 Electronics box
1 Battery housing
1 D-SUB holder

Procedure: **The procedure is divided into 14 steps.**

1. **Attach the experiment housings to the bulkhead according to procedure *M_2 Assembly of bulkhead*.**
2. **Rotate and place the bulkhead so that the Vacuum chamber is located to your right and the Pressurized chamber is located to your left.**
3. **Place the D-SUB9 from the Vacuum chamber from right in the lower hole in the D-SUB holder.**
4. **Place the D-SUB9 assigned for the Vacuum chamber from the Electronics box from left in the lower hole in the D-SUB holder.**
5. **Connect the D-SUB9 from the Vacuum chamber and the D-SUB9 from the Electronics box by pushing them together.**
6. **Attach the D-SUB contacts with 2 M3 lock nuts, 4 M3 spring washers and 2 M3 spacer bolts.**
7. **Place the D-SUB9 assigned for the Pressurized chamber from the Electronics box from right in the above hole in the D-SUB holder.**
8. **Place the D-SUB9 from the Pressurized chamber from left in the above hole in the D-SUB holder.**
9. **Connect the D-SUB9 from the Pressurized chamber and the D-SUB9 from the Electronics box by pushing them together.**
10. **Attach the D-SUB contacts with 2 M3 lock nuts, 4 M3 spring washers and 2 M3 spacer bolts.**
11. **Place the D-SUB15 from the REXUS Module in the left hole in the Electronics box and connect it to the D-SUB in the hole.**
12. **Attach the D-SUB contact with 2 M3 jackposts, 4 M3 washers and 2 M3 lock nuts.**

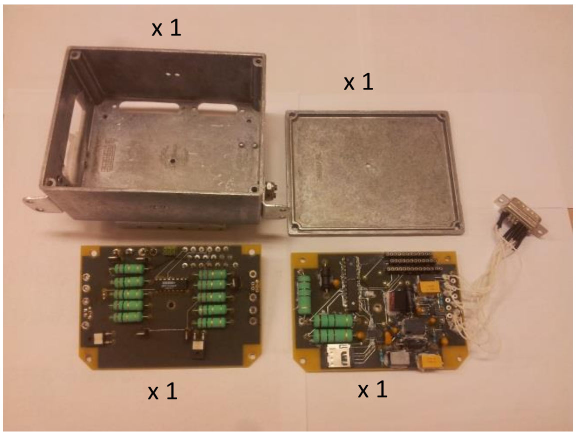
13. **Place the D-SUB5 from the Battery Housing in the right hole in the Electronics box and connect it to the D-SUB in the hole.**
14. **Attach the D-SUB contact with 2 M3 spacer bolts, 4 M3 washers and 2 M3 lock nuts.**

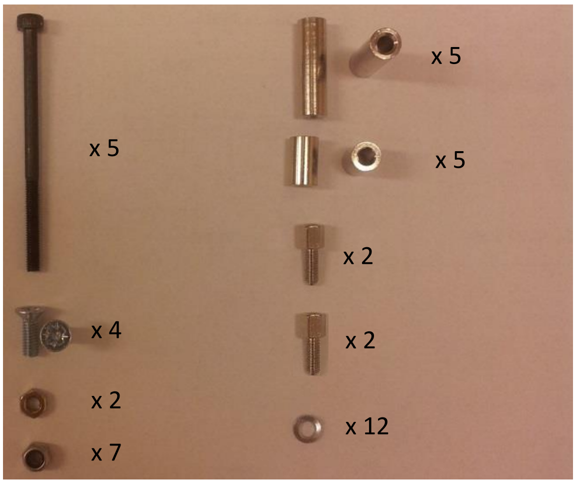
Procedure no: M_11 Assembly of the electronics box

Procedure
Item: Electronics box
Experiment phase: Pre-flight
Responsible project member(s): Björn Sjödahl and Johan Strandgren

Tools:
Allen key: M3
Wrench
Torque wrench
Socket wrench insert, hexagon head suiting the wrenches
Socket 5 mm
Socket 5.5 mm
Bit M3, insex
Bit pozidrive
Needle nose plier
Tape

Materials:
Electronics box (with angel braces attached)
Lid
Allen screws:
5 M3x50
Countersunk screws, pozidrive:
4 M3.5x10
Spacers (steel):
5 M3x18mm
5 M3x10mm
Spring washers:
12 M3,A2
Nuts:
2 UNC 440
Locknuts:
7 M3
Jack posts:
2 UNC 440
Spacer bolts:
2 M3
Lower main PCB
Top main PCB





Procedure:

1. Make sure that all edges of the rectangular holes are smooth.

2. Take the bottom main PCB and attach the D-SUB 15 to the electronics box (jack posts on the outside and spring washer and nuts (UNC 440) on the inside). Tighten to 1.3 Nm.
    a. 2 jack posts: UNC 440
    b. 2 spring washers: M3,A2
    c. 2 nuts: UNC 440

3. Take the second main PCB and attach the D-SUB 4 to the box similarly as the D-SUD 15 but with spacer bolts instead of jack posts
    a. 2 spacer bolts: M3
    b. 2 spring washers: M3
    c. 2 locknuts: M3

4. Insert the long screws through the bottom holes with a spring washer between each screw-head and the box.
    a. 5 Allen screws: M3x50
    b. 5 spring washers: M3

5. Temporarily secure the screws with tape on the outside.

6. Place spacers on each screw on the inside of the box
    a. 5 spacers: 3x10mm

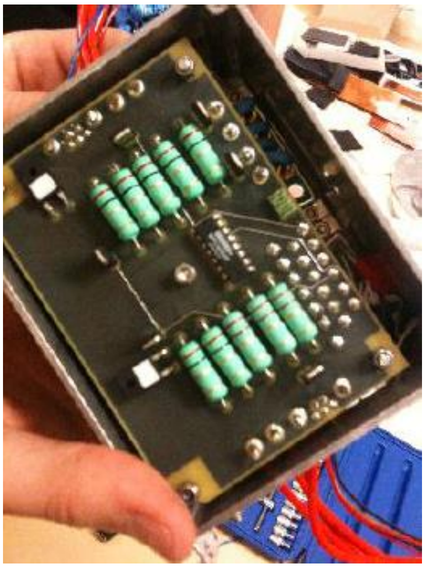
7. Place the lower main PCB in the box by inserting the screws in the PCB holes and slide it to the bottom.
    a. Lower main PCB

8. Place the long spacers on each screw above the lower main PCB
    a. 5 spacers: 3x18mm

9. Take the top main PCB and thread the left and right D-SUB wires through respectively side openings in the electronics box (from inside to outside).

10. Place the top main PCB in the box by inserting the screws in the PCB holes.

11. Secure with lock nuts and spring washers (do not tighten)
    a. 5 spring washers: M3
    b. 5 locknuts: M3



12. Connect the two main PCBs with the multipoint connectors

13. Make sure all cables can move freely

14. Tighten all screws and nuts with 1.3 Nm

15. Attach the lid to the electronics box
    a. 4 countersunk screws: M3.5x10

Item list

Responsible project member(s): Hamoon Shahbazi

Checklist for items to bring to Esrange

Item	Check	Notes
Computer x2		
Mouse		
Programmer x2		
UART Serial Converter		
MAX232+MAX488 circuit		
Extra MAX232		
Extra MAX488		
Extra MCU		
Extra SD Card		
LAN Cable x2		
Power strip		
Micro SD card converter		

Checklist E.CL.1

Recharging of batteries
Responsible team member: Björn Sjödahl
Other attending team members: -
Task: Charge batteries and verify their functionality
Duration: 1 day
When: After transport to Esrange

Step 1 – Inspect batteries and verify them visually if applicable (battery box not fastened to bulkhead)

Step 2 – Connect the battery temperature monitoring system contact

Step 3 – Connect the charger D-sub and a multimeter to measure charging current

Step 4 – Start charging with a charging current of 1.5 A

Step 5 – Monitor the temperature of the batteries every few minutes

Step 6 – Disconnect when if the temperature increases above 28 degrees Celsius (assuming room temperature of battery at start of charging)

Step 7 – Connect battery box to experiment and run ground station for verification of charging

Step 8 – If applicable, run end-to-end test to verify functionality

Checklist E.CL.2

Functional test on main PCBs

Responsible team member: Björn Sjödahl
Other attending team members: Hamoon Shahbazi, Adrian Lindqvist
Task: To test and verify the operation of the main PCbs
Duration: 1 day
When: After transport to Esrange

Resources: Computer with ground station
Resistance wires attached to solder PCB
Main PCBs
Chamber bases
Thermometer

Activity	**Comments**	**Pass/Fail**
Connect all D-subs from main PCBs to T-rex		
Connect chamber D-subs to D-sub holder		
Connect computer to telemetry pins		
Switch on the power		
Receive sensor data and battery voltage from MCU		
Run the experiment with plain resistance wires or with old solder samples if applicable		
Measure the temperature on the resistance wires		

Checklist E.CL.3

Inspection of solder station

Responsible team member: Emil Vincent
Other attending team members: Jens Kanje Nordberg
Task: To inspect solder station
Duration: 1 day
When: After transport to Esrange

Item	**Comments**	**Pass/Fail**
Soldering iron with different sizes of tips		
Soldering bath		
Solder wick		
Solder wire		
Vise		
Round plier		
Needle nose pliers		
Wire cutter		
Isopropyl alcohol with brush		
Fluxing agent		
Wire strippers		
Lint-Free Tissues		

Checklist E.CL.4

Test of safety interlock
Responsible team member: Jens Kanje Nordberg
Other attending team members:
Task: Test and verify that the experiment can be turned off
Duration:
When: After transport to Esrange

Step 1 - Connect the experiment to the simulated RXSM (DC power source).

Step 2 – Turn power on.

Step 3 – Use the ground station to verify that the experiment is turned on and ok.

Step 4 – Turn off the power from the DC source, but keep the battery box connected.

Step 5 – Verify with the ground station that the experiment is completely turned off, and if applicable measure on contacts and circuits with a multimeter for second verification.

Checklist E.CL.5

Test of batteries
Responsible team member: Björn Sjödahl
Other attending team members: Robert Lindberg
Task: Test and verify the operation of the batteries
Duration:
When: After transport to Esrange

Step 1 – Attach the battery box to the experiment, and attach a power source (simulated RXSM).

Step 2 – Turn on the power to the experiment.

Step 3 – Use the ground station to verify the voltage level in the batteries.

Step 4 – If applicable, run an end-to-end test with or without solder samples and use ground station to verify heating of the resistance wires and thereby functionality of the batteries.

Checklist E.CL.6

Test of system
Responsible team member: Emil Vincent
Other attending team members: Robert Lindberg
Task: Test and verify the operation of the system
Duration: 1 hour
When: After transport to Esrange

Step 1 – Attach battery box, DC power source (simulated RXSM), and the chambers.

Step 2 – Turn on the power source, and give lift-off signal.

Step 3 – Review the data from the ground station and make sure the function of sensors, microcontroller, data writing, battery voltage level measurements and telemetry.

Step 4 – Make an end-to-end test without solder samples (or with old ones on) to verify the heating of the resistance wires

Step 5 – Do an end-to-end test with fresh solder samples to verify the functionality of the experiment target.

Checklist E.CL.7

Inspection and qualification of all wiring

Responsible team member: Jens Kanje Nordberg

Other attending team members: -

Task: All items shall be inspected to determine if there is any visual damage due to transport

Duration: 30 minutes

When: Pre-flight inspection

Table 1 - Checklist for inspection and qualification of all wiring after transport to Esrange

Item	Comments	Pass/Fail
Pressurized chamber		
Cables inside to sensor PCB		
Cables inside to solder PCB		
Cables to D-subs		
Vacuum chamber		
Cables inside to sensor PCB		
Cables inside to solder PCB		
Cables to D-sub		
Battery box		
Cables to electronics box		
Electronic box		
Cables from main PCBs to T-Rex		
Cable from RXSM (d-sub bracket) to electronics box		

Checklist E.CL.8

Inspection and qualification of all connectors
Responsible team member: Björn Sjödahl
Other attending team members: -
Task: All items shall be inspected to determine if there is any visual damage due to transport
Duration: 30 minutes
When: Pre-flight inspection

Table 1 - Checklist for inspection and qualification of all connectors after transport to Esrange

Item	Comments	Pass/Fail
D-sub connectors		
Electronics box		
T-Rex		
Vacuum chamber		
Pressurized chamber		
Battery box		
RXSM cable d-sub		
D-sub bracket		
Battery charging temperature connector		

Checklist E.CL.9

Connect batteries

Responsible team member: Emil Vincent
Other attending team members: -
Task: Connect batteries to experiment
Duration: 1 hour
When: During final assembly

Step 1

Assemble battery housing in accordance to procedure M_6 Battery insulation and assembly

Step 2

If not already applied, solder the battery wiring to the D-SUB5 battery connector according to the table bellow

Pin	**Connection**
1	Negative pole battery 1 (black wire)
2	Positive pole battery 1 (red wire)
3	Negative pole battery 2 (black wire)
4	Positive pole battery 2 (red wire)
5	NC

Step 3

Attach battery housing to bulkhead in accordance to procedure M_2 Assembly of bulkhead

Step 4

Check the wires and connectors for damage and verify they are connected correctly

Step 5

Check the battery voltage with ground station to make sure they are charged, connect them to the charging circuit if necessary

Step 6

Connect the batteries according to procedure M_10 Attachment of electronics contacts

Checklist E.CL.10

Detach all electronics

Responsible team member: Jens Kanje Nordberg
Other attending team members: Adrian Lindqvist
Task: Disconnect electronics from experiment
Duration: 20min
When: After recovery
Needed resources: Screwdriver
Tongs
Hex key
Adjustable spanner
Socket wrench

Step 1 – Disconnect all d- sub connectors
Step 2 – Unscrew and remove the battery box
Step 3 – Unscrew and remove the electronics box
Step 4 – Open the electronics box and unscrew the d-subs
Step 5 – Remove the locknuts on the PCBs.
Step 6 – Remove the top PCB, feed chamber cables and d- subs through the holes in the electronics box.
Step 7 – Remove lower PCB.

Checklist E.CL.11

Review and analyze damage of equipment
Responsible team member: Björn Sjödahl
Other attending team members: -
Task: All electronics shall be inspected to determine if there is any visual damage
Duration: 1 day
When: After recovery

Table 1 - Checklist for inspection of damage of equipment

Item	Comments	Pass/Fail
Pressurized chamber		
Cables inside		
Sensor PCB		
Vacuum chamber		
Cables inside		
Sensor PCB		
Battery box		
Cables to/from the box		
Battery packs		
Electronics box		
Cables		
Connectors		
Main PCBs		
Components		

Circuit board		
All D-sub connectors		

Checklist E.CL.12

Analyze voltage of battery pack, and values received from telemetry
Responsible team member: Björn Sjödahl
Other attending team members: Robert Lindquist
Task: Verify that everything went as planned by analyzing the voltage of battery and values received from telemetry
Duration: 1 hour
When: After recovery

Step 1 – Review data from measurements of voltage levels of the battery packs before lift-off.

Step 2 - Review data from flight regarding chamber voltage.

Step 3 – Measure the voltage in both battery packs by using the experiment and ground station if applicable. Otherwise connect to a low resistance load and verify voltage levels in the batteries.

Step 4 – Calculate the temperature that the resistance wires would have achieved with the voltage level supplied.

Checklist E.CL.13

Samples melts before flight

Responsible team member: Emil Vincent

Other attending team members: - Adrian Lindqvist, Jens Kanje Nordberg, Anneli Prenta, Robert Lindquist

Task: Replace the PCB with melted samples with a fresh one.

Duration: 30 min

When: In case of accidental melting of samples

Step 1

– Adrian detach the hats to the chambers, removes connected D-subs and collects the two bases of the chamber. The bases shall be placed on a workbench.

– Robert troubleshoots for software failure

Step 2

– Emil inspects and troubleshoots the wires and connectors to/from the chambers.

– Anneli inspects the battery connections inside the module using a multimeter

In case of found source of error

Batteries – see checklist [G.E.CL.9]

Wiring – see checklist [G.E.CL.7]

Connectors – see checklist [G.E.CL.8]

Software failure –

In case of no found error source

- Adrian detach the electronics box, and attach the spare electronics box
- Emil inspects and troubleshoots the main PCBs

Step 3

– Jens detaches failed solder PCB and replaces it with a new one with fresh samples.

Checklist E.CL.14

Battery discharges
Responsible team member: Björn Sjödahl
Other attending team members: Adrian Lindqvist, Robert Lindberg
Task: What to do in case of battery discharge
Duration: 30 minutes
When: In case of battery discharge

Step 1 – If access to experiment is still possible, a visual review shall be performed to determine the reason for discharge.

Step 2 – Measurement of voltage of each battery pack.

Step 3 – If the problem cannot be fixed, the battery d-sub and battery box shall be removed from the experiment and be replaced by a new battery box with two fully charged battery packs.

Step 4 – Attachment of the new battery box and attachment of the battery d-sub.

Step 5 – Make sure the battery packs are connected to the system by measuring the voltage with the monitoring circuit (ground station).

Checklist E.CL.15

Electrical failure, no experiment start
Responsible team member: Emil Vincent
Other attending team members: Jens Kanje Nordberg, Anneli Prenta
Task: What to do in case of no experiment start
Duration:
When: In case of electrical failure

Step 1
Check wire insulation and connections for damage and short circuits

Step 2
If damage is found, replace the damaged part

Or

If no damage or short circuit is found outside the electronics box, replace electronics box

Step 3
Test run and verify the problem is solved

Checklist E.CL.16

To bring to launch campaign
Responsible team member: Björn Sjödahl
Other attending team members: Emil Vincent
Task: Checklist for packing
Duration: 1 hour
When: Leaving for Esrange

Item	**Responsible team member**
Box of components*	Björn
Breadboard model GL-23	Emil
Prototype main PCBs	
DC Dual power Supply	
6 multicolored cables for power supply	
6 alligator clips	
Multimeter mastec ms8201 with probes	
TES 1300 Thermometer with thermistor	
Battery charger temperature system	
Scissors	
6 Electrical tape rolls	
Packing tape	
document tape	
2 three-cell-NiMh battery packs	
Wire cutter	
Round plier	
Battery charger connector with wires	
2 Chamber connectors for vacuum tests (male and female)	
Solder wire 0.5 mm	
Resistance wire 0.2 mm	

Checklist E.CL.16

Solder PCBs with prepared samples	
Resistors for Component pins	
Box of Signal cables for breadboarding	
Mini-vise	
Printouts of main and sensor PCB layouts and schematics	
Stripping plier	
Needle-nose plier	
Soldering station	
AAA batteries	

*See separate checklist [G.E.CL.17]

Checklist E.CL.17

Contents of box of components
Responsible team member: Björn Sjödahl
Other attending team members: Emil Vincent
Task: Checklist for packing the component box
Duration: 1 hour
When: Leaving for Esrange

Item	**Responsible team member**
Power Resistor MP915-1.001%	Björn
Switches IPU039N03L G	
Power Resistor MCKNP05SJ022JAA9	
Multiplexer MPC508AP	
ISP-connector	
Pin header extended	
Blue power cable small	
Blue power cable large	
Signal wire multicolor	
Hybrid D-SUB 5 FM5W5S-K121	
Hybrid D-SUB 5 FM 5W5P-K120	
Hybrid D-SUB 9 FM 9W4P-K120	
Hybrid D-SUB 9 FM9W4S-K121	
Power Resistor MCKNP07SJ0101B00	
Micro-sd card holder 2908-05WB-MG	
Inductors HM50-100KLF	
Inductors HM50-4R7KLF	
DC/DC converter TSR 1-24120	
DC/DC converter TSR 1-2450	
DC/DC converter TSR 1-2433	

Checklist E.CL.17

Socket Header	
Level converter bidirectional MAX3378EEUD	
Signal transceiver MAX488EESA	
Red cable lugs	
Small shrink tubes	
EMI-Filters SRF0905-251Y	
Optocoupler PC3H7J00000F	
Axial metal film resistors RM0207SFCN-series	
0.1uF Tantalus Capacitors T350A104M035AT	
22uF Tantalus Capacitors Capacitors T350F226M016AT	
10uF Tantalus Capacitors T350E106M016AT	
22uF Tantalus Capacitors 790D-226X0040C2	
10uF Tantalus Capacitors 790D-106X0040C2	
D-SUB 15 male and female	
Power pins for hybrid D-SUB	
Power sockets for hybrid D-SUB	
Pressure sensor HSCDANN015PAAA5	
Temperature sensor KTY84-150	
capacitors TSL2H-series	

Checklist E.CL.18

To bring to the launch from LTU equipment*
Responsible team member: Björn Sjödahl
Other attending team members: Emil Vincent
Task: Checklist for packing with respect to LTU equipment
Duration: 1 hour
When: Leaving for Esrange

Item	**Responsible team member**
Breadboard model GL-23	Björn
DC Dual power Supply	
6 multicolored cables for power supply	
6 alligator clips	
Multimeter mastec ms8201 with probes	
TES 1300 Thermometer with thermistor	
Scissors	
Round plier	
Solder wire 0.5 mm	
Resistors for Component pins	
Mini-vise	
Needle-nose plier	
Soldering station	

*All equipment except soldering station is already in our possession in Viking

Pre-flight inspections of the payload's structures and parts

Responsible project member(s): Johanna Åstrand

First Pre-flight checklist (after arriving to the launch campaign)

Structure/Part	Pass criteria	Pass/Fail	Notes
Bulkhead	No critical structural damages		
Electronic box	No critical structural damages		
	D-SUB contact's firmly secured		
Battery box	No critical structural damages		
	D-SUB contact's firmly secured		
D-SUB holder	No critical structural damages		
	D-SUB contact's firmly secured		
Hat for vacuum	No critical structural damages		
Hat for pressurized	No critical structural damages		
	No damages or dirt to/on the O-ring		
	No damages or dirt in the track for the O-ring		
Base for vacuum	No critical structural damages		
Base for pressurized	No critical structural damages		
	No damages or cracks in the silicon insulation		
Electronic PCB's	No critical structural damages		
Soldering PCB's	No critical structural damages		
Sensor PCB's	No critical structural damages		
Cable attachments	No critical structural damages		
Copper plate	No critical structural damages		

Checklist no: M_1 Pre-flight inspections of the payload's structures and parts

Second Pre-flight checklist (Before mounting to the rocket)

Structure/Part	Pass criteria	Pass/Fail	Notes
Bulkhead	No critical structural damages		
Electronic box	No critical structural damages		
	D-SUB contact's firmly secured		
Battery box	No critical structural damages		
	D-SUB contact's firmly secured		
D-SUB holder	No critical structural damages		
	D-SUB contact's firmly secured		
Hat for vacuum	No critical structural damages		
Hat for pressurized	No critical structural damages		
	No damages or dirt to/on the O-ring		
	No damages or dirt in the track for the O-ring		
Base for vacuum	No critical structural damages		
Base for pressurized	No critical structural damages		
	No damages or cracks in the silicon insulation		
Electronic PCB's	No critical structural damages		
Soldering PCB's	No critical structural damages		
Sensor PCB's	No critical structural damages		
Cable attachments	No critical structural damages		
Copper plate	No critical structural damages		

Pre-flight inventory of the payload structures and parts

Responsible project member(s): Johan Strandgren

Pre-flight checklist

Structure/Part	Amount	Pass/Fail	Remarks
Electronics box with lid	1		
Rod	1		
Lower PCB	1		
Upper PCB	1		
Angle brace 1 (Large)	1		
Angle brace 2 (small)	2		
Battery housing	1		
Battery pack (3 cells)	2		
Armaflex insulation plate (60x60)	3		
Armaflex insulation plate (60x65)	4		
Zip ties	2		
D-SUB holder	1		
Hat for vacuum chamber	1		
Base for vacuum chamber	1		
Hat for pressurized chamber	1		
Base for pressurized chamber	1		
O-ring	1		
Soldering PCB	2		
Sensor PCB	2		
Copper plate	4		
Solder (Sn_{63}/Pb_{37})	**1**		
Resistance wire	1		
Component pin	**6**		

Pre-flight inventory list of tools

Responsible project member(s): Adrian Lindqvist

Inventory list of tools	Amount	Pass/Fail	Remarks
M2 Allen key	2		
M3 Allen key	2		
M4 Allen key	2		
Torque wrench 3 Nm	2		
Socket wrench extension, >100 mm	2		
Socket wrench insert, hexagon head suiting the torque wrench	2		
Insex bit for M2 allen screw	2		
Insex bit for M3 allen screw	2		
Insex bit for M4 allen screw	2		
A sharp knife	1		
Ruler	2		
Ink pencil	2		
Pillar drill	1		
Pillar M1 drill	1		
Pillar M2 drill	1		
Pillar M3 drill	1		
Pillar M3.2 drill	1		
A small adjustable wrench	2		
Template for production of copper plates	1		

Checklist no: M_4 Pre-flight inspection of new screws, washers, nuts, spacer bolts, tie straps and o-ring to use during flight

Pre-flight inspection of new screws, washers, nuts, spacer bolts, tie straps and o-ring to use during flight

Responsible project member(s): Johan Strandgren

Pre-Flight checklist

Part	Amount	Pass/Fail	Remarks
Screw M5x25	11		
Screw M4x30	16		
Screw M4x8	21		
Countersunk screw M4x12	9		
Countersunk screws M3.5x10	4		
Screw M3x50	5		
Screw M3x12	13		
Screw M3x6	7		
Screw M3x8 oval head	0		
Screw M3x5 oval head	0		
Screws M2x6	20		
Locknut M5	11		
Locknut M4	9		
Locknut M3	13		
Nut M2	20		
Spring washer M5	11		
Spring washer M4	46		
Spring washer M3	40		
Flat washer M3	8		
Flat washer M2	40		
Spacer bolt M3 - M3	6		
Spacer bolt M3 - 4-40	2		
Tie straps 550 mm	2		
O-ring	1		

Checklist no: M_4 Pre-flight inspection of new screws, washers, nuts, spacer bolts, tie straps and o-ring to use during flight

Checklist no: M_5 Pre-flight inspection of extra screws, washers, nuts, spacers, spacer bolts, tie straps and additional items in case of damage or loss

Pre-flight inspection of extra screws, washers, nuts, spacers, spacer bolts, tie straps and additional items in case of damage or loss

Responsible project member(s): Johan Strandgren

Pre-Flight checklist

Part	Amount	Pass/Fail	Remarks
Screw M5x25	21		
Screw M4x30	4		
Screw M4x8	18		
Countersunk screw M4x12	15		
Countersunk screws M3.5x10	88		
Screw M3x50	4		
Screw M3x12	25		
Screw M3x6	20		
Screw M3x8 oval head	6		
Screw M3x5 oval head	21		
Screws M2x6	49		
Locknut M5	22		
Locknut M4	12		
Locknuts M3	42		
Nuts M2	52		
Spring washer M5	9		
Spring washers M4	9		
Spring washers M3	83		
flat washer M3	17		
flat washers M2	117		
Spacer bolts M3 - M3	20		
Spacer bolts M3 - 4-40	10		
Spacer 20 mm	5		
Spacer 10 mm	8		
Spacer 3 mm	4		
Tie straps 550 mm	10		
Tie straps 200 mm	20		
Tie straps 100 mm	23		
Cable tie mount	6		
Fully assembled Electronics box	1		
Solder PCBs with all screws and samples	4		
Solder PCBs	3		
Copper plates	6		
Armaflex (insulation) small	3		
Armaflex (insulation) large	2		
Armaflex (insulation) pad	2		
O-ring	3		

Checklist no: M_5 Pre-flight inspection of extra screws, washers, nuts, spacers, spacer bolts, tie straps and additional items in case of damage or loss

Pre-flight inspection of spare parts and consumables

Responsible project member(s): Sara Widbom

Pre-flight checklist

Part	Minimum amount	Pass/Fail	Remarks
O-ring	6		
Vacuum grease tube	1		
Copper plates	8		
Prepared battery housing with batteries, insulation and zip ties	1		
Electrical tape roll	1		
Prepared electrical box with main PCB's	1		
Solder PCB	8		
Prepared sensor PCB	2		
Silicone adhesive tube	1		
ArmaFlex insulation set	2		
Zip ties	8		

Checklist no: M_8 Pre-flight final assembly of payload before flight

Final assembly of payload before flight

Responsible project member(s): Adrian Lindqvist, Johan Strandgren

Activity	Success criteria	Pass/Fail	Remarks
Inspection of payload for structural issues	No critical issues can be found		
Perform a vacuum test	The pressurized chamber shall be able to keep its initial pressure for at least 10 min with a maximum of ± ~10 % change in pressure		
Assemble the battery housing if needed, following the [G.M.6] procedure	The battery housing is successfully assembled		
Mount the battery housing on the bulk head following the [G.M.2] procedure	The battery housing can be mounted on the bulk head		
Assemble the electronics box if needed, following the [G.M.11] procedure	The electronics box is successfully assembled		
Mount the electronics box on the bulk head following the [G.M.2] procedure	The electronics box can be mounted on the bulk head		
Mount the D-SUB holder on the bulk head following the [G.M.2] procedure	The D-SUB holder can be mounted on the bulk head		
Assemble the chambers following the [G.M.7] & [G.M.8] procedures	The chambers is successfully assembled		
Mount the chambers on the bulk head following the [G.M.2] procedure	The chambers can be mounted on the bulk head		
Connect the contacts from the electronics box, chambers and the battery housing following the [G.M.10] procedure	All of the D-SUB's can be connected		
Secure all loose cables on the bulkhead	There are no loose cables on the bulkhead		

Post-flight disassembly of the experiment from the bulkhead

Responsible project member(s): Johan Strandgren

Post-flight checklist

Action	Pass/Fail	Remarks
Disengage the D-SUB 4 contact from the battery from the electronics box		
Disengage the D-SUB 24 contacts from the electronics box from D-SUB holder		
Disengage the D-SUB 24 contact from the pressurized chamber from the D-SUB holder		
Disengage the D-SUB 24 contact from the vacuum chamber from the D-SUB holder		
Unscrew the eight screws holding the vacuum chamber		
Unscrew the eight screws holding the pressurized chamber		
Unscrew the four screws holding the D-SUB holder		
Unscrew the nine screws holding the electronics box		
Unscrew the eight screws holding the battery box		

During this disassembly, make sure that all screws, spring washers and spacer bolts are put in separate marked boxes or plastic bags

Post-flight inspection of the payload's structures and parts

Responsible project member(s): Johanna Åstrand

Post-flight checklist

Structure/Part	Actions	Notes
The whole structure before disassembly	Overall structural damages review	
Bulkhead	Structural damages review	
Electronic box	Structural damages review	
	Review of the D-SUB contacts	
Battery box	Structural damages review	
	Review of the D-SUB contacts	
D-SUB holder	Structural damages review	
	Review of the D-SUB contacts	
Hat for vacuum	Structural damages review	
Hat for pressurized	Structural damages review	
	Review the O-ring and the track	
Base for vacuum	Structural damages review	
Base for pressurized	Structural damages review	
	Review the insulation	
Electronic PCB's	Damages review	
Soldering PCB's	Damages review	
Sensor PCB's	Damages review	
Cable attachments	Damages review	
Copper plate	Structural damages review	

Post-flight inspection of the soldering and storing the samples

Responsible project member(s): Adrian Lindqvist

Activity	Success criteria	Pass/Fail	Remarks
Inspect the soldering area for any anomalies from regular soldering tests	No anomalies can be found		
Mark each samples in an order of 1, 2, 3 in each chamber with 1 being the sample furthest away from the inlet in the base	Mark the samples in the correct order with 1 being furthest away from the inlet in the base and 3 being the closest		
Inspect the samples for any visual deformations	No visual deformations can be seen		
Inspect the samples if they have made a soldering to the component pin	All samples have done a soldering to the component pin		
Inspect the resistance wire for damages	No damage to the resistance wire can be found		
Store the samples from the pressurized chamber in the plastic bag named Pressurized chamber samples	Stored the samples from the pressurized chamber in the plastic bag named Pressurized chamber samples		
Store the samples from the vacuum chamber in the plastic bag named Vacuum chamber samples	Stored the samples from the vacuum chamber in the plastic bag named Vacuum chamber samples		

Post-flight inventory of the payload structures and parts

Responsible project member(s): Johan Strandgren

Post-flight checklist

Structure/Part	Amount	Pass/Fail	Remarks
Electronics box with lid	1		
Rod	1		
Lower PCB	1		
Upper PCB	1		
Angle brace 1 (Large)	1		
Angle brace 2 (small)	2		
Battery housing	1		
Battery pack (3 cells)	2		
Armaflex insulation plate (60x60)	3		
Armaflex insulation plate (60x65)	4		
Zip ties	2		
D-SUB holder	1		
Hat for vacuum chamber	1		
Base for vacuum chamber	1		
Hat for pressurized chamber	1		
Base for pressurized chamber	1		
O-ring	1		
Soldering PCB	2		
Sensor PCB	2		
Copper plate	4		
Solder (Sn_{63}/Pb_{37})	**1**		
Resistance wire	1		
Component pin	**6**		

Post-flight inventory list of tools

Responsible project member(s): Adrian Lindqvist

Inventory list of tools	Amount	Pass/Fail	Remarks
M2 Allen key	2		
M3 Allen key	2		
M4 Allen key	2		
Torque wrench 3 Nm	2		
Socket wrench extension, >100 mm	2		
Socket wrench insert, hexagon head suiting the torque wrench	2		
Insex bit for M2 allen screw	2		
Insex bit for M3 allen screw	2		
Insex bit for M4 allen screw	2		
A sharp knife	1		
Ruler	2		
Ink pencil	2		
Pillar drill	1		
Pillar M1 drill	1		
Pillar M2 drill	1		
Pillar M3 drill	1		
Pillar M3.2 drill	1		
A small adjustable wrench	2		
Template for production of copper plates	1		

Post-flight inspection of spare parts and consumables

Responsible project member(s): Sara Widbom

Post-flight checklist

Part	Minimum amount	Pass/Fail	Remarks
O-ring	6		
Vacuum grease tube	1		
Copper plates	8		
Prepared battery housing with batteries, insulation and zip ties	1		
Electrical tape roll	1		
Prepared electrical box with main PCB's	1		
Solder PCB	8		
Prepared sensor PCB	2		
Silicone adhesive tube	1		
ArmaFlex insulation set	2		
Zip ties	8		

Checklist no: M_15 Pre-flight inspection of all packed tools and experiment items before and after the launch campaign

Pre-flight checklist for all packed tools and experiment items before and after the launch campaign

Responsible project member(s): Johan Strandgren

Pre-Flight checklist

Tool	Amount	Pass/Fail	Remarks
Drivers			
Ratchet driver	1		
Torque wrench	1		
Bit screw driver	1		
Sockets			
Socket wrench insert, hexagon head suiting the ratchet driver and torque wrench	1		
Socket M2 (4 mm)	1		
Socket jackposts & spacer bolts (4.5 mm)	1		
Socket M3 (5.5 mm)	1		
Socket M4 (7 mm)	1		
Socket M5 (8 mm)	1		
Bits			
Bit set with various bits and a bit extension	2		
Allen keys			
Allen key suiting M2 socket screw	2		
Allen key suiting M3 socket screw	2		
Allen key suiting M4 socket screw	2		
Allen key suiting M5 socket screw	2		
Additional Tools			
Needle nose plier	1		

Checklist no: M_15 Pre-flight inspection of all packed tools and experiment items before and after the launch campaign

Socket wrench extension >100mm	1		
knife	1		
ruler	1		
small adjustable wrench	1		
Sliding calliper	1		
Round-nosed plier	1		
File	1		

Additional Materials and Items	**Amount**	**Pass/Fail**	**Remarks**
Tape	1		
Super O-lube (vacuum grease)	1		
Silicone Adhesive	2		
Locktite 243	2		
Locktit 270	1		
O-ring	1		
Tie straps 550 mm	2		
Solder PCBs with all screws and samples	2		

Screws, washers, nuts and spacer bolts	**Amount**	**Pass/Fail**	**Remarks**
Screw M5x25	11		
Screw M4x30	16		
Screw M4x8	21		
Countersunk screw M4x12	9		
Countersunk screws M3.5x10	4		
Screw M3x50	5		
Screw M3x12	13		
Screw M3x6	7		
Screw M3x8 oval head	0		
Screw M3x5 oval head	0		
Screws M2x6, A2	20		

Checklist no: M_15 Pre-flight inspection of all packed tools and experiment items before and after the launch campaign

Locknut M5	11		
Locknut M4	9		
Locknuts M3	13		
Nuts M2	20		
Spring washer M5	11		
Spring washers M4, A2	46		
Spring washers M3, A2	40		
flat washer M3	8		
flat washers M2, A2	40		
Spacer bolts M3 - M3	6		
Spacer bolts M3 - 4-40	2		

Spare Parts	**Amount**	**Pass/Fail**	**Remarks**
Screw M5x25	21		
Screw M4x30	4		
Screw M4x8	18		
Countersunk screw M4x12	15		
Countersunk screws M3.5x10	88		
Screw M3x50	4		
Screw M3x12	25		
Screw M3x6	20		
Screw M3x8 oval head	6		
Screw M3x5 oval head	21		
Screws M2x6, A2	49		
Locknut M5	22		
Locknut M4	12		
Locknuts M3	42		
Nuts M2	52		
Spring washer M5	9		
Spring washers M4, A2	9		
Spring washers M3, A2	83		
flat washer M3	17		

Checklist no: M_15 Pre-flight inspection of all packed tools and experiment items before and after the launch campaign

flat washers M2, A2	117		
Spacer bolts M3 - M3	20		
Spacer bolts M3 - 4-40	10		
Spacer 20 mm	5		
Spacer 10 mm	8		
Spacer 3 mm	4		
Tie straps 550 mm	10		
Tie straps 200 mm	20		
Tie straps 100 mm	23		
Cable tie mount	6		
Fully assembled Electronics box	1		
Solder PCBs with all screws and samples	4		
Solder PCBs	3		
Copper plates	6		
Armaflex (insulation) small	3		
Armaflex (insulation) large	2		
Armaflex (insulation) pad	2		
oring	3		

APPENDIX H

Tests

Test Number	OST.1
Test Type	Vibration
Test Facility	IRF
Tested Item	D-SUB holder, electronics box, vacuum chamber
Test Level/procedure and duration	1. The structures of the experiment will be put on a shaker and will vibrate according to directives from the REXUS manual.
Test campaign duration	1 day
Verifies	The main structures will hold for the vibrations expected during launch and M.D.5
Pass/Fail	Pass

Test date: *2012-10-16*
Responsible for test and report: Fredrik Persson
Participating in test: Fredrik Persson, Johan Strandgren

1. Test Plan

Objective
Step 1:
A preliminary test is made to make sure that the most critical structures will cope with the rocket environment during flight.

Applicability
Step 1:
This is a vibration test that simulates the vibration levels expected during flight. If the structures pass the test then our design is good enough for proceeding with the step 2 test.

Items to test
D-SUB holder, electronics box and the vacuum chamber is tested.

Test configuration
A computer with a software for vibration testing was connected with a power source and a shaker.

Test type
Vibration

Success criteria
Step 1: No eigenfrequencies less than 100 Hz shall occur.
No damage on the structures shall occur.

2. Test Design Specification

Test Conditions

The test was performed indoors in IRF's facilities using a shaker from SRT. Room temperature, normal pressure (1 bar) and probably a low relative humidity would define the environment of the room.

3. Test Procedure Specification

Personnel

During the test we had help from an experienced IRF professional to operate the shaker and discuss the results with us. A representative from SRT was also present to assist during the test procedure. Fredrik and Johan had an observational and analytical function.

Pre-test Activities

Put dummy weights on the PCB cards in the electronics box to simulate the electronics components on the PCB's. All the bolts and screws needed to be attached to the bulkhead were fastened using a torque wrench. The same was needed when the bulkhead was mounted on the shaker module attached to the shaker.

Test Procedure

Start with a sine sweep of 0.25g to make sure everything is ok. Then a test according to the levels for qualification of sinusoidal vibration is used to be on the safe side. A random vibration acceptance test is made. Finally, another sine sweep of 0.25g is made to see if the vibration profile has changed. The levels for all the tests can be found in the REXUS manual.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
00:00:00	Experiment start
00:09:00	Sine sweep of 0.25g
00:17:00	Sinusoidal vibrations qualification test
00:20:00	Random vibrations acceptance test
00:24:00	Sine sweep of 0.25g
00:30:00	Experiment Stop

A difference between the first and last sine sweep can be seen.

5. Test Incident Report

Step 1:
A difference between the first and last sine sweep can be seen. The lowest natural frequency can be found at about 200-250 Hz, which is low, but still above our limit for re-design of 100 Hz.

6. Test Summary Report

Step 1:

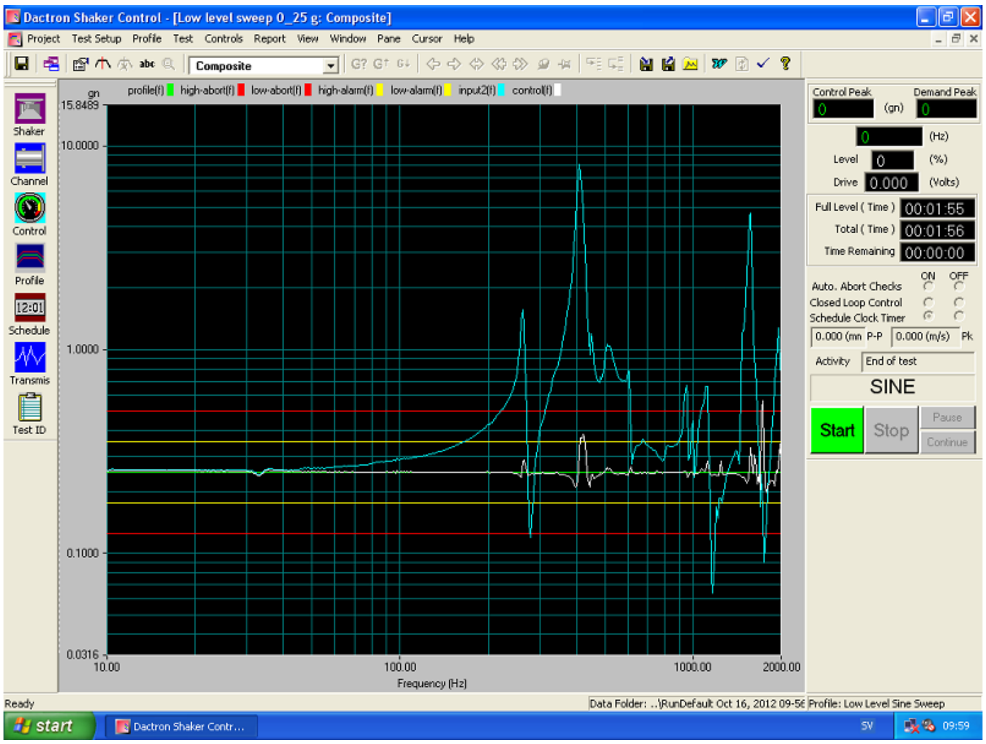


Figure 1 - Sine sweep 0.25g results before sinusoidal and random vibration test.

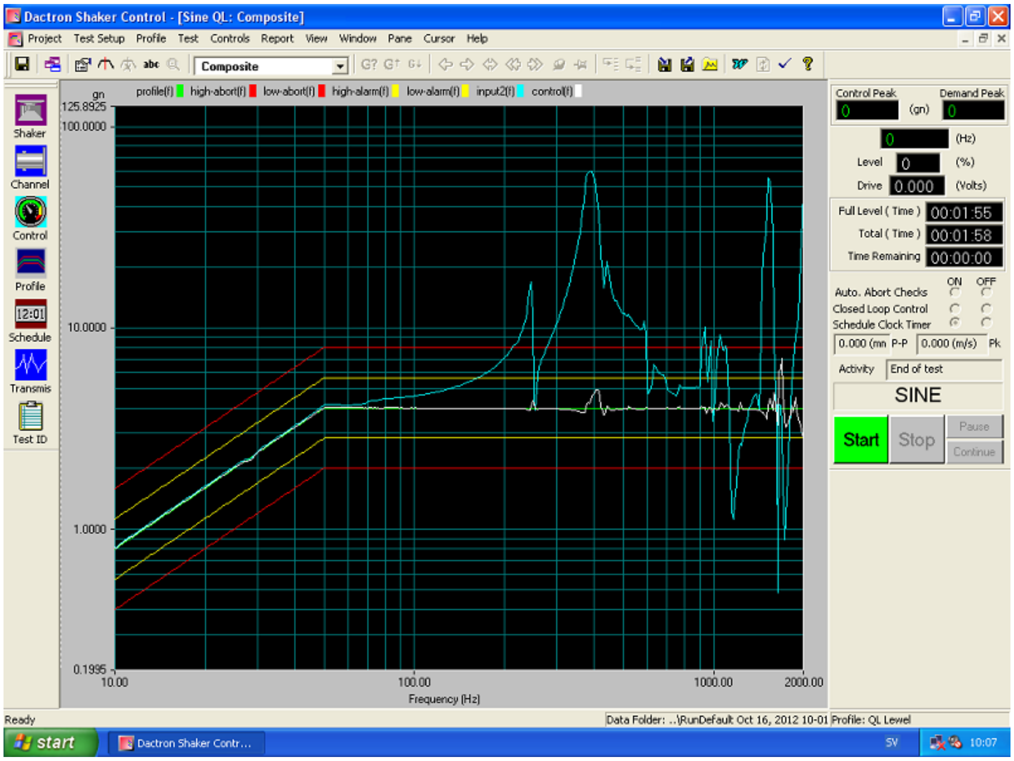


Figure 2 - Sinusoidal vibrations qualification test results. A first natural frequency can be found at 250 Hz.

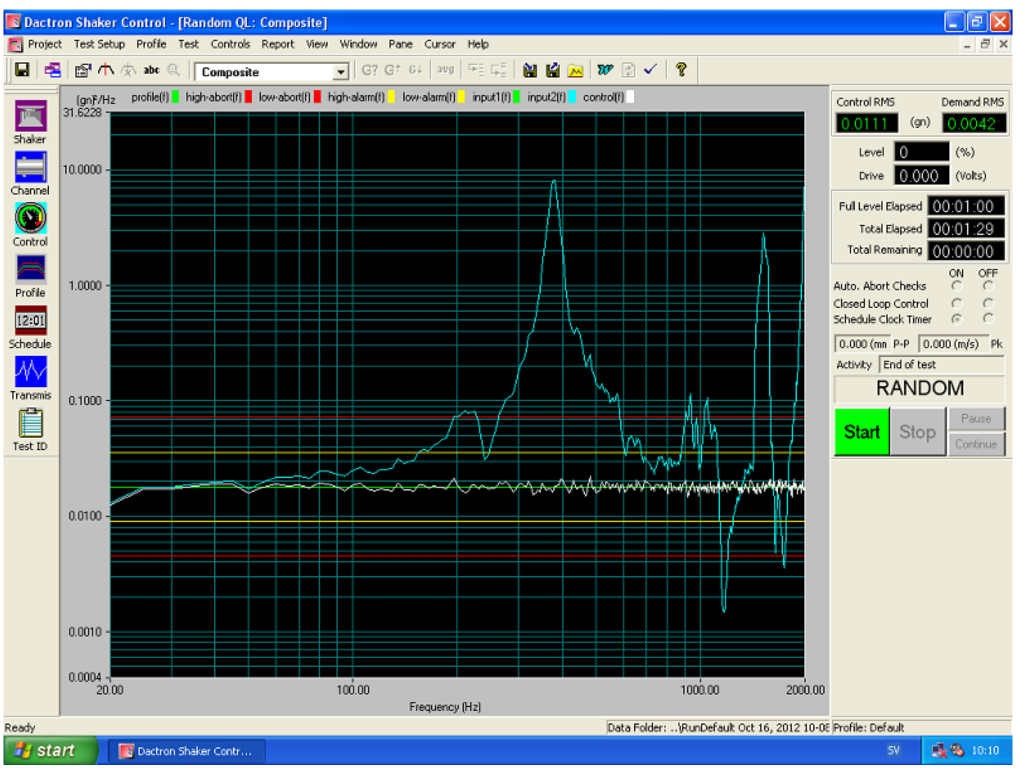


Figure 3 - Random vibrations acceptance test results. Peaks can be seen at frequencies exceeding 200 Hz.

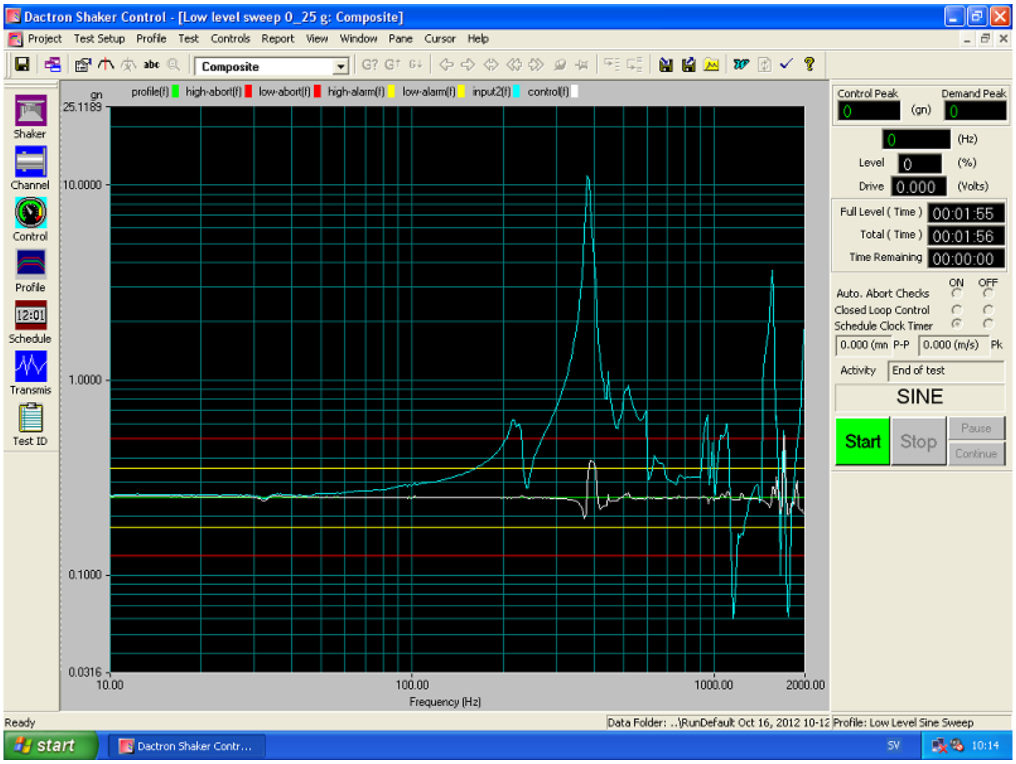


Figure 4 - Sine sweep 0.25g results after the sinusoidal and random vibration test.

It can be seen that the first peak at just over 200 Hz has changed its shape. Also, the second peak is larger than the second peak from the first sine sweep. A difference in the profiles like this is usually due to a change in the experiment or something settling. In our case we found a loose dummy weight on one of our PCB's in the electronics box that might explain this difference.

Test Number	OST.1
Test Type	Vibration
Test Facility	IRF
Tested Item	The whole experiment including components
Test Level/procedure and duration	2. The whole experiment with all components installed will be put on a shaker which will vibrate according to directives from the REXUS manual
Test campaign duration	1 day
Verifies	M.D.2, M.D.5
Pass/Fail	Pass

Test date: *2012-11-15*
Responsible for test and report: Adrian Lindqvist
Participating in test: Adrian Lindqvist, Björn Sjödahl

1. Test Plan

Objective
Step 2:
Test to see and verify that all components will still function and are intact after the vibrations that will occur on the rocket.

Applicability
Step 2:
This is a vibration test that simulates the vibration levels expected during flight. If the structures and components pass the test then our design is good enough to be launched on the rocket.

Items to test
Whole experiment including components.

Test configuration
A computer with a software for vibration testing was connected with a power source and a shaker.

Test type
Vibration

Success criteria
Step 2: No eigenfrequencies less than 100 Hz shall occur.
No damage on the structures shall occur.
No damage to the components shall occur.
The experiment shall be able to run afterwards.

2. Test Design Specification

Test Conditions

The test was performed indoors in IRF's facilities using a shaker from SRT. Room temperature, normal pressure (1 bar) and probably a low relative humidity would define the environment of the room.

3. Test Procedure Specification

Personnel

During the test we had help from an experienced IRF professional to operate the shaker and discuss the results with us. A representative from SRT was also present to assist during the test procedure. Adrian and Björn had an observational and analytical function.

Pre-test Activities

All the bolts and screws needed to be attached to the bulkhead were fastened using a torque wrench. The same was needed when the bulkhead was mounted on the shaker module attached to the shaker.

Test Procedure

Start with a sine sweep of 0.25g to make sure everything is ok. Then a test according to the levels for qualification of sinusoidal vibration is used to be on the safe side. A random vibration acceptance test is made. Finally, another sine sweep of 0.25g is made to see if the vibration profile has changed. The levels for all the tests can be found in the REXUS manual.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
00:00:00	Experiment start
00:09:00	Sine sweep of 0.25g
00:17:00	Sinusoidal vibrations qualification test
00:20:00	Random vibrations acceptance test
00:24:00	Sine sweep of 0.25g
00:30:00	Experiment Stop

A difference between the first and last sine sweep can be seen.

5. Test Incident Report

Step 2:
A difference between the first and last sine sweep can be seen. The lowest natural frequency can be found at about 200-250 Hz, which is low, but still above our limit for re-design of 100 Hz.

6. Test Summary Report

Step 1:

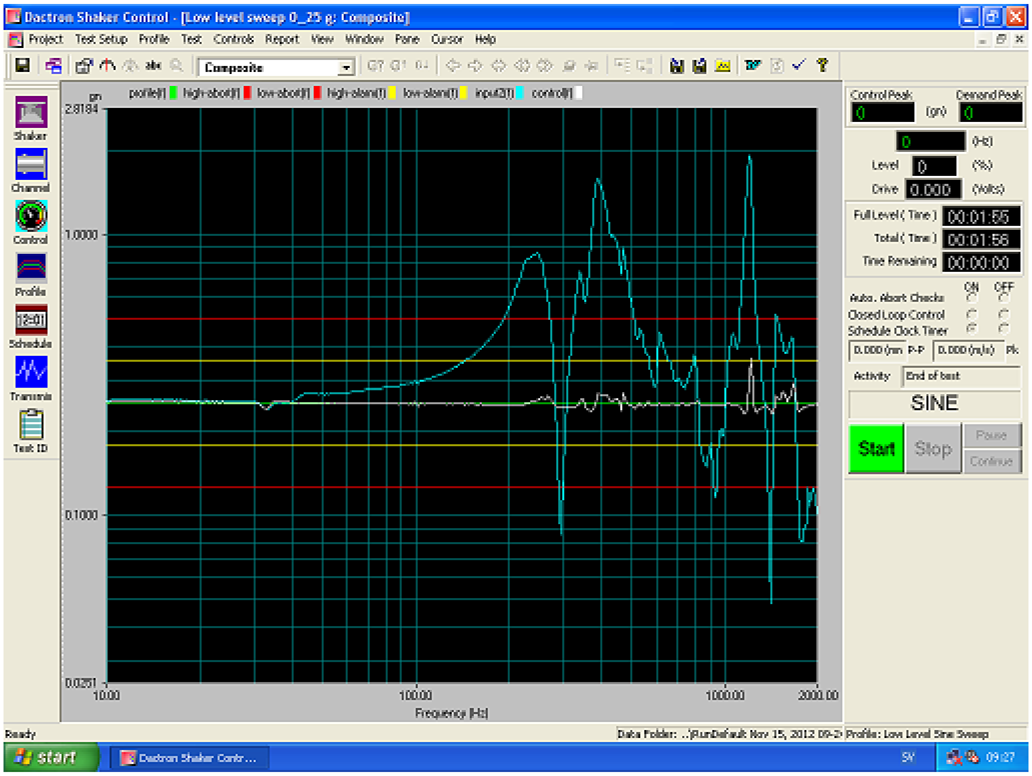


Figure 1 - Sine sweep 0.25g results before sinusoidal and random vibration test.

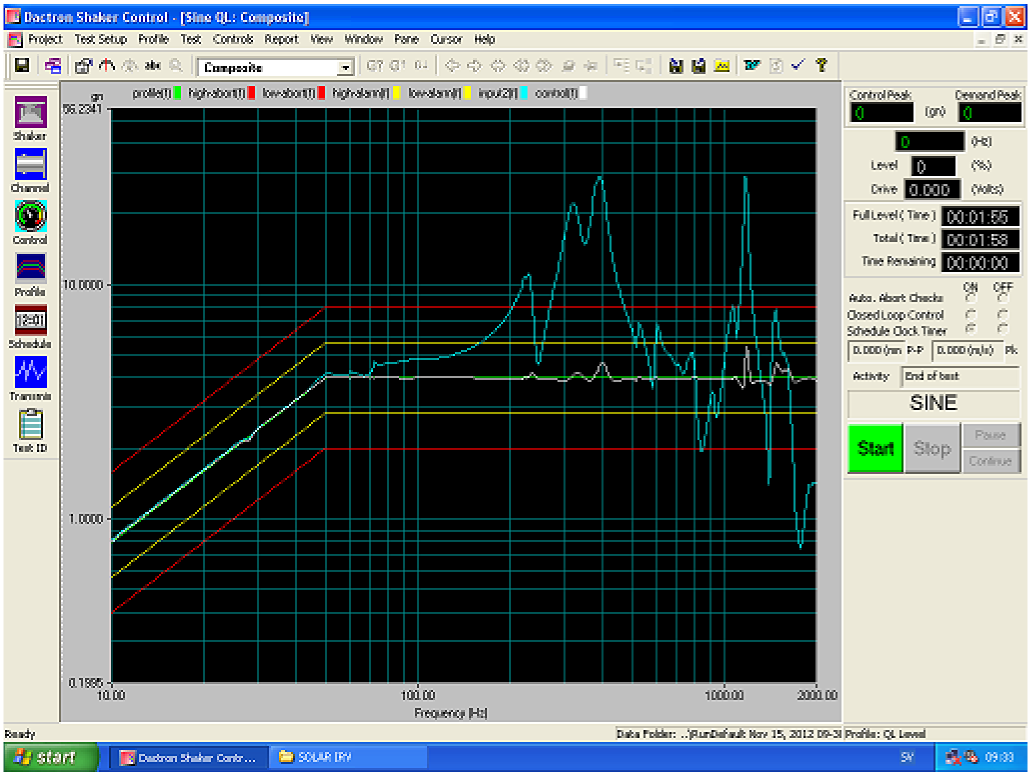


Figure 2 - Sinusoidal vibrations qualification test results. A first natural frequency can be found at 250 Hz.

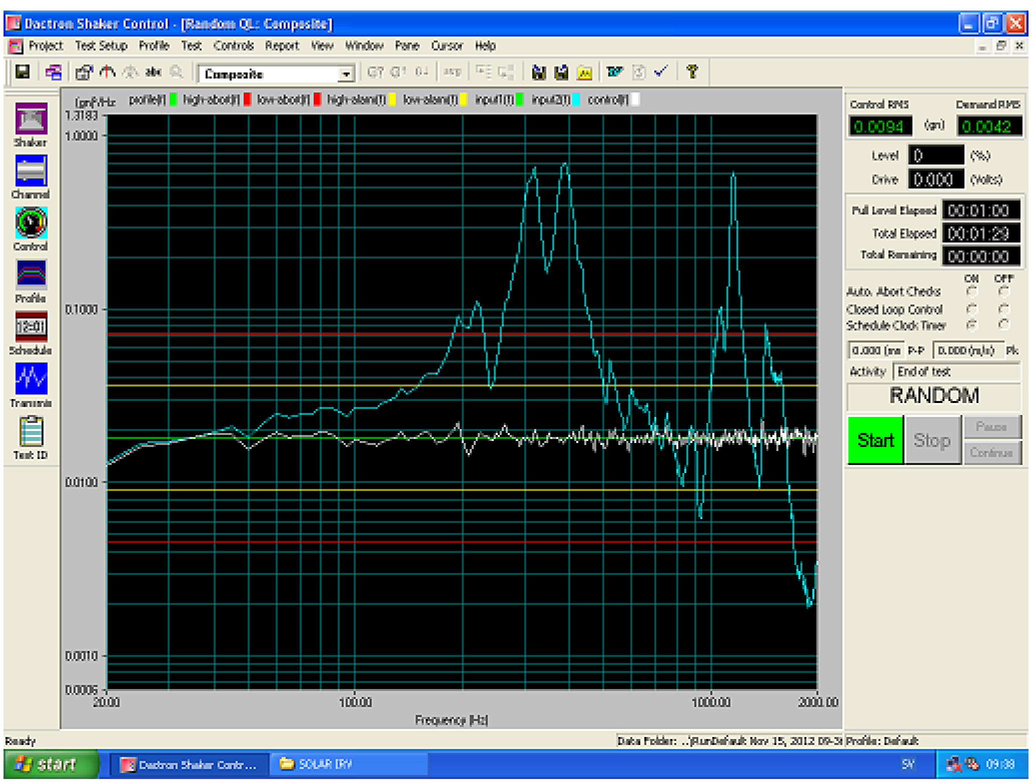


Figure 3 - Random vibrations acceptance test results. Peaks can be seen at frequencies exceeding 200 Hz.

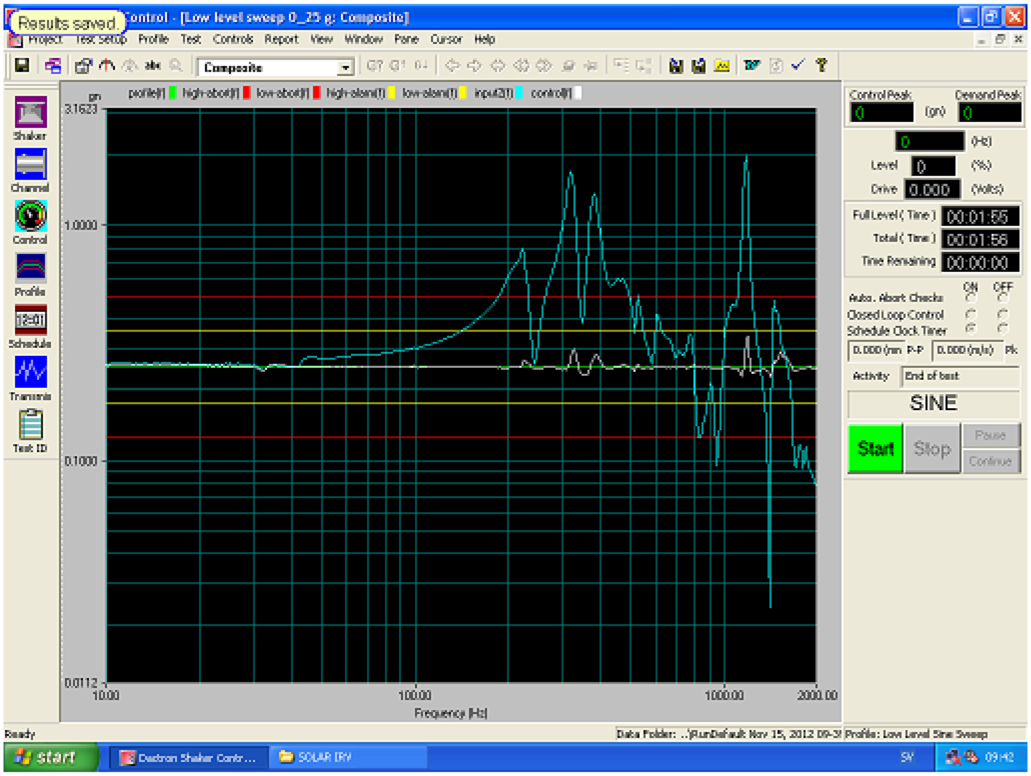


Figure 4 - Sine sweep 0.25g results after the sinusoidal and random vibration test.

It can be seen that the first dip at 250 Hz has changed its shape. Also, the second peak has been split in two now from the first sine sweep. A difference in the profiles like this is usually due to a change in the experiment or something settling. After the examination we could not find anything that had been damaged or was loose, though the pressurized chamber performed a lot better at keeping its pressure constant in the vacuum chamber so the change in the graphs above can be the insulation that settles.

Test Number	OST.2
Test Type	Verification
Test Facility	IRF
Tested Item	Pressurized chamber
Test Level/procedure and duration	1 day
Test campaign duration	2 days
Verifies	M.D.6
Pass/Fail	Pass

Test date: *2012-10-16*
Responsible for test and report: Adrian Lindqvist
Participating in test: Adrian Lindqvist, Johanna Åstrand, Jens Kanje Nordberg

1. Test Plan

Objective
Test to see how long the pressurized chamber could hold its initial pressure with a diff of ± 10 kPa when put in a vacuum chamber.

Applicability
To get an accurate reference sample that can be compared to the solder sample that will be exposed to an vacuum like environment plus be compared to a sample that has been solder at the same pressure on earth.

Items to test
The pressurized chamber

Test configuration
The hole in the base plus the duct had been insulated with an silicon adhesive with the cables in place two days before the test. Just before the test the cables that are leading in to the chamber were tinned to ensure that no air could escape through them. O-ring was then greased and put in place, with the pressure sensor inside the chamber. The hat and chamber were then screwed together. The edge between the base and the hat were taped, also the cables on the outside were taped. A voltmeter will be connected to the pressure sensor in the chamber to determine the pressure inside.

Test type
Vacuum and performance

Success criteria
The chamber should at a minimum hold its initial pressure with a maximum change of ± 10 kPa for at least 70 sek.

2. Test Design Specification

Test Conditions

The test is performed in a small vacuum chamber at IRF. Initial pressure of the chamber was ~95 kPa.

3. Test Procedure Specification

Personnel

Johanna insulated the base and greased the O-ring.
Kanje installed the power source and connected all the cables to the chamber.
Adrian supervised the test.

Pre-test Activities

Insulate the base, grease the O-ring and tape the edge between the hat and base plus the cables that are on the outside of the chamber.

Test Procedure

The pressurized chamber will be put in the vacuum chamber and then be supervised and record the voltage of the pressure sensor. The experiment will run for four minutes with a declining pressure in the vacuum chamber. After the test is done the voltage will be compared to a performance graph of the pressure sensor to determine the actual pressure in the chamber.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	**Event**
Hh:mm:ss	Experiment start
00:00:00	V = 3.929 P = 95 kPa
00:00:15	V = 3.916 P = 94 kPa
00:00:30	V = 3.883 P = 93.5 kPa
00:00:45	V = 3.827 P = 93 kPa
00:01:00	V = 3.770 P = 91 kPa
00:01:15	V = 3.710 P = 90 kPa
00:01:30	V = 3.641 P = 87 kPa
00:01:45	V = 3.582 P = 85.5 kPa
00:02:00	V = 3.526 P = 85 kPa
00:02:15	V = 3.468 P = 84 kPa
00:02:30	V = 3.415 P = 83 kPa
00:02:45	V = 3.364 P = 82 kPa
00:03:00	V = 3.312 P = 81 kPa

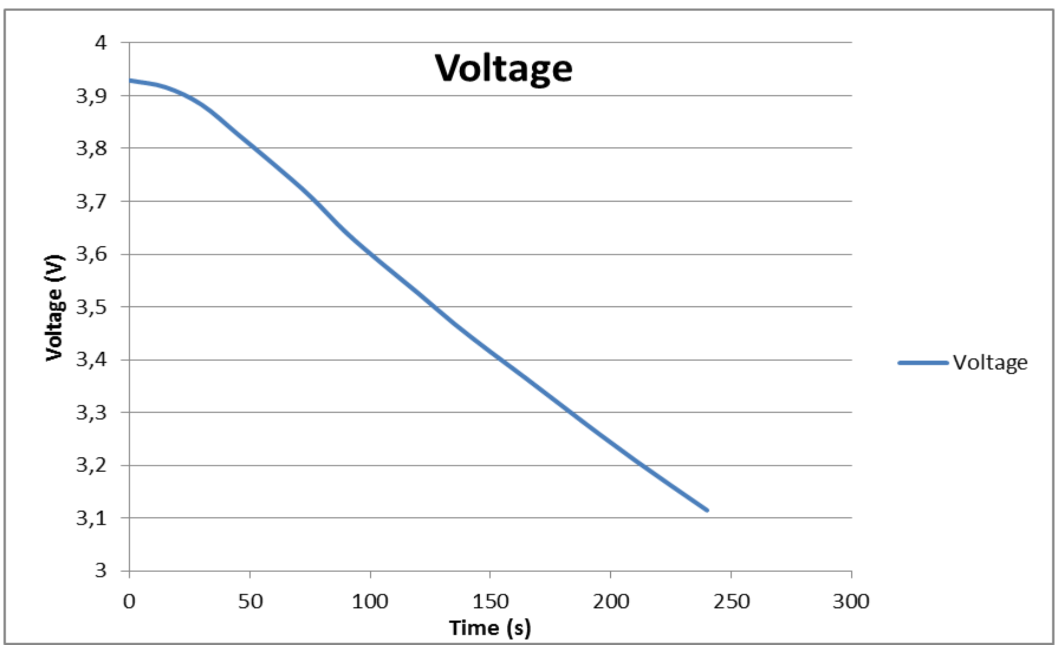
00:03:15	V = 3.260 P = 79 kPa
00:03:30	V = 3.210 P = 77 kPa
00:03:45	V = 3.162 P = 76.5 kPa
00:04:00	V = 3.115 P = 76 kPa
00:04:00	Experiment Stop

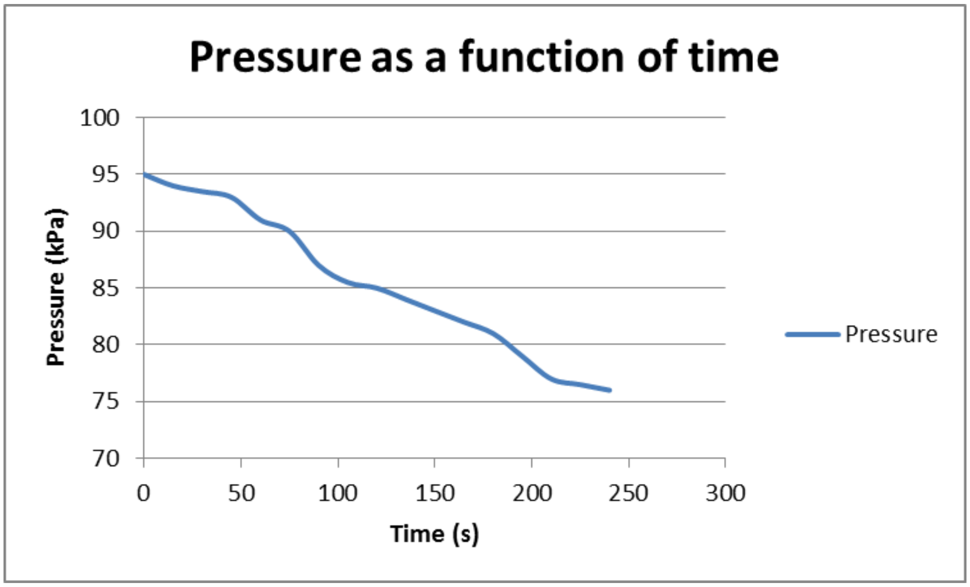
5. Test Incident Report

An issue occurred during the testing that the insulated started to deform under at the duct. This incident probably occurred because that there were not a solid surface directly under the base during this test, a new test with a thin plate that will be placed directly under the base can be a solution to ensure that the insulation will stay in place.

6. Test Summary Report

The pressurized chamber could hold its initial pressure with a change in pressure of 10 kPa for 1:45 min or 105 seconds, as this is more than the minimum level that is required of 70 seconds this test can be counted as a pass. More tests will be needed to improve the sealing of the chamber to create a bigger margin. The most probably area where leakage of air occurs might be the insulation because of the deformation that occurred during the test.





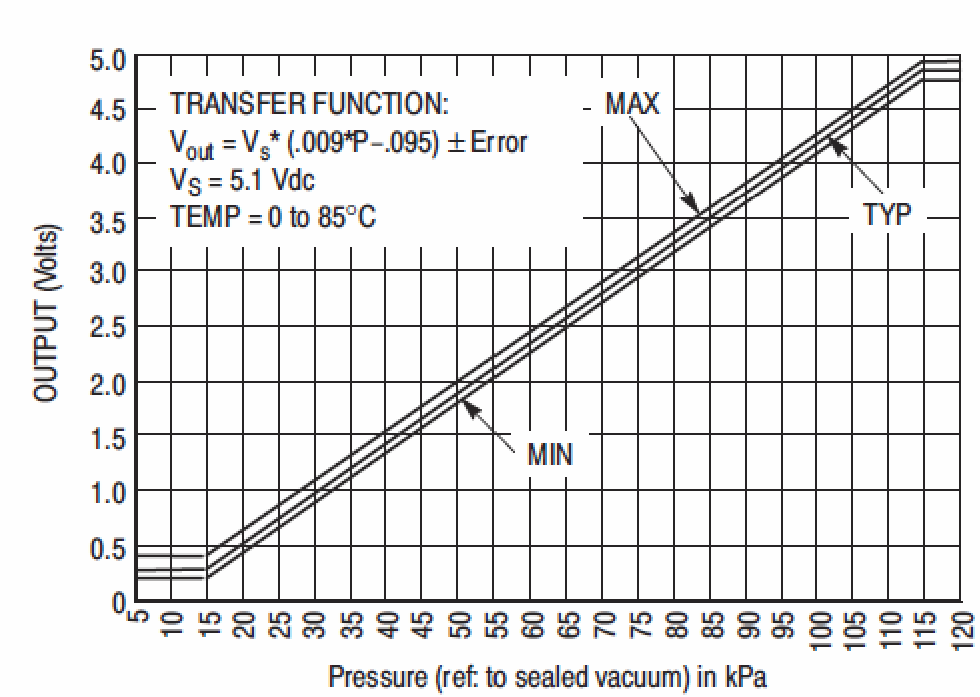


Figure 4. Output versus Absolute Pressure

Figure 1 -

Test Number	OST.2
Test Type	Verification
Test Facility	IRF
Tested Item	Pressurized chamber
Test Level/procedure and duration	1 day
Test campaign duration	2 days
Verifies	M.D.6
Pass/Fail	Pass

Test date: *2012-10-27*
Responsible for test and report: Adrian Lindqvist
Participating in test: Adrian Lindqvist, Björn Sjödahl

1. Test Plan

Objective

Test to see how long the pressurized chamber could hold its initial pressure with a diff of ± 10 kPa when put in a vacuum chamber.

Applicability

To get an accurate reference sample that can be compared to the solder sample that will be exposed to an vacuum like environment plus be compared to a sample that has been solder at the same pressure on earth.

Items to test

The pressurized chamber

Test configuration

The hole in the base plus the duct had been insulated with a silicone adhesive with the cables in place two weeks before the test. Two hours before the test the cables that were on the outside of the chamber where insulated at the ends with a silicone adhesive. O-ring was then greased and put in place, with the pressure sensor inside the chamber. The hat and chamber were then screwed together. A voltmeter will be connected to the pressure sensor in the chamber to determine the pressure inside.

Test type

Vacuum and performance

Success criteria

The chamber should at a minimum hold its initial pressure with a maximum change of ± 10 kPa for at least 70 sek.

2. Test Design Specification

Test Conditions

The test is performed in a small vacuum chamber that was borrowed from IRF. Initial pressure of the chamber was ~94 kPa.

3. Test Procedure Specification

Personnel

Björn Sjödahl installed the power source and connected all the cables to the chamber.
Adrian Lindqvist sealed the chamber and put it together and recorded the procedure.

Pre-test Activities

Insulate the base and cables, grease the O-ring.

Test Procedure

The pressurized chamber will be put in the vacuum chamber and then be supervised and record the voltage of the pressure sensor. The experiment will run for ten minutes with a declining pressure in the vacuum chamber. After the test is done the voltage will be compared to a performance graph of the pressure sensor to determine the actual pressure in the chamber.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time (s)	Voltage (V)	Pressure (kPa)
0	3,87	93,5
15	3,86	93,3
30	3,86	93,3
45	3,85	93,1
60	3,83	92,6
75	3,83	92,6
90	3,82	92,4
105	3,81	92,2
120	3,8	91,9
135	3,79	91,7
150	3,78	91,5
165	3,77	91,3
180	3,76	91,1
195	3,75	90,8
210	3,74	90,6
225	3,73	90,4
240	3,73	90,4
255	3,72	90,2

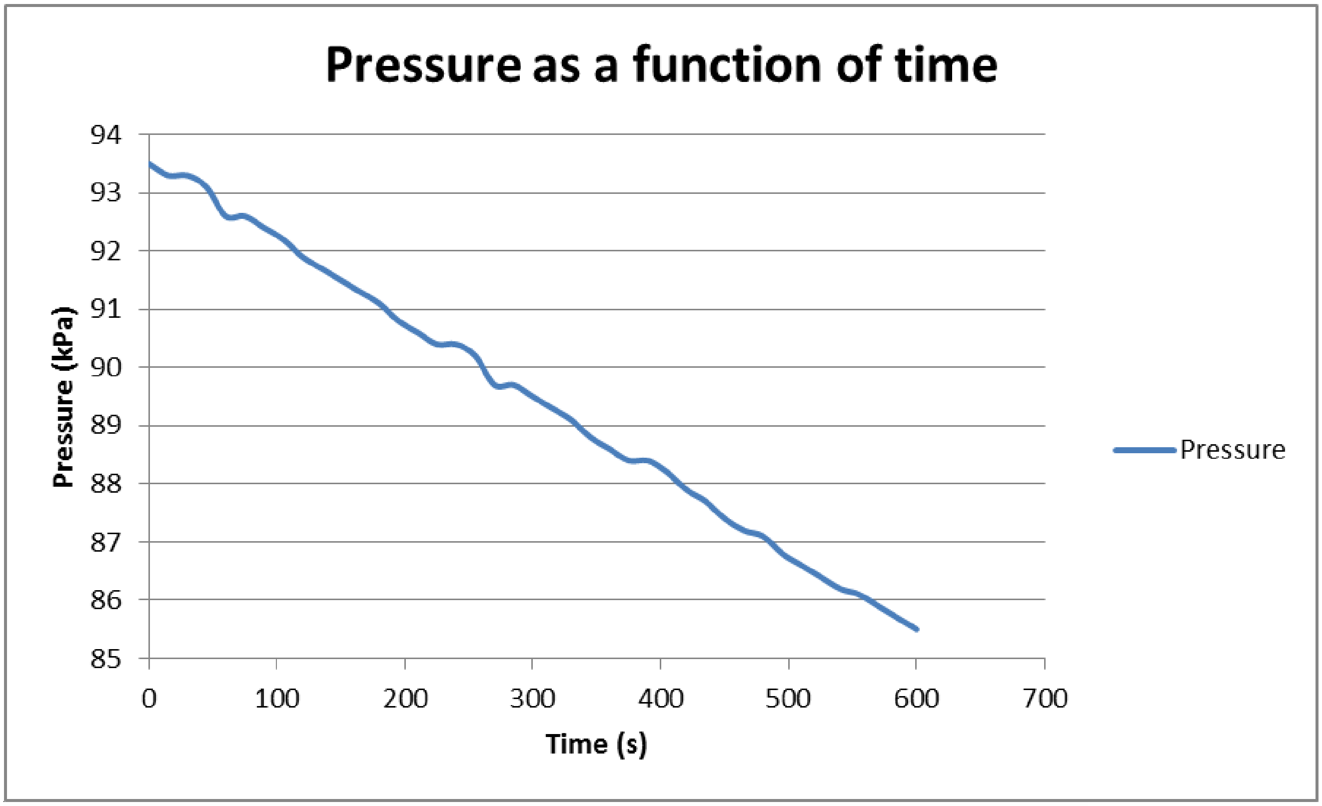
270	3,7	89,7
285	3,7	89,7
300	3,69	89,5
315	3,68	89,3
330	3,67	89,1
345	3,66	88,8
360	3,65	88,6
375	3,64	88,4
390	3,64	88,4
405	3,63	88,2
420	3,62	87,9
435	3,61	87,7
450	3,6	87,4
465	3,589	87,2
480	3,581	87,1
495	3,573	86,8
510	3,565	86,6
525	3,557	86,4
540	3,548	86,2
555	3,54	86,1
570	3,532	85,9
585	3,525	85,7
600	3,516	85,5

5. Test Incident Report

No issues were found during the test. The problem with the last test were the insulation had been deformed during the test did not happen now and it was still the same insulation so it was probably due to that the silicone did not have enough time to harden.

6. Test Summary Report

The pressurized chamber could hold its initial pressure with a change in pressure of 10 % from its initial value for 10 min or 600 seconds, as this is more than the minimum level that is required of 70 seconds this test can be counted as a pass. The chamber dropped from 93,5 kPa to 85,5 kPa in the time of 10 minutes and the margin was at 84,1 kPa. As this is a clear improvement from the last test OST.2 2012-10-16 this will now be the final design for the insulation of the pressurized chamber.



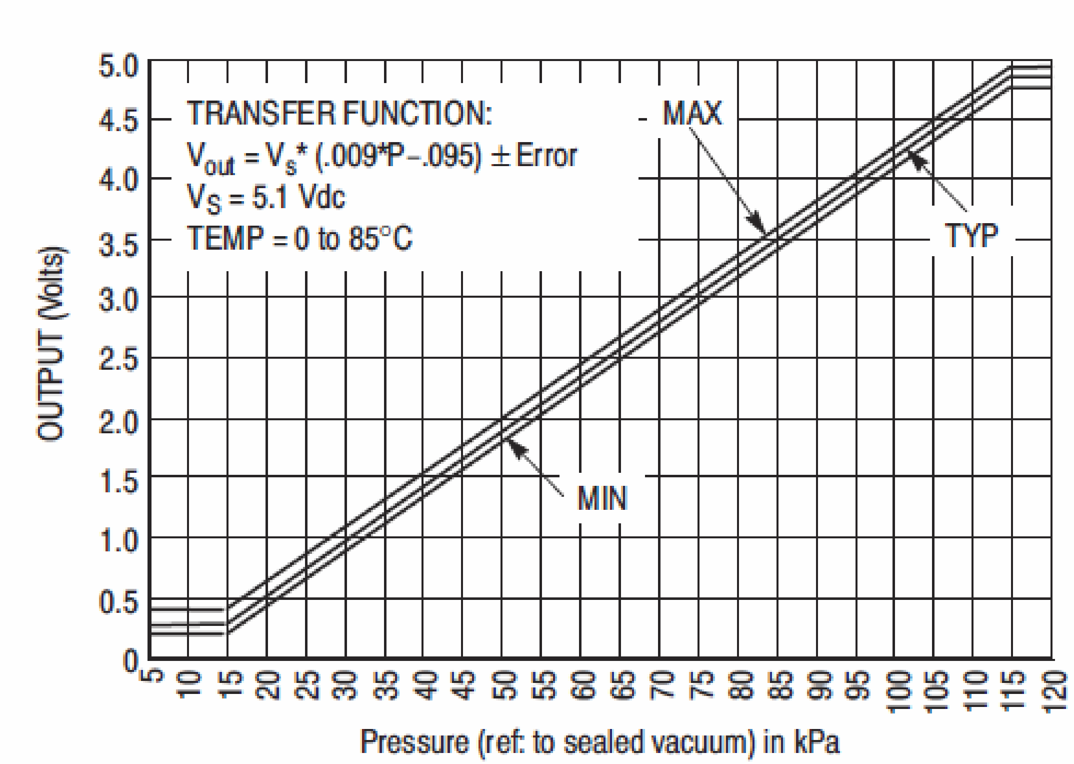


Figure 4. Output versus Absolute Pressure

Figure 1 -

Test Number	OST.2
Test Type	Verification
Test Facility	IRF
Tested Item	Pressurized chamber
Test Level/procedure and duration	1 day
Test campaign duration	6 days
Verifies	M.D.6
Pass/Fail	Pass

Test date: *2012-11-19*
Responsible for test and report: Adrian Lindqvist
Participating in test: Adrian Lindqvist, Emil vincent

1. Test Plan

Objective
Test to see how long the pressurized chamber could hold its initial pressure with a diff of ± 10 kPa when put in a vacuum chamber.

Applicability
To get an accurate reference sample that can be compared to the solder sample that will be exposed to an vacuum like environment plus be compared to a sample that has been solder at the same pressure on earth.

Items to test
The pressurized chamber

Test configuration
The hole in the base plus the duct had been insulated with a silicone adhesive, the cables had been insulated on the outside at their ends. O-ring had been greased since before and put in place. The hat and chamber were then screwed together. A voltmeter will be connected to the pressure sensor in the chamber to determine the pressure inside.

Test type
Vacuum and performance

Success criteria
The chamber should at a minimum hold its initial pressure with a maximum change of ± 10 kPa for at least 70 sek.

2. Test Design Specification

Test Conditions

The test is performed in a small vacuum chamber that was borrowed from IRF. Initial pressure of the chamber was ~102 kPa.

3. Test Procedure Specification

Personnel

Emil Vincent installed the power source and connected all the cables to the chamber.
Adrian Lindqvist sealed the chamber and put it together and recorded the procedure.

Pre-test Activities

None.

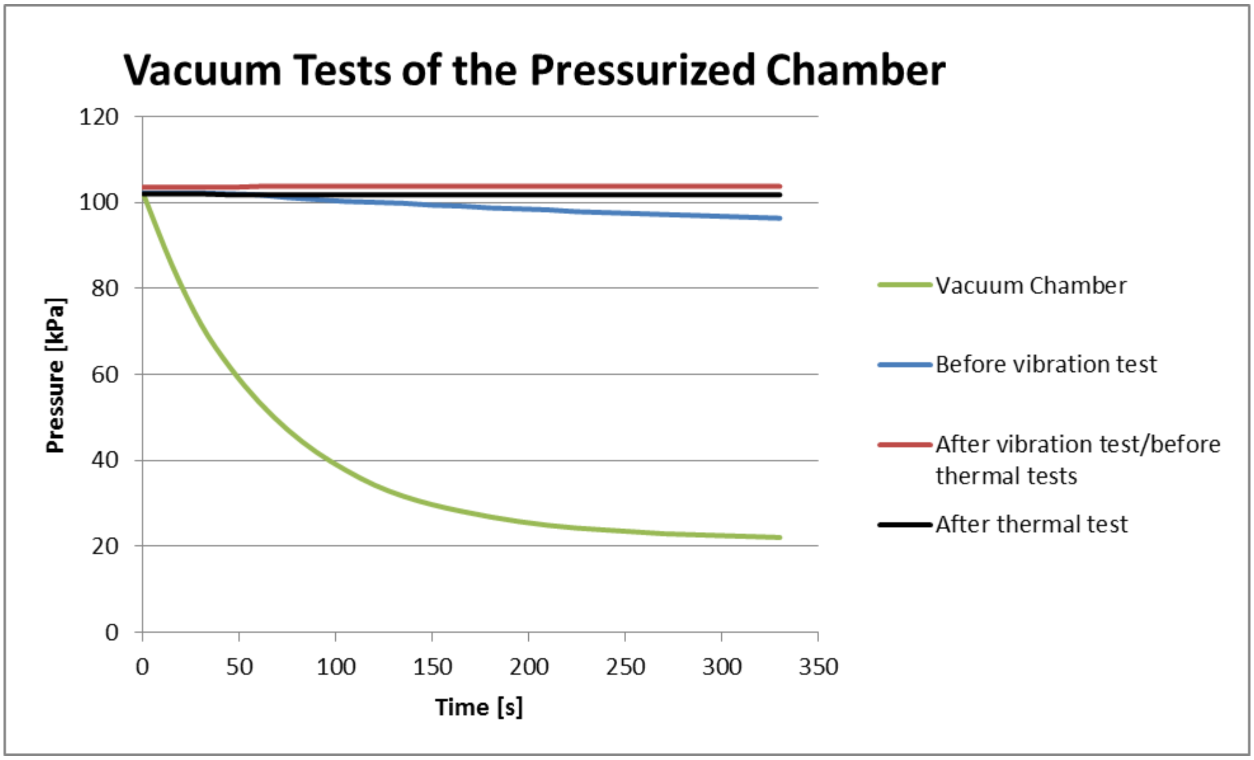
Test Procedure

The pressurized chamber will be put in the vacuum chamber and then be supervised and record the voltage of the pressure sensor. The experiment will run for ten minutes with a declining pressure in the vacuum chamber.

4. Test Log

There will be four tests:

1. Test how the pressure in the vacuum chamber changes over time
2. Test of the pressurized chamber before the vibration test
3. Test of the pressurized chamber after the vibration test and before the thermal test
4. Test of the pressurized chamber after the thermal test

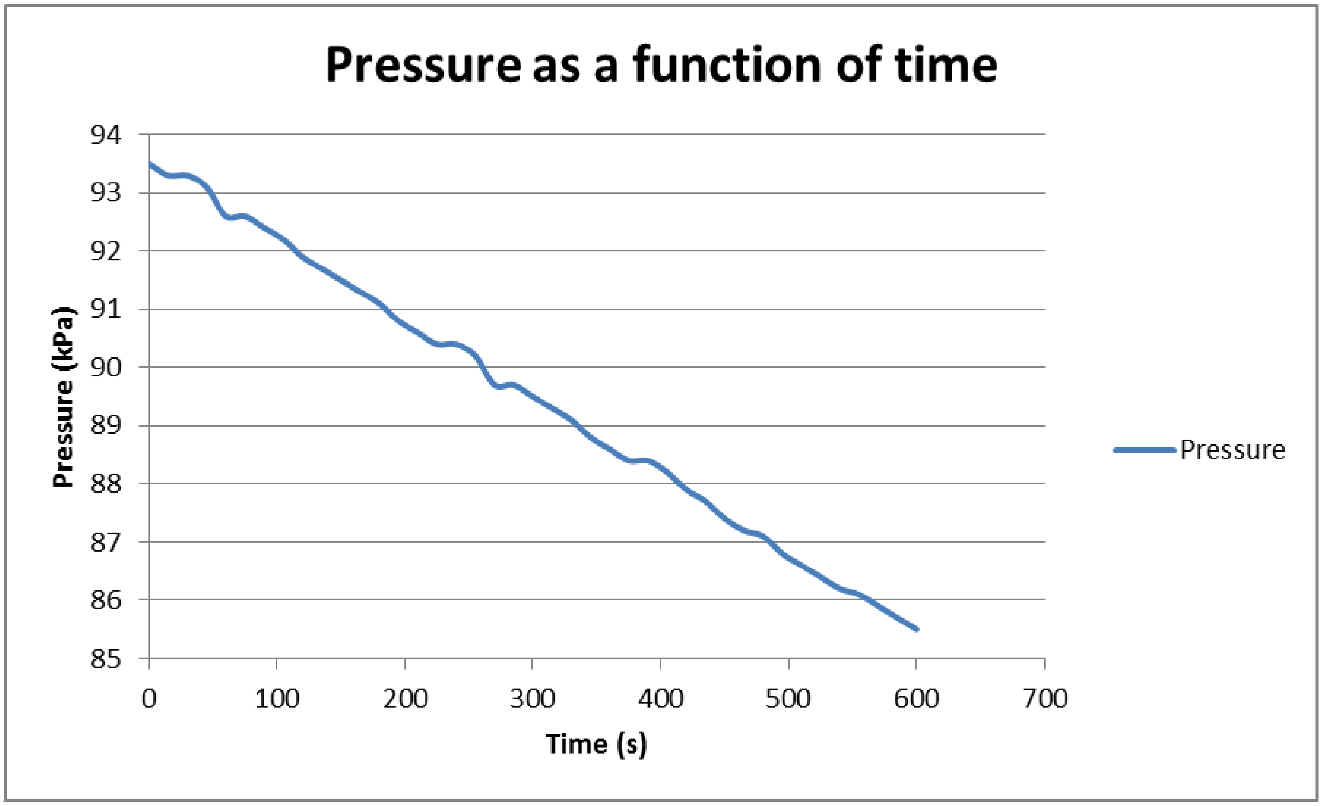


5. Test Incident Report

An issue occurred after the thermal test where the insulation at the base had started to be deformed and the insulation around the cable ends had loosed and therefore started to leak air. This was solved by applying new silicon adhesive at both the base and the cables and let it harden for two days.

6. Test Summary Report

The test after the vibration test showed an increase in performance of the pressurized chamber where it would hold the pressure even better. This is probably due to something in the insulation of the base that “settled” and stopped the leakage through it. Both the test after the vibration test and the thermal test showed no signs at all of leakage when testing for 10 minutes in the vacuum chamber. Another test will need to be done where the pressure of the vacuum chamber is even lower so it can represent the environment of that at 90 km above the earth.



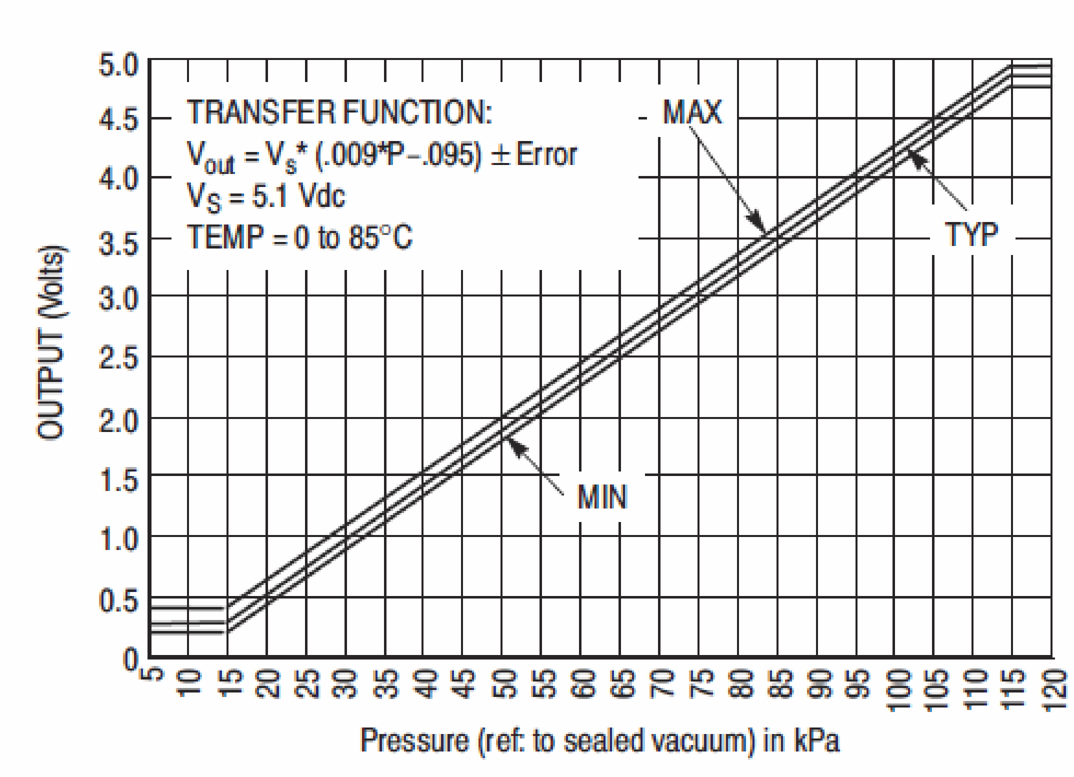


Figure 4. Output versus Absolute Pressure

Figure 1 -

Test Number	OST.5
Test Type	Weight
Test Facility	SRT
Tested Item	Entire experiment
Test Level/procedure and duration	Acceptance Measure the weight of the entire final experiment
Test campaign duration	1 day
Verifies	N.D.3, E.D.2
Pass/Fail	Pass

Test date: *2012-11-17*
Responsible for test and report: Maja Nylén
Participating in test: Maja Nylén

1. Test Plan

Objective
The entire final experiment weight needs to be recorded prior to flight.

Applicability
Always applicable for the fully assembled experiment.

Items to test
All parts of the experiment

Test configuration
Every part of the experiment is weighted separately and the result summed at the end for the total weight.

Test type
Weight.

Success criteria
When every component including screws and washers are present in a fully functional system.

2. Test Design Specification

Test Conditions
The test is performed in normal indoor conditions and always with the same scale.

3. Test Procedure Specification

Personnel
Maja measured the weight of every part separately and recorded the results.

Pre-test Activities
Every part of the experiment needs to be fully prepared and all assembly material needs to be collected.

Test Procedure
Every part of the experiment will be placed on the scale separately including all the assembly materials. The results will be recorded and later summed together to gain the total, final weight.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
15:00:00	Experiment start
15:01:00	Bulkhead (empty) : 1214.3 g
15:05:00	Battery housing: 593.5 g
15:20:00	Vacuum chamber: 875.0 g
15:22:00	D-SUB holder (empty): 29.3 g
15:30:00	Pressurized chamber: 886.4 g
15:35:00	Electronics box: 639 g
15:37:00	Protection cap: 18g (2 items=36g)
15:40:00	Rocket module: 3543 g (result from CAD-model)
15:42:00	Experiment stop
Results:	Entire experiment (excluding the rocket module+ protection cap): 4237g
	Entire experiment (including the rocket module+ protection cap): 7816 g

5. Test Incident Report

The scale showed different values for the battery housing but a correct placement of the protruding D-SUB wires resulted in the correct value.

6. Test Summary Report

The entire experiment (fully assembled) weighs 4.237 kg excluding the rocket module. The entire experiment including the rocket module (+ protection caps) weighs 7.816 kg.

Test Number	CPS.3
Test Type	Operational
Test Facility	IRF
Tested Item	Pressure sensors
Test Level/procedure and duration	Verification test. The sensors shall be placed in a pressure chamber for 30 min and verified to operate.
Test campaign duration	1 day
Verifies	E.F.4, E.P.4, E.P.5
Pass/Fail	Pass

Test date: *2012-11-08*
Responsible for test and report: Anneli Prenta
Participating in test: Anneli Prenta, Emil Vincent

1. Test Plan

Objective

The test is performed to verify that the pressure sensors are operational in the required pressure range.

Applicability

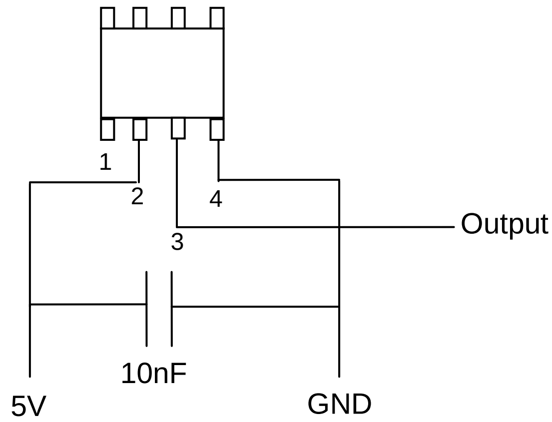
The results of this test is applicable for the pressure measurement part of the experiment

Items to test

Pressure sensors

Test configuration

The pressure sensors were connected on a breadboard in the configuration displayed in figure below. The breadboard was then placed inside a pressure chamber, connected to a power supply of 5V. A output voltage was measured using a multimeter.



Test type
Operational.

Success criteria
The test passes if the pressure sensor is verified to operate in the required range of 0.0005-1 bar.

2. Test Design Specification

Test Conditions
The test was performed under normal conditions with a temperature of 25°C.

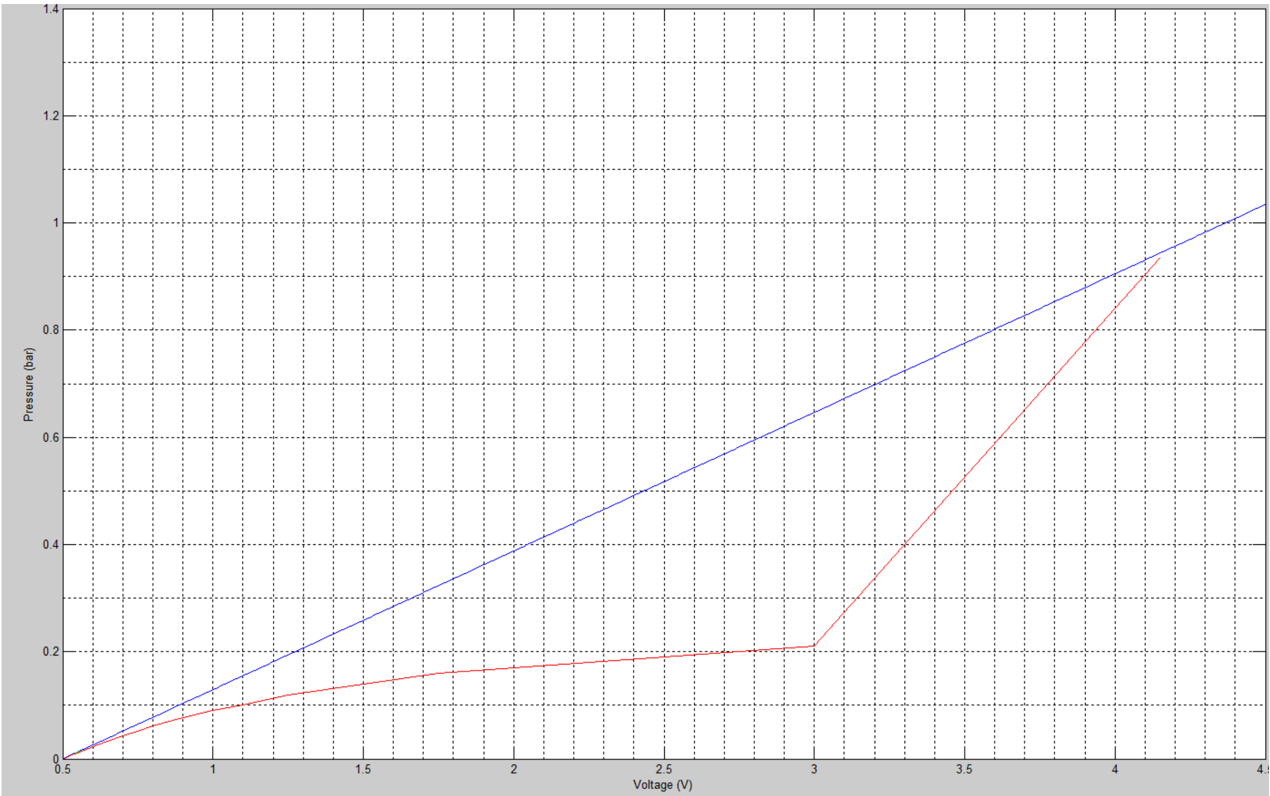
3. Test Procedure Specification

Personnel
Emil implemented the test items on a bread board. Anneli and Emil did the measurements and was both in charge of the documentation.

Pre-test Activities
Connection of components on a bread board.

Test Procedure
The pressure sensors were placed inside the chamber and connected to a 5V power supply. The chamber was sealed and depressurized and measurements were made during the depressurization. The internal pressure sensor in the chamber had a value of about 230mbar at the start of the test. This value should have been about 934mbar as was measured by another source, which resulted in a large error factor during the test-phase. Measurements of the pressure were obtained on predefined output voltage values using the internal sensor. The test was performed four times for a good comparison. The results were then plotted in MATLAB®

and are displayed below. The red line indicates three of the four performed tests. The blue line represents the actual linearity obtained from the data sheet for the sensor.



The deviation might be a result of faulty internal sensor of the pressure chamber. The sensors were although verified to operate without problem.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
14:34:06	Experiment start
14:34:10	Implementation of test items on bread board
14:50:27	Setup of test configuration in pressure chamber
15:05:04	The chamber was sealed and depressurization was started
15:10:39	Measurements of output voltage and internal pressure down to 0.5mbar
15:15:07	Test 2 start
15:20:13	Test 3 start
15:30:45	Test 4 start
15:40:32	Pressure chamber testing session ended
15:47:54	Results implemented in MATLAB® and plotted.

15:57:28	Experiment start

5. Test Incident Report

The internal pressure sensor was displaying faulty values at higher pressure which made it difficult to obtain a correct conclusion of the measurements.

6. Test Summary Report

The pressure sensors were operating as expected but a correct reference sensor is required to conclude the linearity of the sensor measurements.
The sensor was verified to operate within the required range which fulfills the test criteria so the test passes.

Test Number	CPS.4
Test Type	Operational
Test Facility	SRT
Tested Item	All electronics except batteries
Test Level/procedure and duration	Verification test. Test items shall be tested on a bread board to ensure that they withstand the expected current and voltage with a margin for 30 min. 8h.
Test campaign duration	1 day
Verifies	E.D.3
Pass/Fail	Pass

Test date: *2012-09-22*
Responsible for test and report: Jens Kanje Nordberg
Participating in test: Jens Kanje Nordberg, Björn Sjödahl, Anneli Prenta

1. Test Plan

Objective
The test is performed to verify that the electronics withstand the incoming current and voltage with a margin for 30 minutes.

Applicability
The results of this test is applicable for the entire electronic part of the experiment

Items to test
All electronics except batteries.

Test configuration
The test items were implemented on a bread board connected to a power supply.

Test type
Operational.

Success criteria
The test passes if all components withstand and is operational under the incoming current and voltage.

2. Test Design Specification

Test Conditions
The test was performed under normal conditions with a temperature of 25°C.

3. Test Procedure Specification

Personnel
Jens and Anneli implemented the test items on a bread board and were also in charge of the documentation. Björn did the measurements.

Pre-test Activities
Connection of components on a bread board.

Test Procedure
The circuit was connected to a power supplier for 30 minutes and the current and voltage was measured at the beginning and the end of the test using a multimeter.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	**Event**
13:04:38	Experiment start
13:04:38	Implementation of test items on bread board
14:10:27	Test of temperature sensor with successful result.
15:10:04	The circuit was supplied with 25V and 30mA.
15:10:39	Measurement of voltage over all components
15:45:16	Measurement of voltage over all components
15:46:13	Experiment Stop

5. Test Incident Report

No anomalies.

6. Test Summary Report

There were no unforeseen complications and everything worked as expected with a successful result.

Test Number	CPS.5
Test Type	Functional
Test Facility	SRT
Tested Item	All electronics
Test Level/procedure and duration	Verification test. The entire system shall be placed in the dedicated area and easy access for specific components shall be verified
Test campaign duration	1 day
Verifies	E.D.7
Pass/Fail	Pass

Test date: *2012-11-10*
Responsible for test and report: Emil Vincent
Participating in test: Björn Sjödahl, Jens Kanje Nordberg, Anneli Prenta, Emil Vincent

1. Test Plan

Objective

The test is performed to verify that the PCBs with all components, wires and connectors fits inside the electronics box. This test also results in a procedure for optimal assembly of the electronics inside the electronics box.

Applicability

The results of this test is applicable for the electronics box and the components inside it.

Items to test

Electronics box, all electronics inside the electronics box.

Test configuration

The main PCBs with all its components and wires and connectors mounted will be mounted inside the electronics box using the proper screws, washers and distances.

Test type

Functional

Success criteria

The test passes if all the electronics fits inside the electronics box and can be verified to operate after mounting..

2. Test Design Specification

Test Conditions

The test was performed under normal conditions with a temperature of 25°C.

3. Test Procedure Specification

Personnel

Emil was keeping the logbook during the test. Björn,Maja, Jens and Anneli were doing the assembly. Maja also wrote the procedure for assembling.

Pre-test Activities

None.

Test Procedure

No predetermined procedure is applicable for this test since one of the goals of the test is to develop such a procedure. Many different procedures were tested and the result can be viewed in procedure [G.M.11] Assembly of the electronics box, Appendix G.

4. Test Log

Time	**Event**
17:09:00	Test start
17:02:13	The PCBs were attached to eachother.
17:19:22	The DSUB15 connector was attached inside the electronics box.
17:20:27	The chamber connectors and wires were fed through the slits in the electronic box's sides.
17:22:18	The screws and washers were put in place, but the bottom distances were too small and were taken to a workshop to be drilled through.
17:25:04	Mounting of the battery connectors were attempted but failed
17:35:39	The chamber cables were fed back of the box and Upper and lower PCBs were disconnected from each other. The electronics box's rod was attached to the upper PCB.
17:54:21	The drilled bottom distances were put in place on the screws and the lower PCB was placed in the box.
18:01:13	Middle distances were too small as well and were taken to the workshop.
18:10:32	Everything was removed to test the procedure. D-SUB15->screws with washers->distances->lower PCB->distances->chamber connectors and wires.
18:15:15	Battery connector was too large to fit between PCB and box wall and was taken to the workshop for a small tweak.
18:20:54	Chamber connectors and wires, middle distances and lower PCB removed.
18:40:24	The battery connector was fitted.
18:45:02	Lower PCB fitted.
18:48:30	Middle screw secured at bottom with a lock nut.

18:52:04	Chamber wire and connectors fed through again.
18:57:50	Electronics box's rod was removed from the upper PCB and mounted inside the box.
19:03:39	The rod was removed again to be tweaked in the workshop.
19:30:32	Everything fitted, the assembly was completed.
19:40:27	Test run was started
19:54:00	Test run passed
20:02:02	End of test.

5. Test Incident Report

The distances did not fit due to the screws in this test had a slightly larger dimension than the ones used earlier.

6. Test Summary Report

The procedure was not as obvious as one could think. The limited amount of space makes this procedure challenging. However in the end we successfully completed the assembly and the test is passed.

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Test Number	CPS.6
Test Type	Operational
Test Facility	SRT
Tested Item	Resistance Wires
Test Level/procedure and duration	Verification Test
Test campaign duration	1 days
Verifies	E.P.7
Pass/Fail	Pass

Test date: *2012-04-23*
Responsible for test and report: Björn Sjödahl
Participating in test: Björn Sjödahl

1. Test Plan

Objective
To verify that the resistance wires can reach the specific temperature of 310 degrees centigrade and measure the voltage and current needed.

Applicability

Items to test
The resistance wires

Test configuration
A resistance wire of length 3 cm, attached in both ends to wires connected to a DC power supply. A wire thermometer was used to measure the temperature of the resistance wires.

Test type
Operational

Success criteria
If the resistance wires can reach the required temperature without breaking and with a reasonable current drawn, the test will pass.

2. Test Design Specification

Test Conditions
The test is performed in the electronics lab at SRT. Indoor conditions, with normal temperature, pressure and humidity.

3. Test Procedure Specification

Personnel
Björn built the test configuration operated the DC source and made the measurements.

Pre-test Activities
Build test configuration and require a wire thermometer.

Test Procedure
The wire thermometer shall be held against the resistance wire and the voltage from the DC source shall be varied until the correct temperature value is measured. At that point the needed amount of power shall be verified.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
15:00:00	Experiment start
15:01:00	DC power supply turned on
15:01:10	The voltage gradually increases
15:01:30	310 degrees centigrade is achieved, the display of the DC source showing 1.4V and 1.42A.
15:02:00	The temperature was brought up to 530 degrees centigrade to verify the durability of the resistance wire. The wire was very good.
15:05:00	The test was repeated with 2 and 3 wires in parallel with the result of adding 1.42A drawn for each added wire.
15:30:00	Experiment Stop

5. Test Incident Report

6. Test Summary Report

The result of the test is considered to be very good. The sustainability of the resistance wire was very good and it could be kept at a specific temperature with a reasonable amount of power.

Test Number	CPS.7
Test Type	Performance
Test Facility	SRT
Tested Item	Temperature sensors
Test Level/procedure and duration	Verification Test. Test 1: Test items shall be placed in a high temperature chamber and verified to a calibration sensor Test 2: Test items shall be placed in a low temperature chamber and verified to a calibration sensor
Test campaign duration	1 day
Verifies	E.F.3, E.P.2, E.P.3
Pass/Fail	Pass

Test date: *2012-09-18*
Responsible for test and report: Anneli Prenta
Participating in test: Anneli Prenta, Björn Sjödahl, Emil Vincent, Jens Kanje Nordberg

1. Test Plan

Objective

The test is performed to verify the performance requirements of the temperature sensors.

Applicability

The results of the test are applicable for the integration between the temperature sensors and microcontroller.

Items to test

KTY84-1 Temperature sensors.

Test configuration

The test item is assembled on a bread board and connected to a power supplier that is located outside the test area.

Test type

Performance.

Success criteria

The temperature sensor is compared to a reference sensor and a pass is defined by verification that the test item provides a temperature measurement within a given interval of +-3 degrees from the reference temperature.

2. Test Design Specification

Test Conditions
The test is performed at SRT in Kiruna under normal conditions.

3. Test Procedure Specification

Personnel
Björn was in charge of voltage and current measurements. Anneli and Jens were in charge of assembly and reference temperature measurements. Emil was in charge of recording all events during the test.

Pre-test Activities
The test item was assembled and pre-tested on a dedicated testing bread board. Reference temperatures were monitored before and during the test.

Test Procedure
Test 1: The test item will be placed in a high temperature chamber. The temperature will be set to five predefined levels; 70, 100, 125, 150 and 170 degrees centigrade. For each reference temperature, the voltage and current through the test item will be measured and recorded using multimeters. The resistance will then be calculated and compared to a temperature table where a value of the temperature will be obtained and recorded.
Test 2 will be performed in a similar way as Test 1, except in two separate low temperature chambers for two different reference values of 10 and -15 degrees centigrade respectively.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
17:10:45	Experiment start
17:10:45	Assembly of test circuit
17:21:10	
17:24:03	Ambient room temperature 625 Ohm @ 25C
17:25:12	The testcircuit was placed inside the chamber
	750 Ohm @70C

17:37:45	937 Ohm @100C
17:40:37	1114Ohm@125C
17:41:35	1254Ohm@150C
17:43:24	1359Ohm@170C
17:46:40	The test circuit was removed from the high temperature chamber
17:53:19	The temperature sensor was placed in the first low temperature chamber
17:57:13	The temperature inside the first low temperature chamber was measured to 10C
18:04:15	568Ohm@10C
18:08:20	The temperature sensor was removed from the first low temperature chamber
18:13:34	The temperature sensor was placed inside the second low temperature chamber
18:14:32	The temperature inside the second low temperature chamber was measured to –15C
18:17:48	447Ohm@-15C
18:19:04	The temperature sensor was removed from the second low temperature chamber
18:20:00	Experiment stop

5. Test Incident Report

During the test in the high temperature chamber, two cables began to smoke due to high temperature. The incident did not affect the test since the required temperature measurement had already been recorded and the test item could be removed without further problems.

6. Test Summary Report

The data sheet for the temperature sensor was studied throughout the test to verify that the values of the obtained resistances corresponded to a temperature inside the limit of +-3 degrees centigrade. The results lead to the conclusion that the temperature sensor behaved as anticipated.

Test Number	CPS.8
Test Type	Operational
Test Facility	SRT
Tested Item	Resistance wires
Test Level/procedure and duration	Verification test
Test campaign duration	1 day
Verifies	E.F.6
Pass/Fail	Pass

Test date: *2012-04-24*
Responsible for test and report: Björn Sjödahl
Participating in test: Björn Sjödahl

1. Test Plan

Objective
To make sure the resistance wires can be used to melt the solder samples.

Applicability

Items to test
Resistance wires, solder samples.

Test configuration
One resistance wire is connected by cables to a DC power source. The resistance wire is wired around a component leg with also 0.5 mm solder wired around it.

Test type
Operational

Success criteria
If the solder sample is melted and solidifies within reasonable time limits.

2. Test Design Specification

Test Conditions
The test was performed in the electronics lab at SRT. There was normal indoor conditions with normal temperature, pressure and humidity.

3. Test Procedure Specification

Personnel
Björn performed the test.

Pre-test Activities
Set up the test configuration and set the DC power supply to a predefined level which corresponds to a temperature of the resistance wires of 310 degrees centigrade.

Test Procedure
The DC power source will be turned on at a specific mark, then the solder process will be timed and observed. When the soldering is done, the DC supply will be switched of and the cooling phase will be timed.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	**Event**
16:30:00	Experiment start
16:31:00	DC power supply was switched on
16:31:11	The sample melted
16:31:13	The DC power supply was switched off
16:31:17	The solder sample was observed to be fully solidified.
16:32:00	4 more similar tests were performed to verify the results
16:50:00	Experiment Stop

5. Test Incident Report

6. Test Summary Report

The resistance wire was considered to very well be able to melt the solder samples. The time it took to melt the samples was also well within tolerated values.

Test Number	OBDH.1
Test Type	Verification
Test Facility	SRT
Tested Item	MCU
Test Level/procedure and duration	MCU 6h
Test campaign duration	2 days
Verifies	S.F.2, S.P.2, S.P.3, S.D.1
Pass/Fail	Conditional pass

Test date: *2012-08-20*
Responsible for test and report: Björn P, Hamoon, Robert
Participating in test: Björn P, Hamoon, Robert

1. Test Plan

Objective
To verify the basic functionality of the MCU, and making sure the MCU timeline complies with the actual timeline.

Applicability
-

Items to test
MCU, SD-Card

Test configuration
MCU and SD-Card, levelconverter

Test type
Verification

Success criteria
The test is considered a success if all the data is written to the SD card, all vital data is transmitted, the loop runs at 10Hz.

2. Test Design Specification

Test Conditions
Everything at room conditions.

3. Test Procedure Specification

Personnel
Björn – All tests through UART
Robert, Hamoon – All tests with LED lights.

Pre-test Activities
Connect through UART

Test Procedure
Breadboard, UART, LEDlights connected to experiment. Start SOLAR GROUND STATION. Start experiment, observe dat-

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	**Event**
Hh:mm:ss	Experiment start

	Experiment Stop

5. Test Incident Report

SD-Card has not yet been tested

6. Test Summary Report

All components behaved as expected but another test will be required to verify SD-Card.

Test Number	OBDH.1 complement
Test Type	Verification
Test Facility	SRT
Tested Item	MCU, SD-card
Test Level/procedure and duration	The system power shall be shut down several times for duration of more than 3 seconds. The system shall also be put into high stress and be forced to reboot at multiple occasions. The tests are run for a complete experiment run (according to the timeline).
Test campaign duration	3 days
Verifies	S.F.2, S.D.1
Pass/Fail	Pass

Test date: *2013-02-11*
Responsible for test and report: Hamoon, Robert
Participating in test: Hamoon, Robert

1. Test Plan

Objective
To verify the functionality of the SD-card emergency system, and making sure that it works for both power loss and system reboot.

Applicability
Emergency code in case of errors during launch.

Items to test
MCU, SD-Card

Test configuration
MCU, SD-Card and also with complete experiment equipment.

Test type
Verification

Success criteria
The test is considered a success if the stage information data, without any corruption, can be stored and read from the SD card after a power loss, system crash or forced reboot.

2. Test Design Specification

Test Conditions
Everything at room conditions.

3. Test Procedure Specification

Personnel
Robert, Hamoon – Tests with header board prototype

Pre-test Activities
Connect through UART

Test Procedure
Check all equipment and connections. Start SOLAR GROUND STATION. Start experiment, observe data, cut off power, turn back on and observe data. Verify by also reading SD card manually. Redo the procedure but with forced reboot and system overload (no watchdog timer reset).

4. Test Incident Report

No incidents.

5. Test Summary Report

All components behaved as expected and the SD-card emergency system is now verified working.

Test Number	OBDH.2
Test Type	Verification
Test Facility	SRT
Tested Item	UART
Test Level/procedure and duration	Networking, 6 hours
Test campaign duration	2 days
Verifies	S.F.3
Pass/Fail	Pass

Test date: *2012-09-28*
Responsible for test and report: Robert, Björn, Hamoon
Participating in test: Robert, Björn, Hamoon

1. Test Plan

Objective
To verify UART and cheking the data passed to verify a minimum of CRC errors occur and if they do handle them correctly.

Applicability
This test can be done at anytime aslong as a SOLAR GROUND STATION is available and connected to the experiment.

Items to test
UART and CRC

Test configuration
This test can be done at anytime aslong as a SOLAR GROUND STATION is available and connected to the experiment through a level converter (MAX232).

Test type
Verification

Success criteria
The test is a success when the the experiment is completed and all vital messages are recieved.

2. Test Design Specification

Test Conditions
Hot and cold environments tested. Normal humidity and 1 atm pressure.

3. Test Procedure Specification

Personnel

Björn – Hot and cold testing, data integrity check
Robert, Hamoon – Integration test with full experiment

Pre-test Activities

Build a level converter, get a computer

Test Procedure

Connect the experiment to SOLAR GROUND STATION throughg the level converter. Start the SOLAR GROUND STATION. Start the experiment. Watch for CRC errors reported by SOLAR GROUND STATION and observe that all the stages execute as expected and experiment data is recieved.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event

	Experiment Stop

5. Test Incident Report

Some CRC erros were encountered, and 1 of them in a vital message, we did not recieve one of the stage change messages.

6. Test Summary Report

Overall UART worked well and as intended, and we have rectified the problems with the vital message we did not recieve. We did another identical test after where no problems were encountered.

Test Number	OBDH.3
Test Type	Functional
Test Facility	SRT
Tested Item	Sensors, ADC Software
Test Level/procedure and duration	Verification, 8h
Test campaign duration	3 days
Verifies	S.F.3, S.F.5, S.P.4, S.P.5, S.P.7, S.P.8
Pass/Fail	Pass

Test date: *2012-10-02*
Responsible for test and report: Robert, Björn P, Hamoon
Participating in test: Robert, Björn P, Hamoon

1. Test Plan

Objective
To verify the sensors are working and is compatible with the MCU.

Applicability
-

Items to test
Sensors

Test configuration
Sensors connected in a circuit with the MCU. UART is used to see the values on the SGS. A multimeter is used to see the voltage value directly in the circuit.

Test type
Verification

Success criteria
The test is considered a success if the values of the sensors are shown on the SGS and they comply with the values calculated/measured with a multimeter directly in the circuit.

2. Test Design Specification

Test Conditions
Everything at room conditions.

3. Test Procedure Specification

Personnel
Robert, Hamoon - Tested the ADC with the circuit.
Björn - Verified the SGS showed the correct values.

Pre-test Activities
Build the circuit according to the Electronic's drawings.

Test Procedure
A full run through of the experiment will be preformed where the values constantly are sent to the SGS for verification.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
Hh:mm:ss	Experiment start

	Experiment Stop

5. Test Incident Report

-

6. Test Summary Report

All sensors gave the correct results.

Test Number	OBDH.4
Test Type	Functional
Test Facility	SRT
Tested Item	MCU, ECS
Test Level/procedure and duration	Verification, 8h
Test campaign duration	3 days
Verifies	S.O.1, S.O.2
Pass/Fail	Pass

Test date: *2013-02-05*
Responsible for test and report: Robert, Hamoon
Participating in test: Robert, Hamoon

1. Test Plan

Objective
To verify the MCU is able to operate autonomously.

Applicability
-

Items to test
MCU; Watchdog timer, restart system

Test configuration
The whole of the experiment put together

Test type
Verification

Success criteria
The test is considered a success if the experiment is running the entire procedure from startup to shutdown. It should also be able to handle power loss by restarting at the same point it was interrupted as well as restart the system when entering the infinite loop.

2. Test Design Specification

Test Conditions
Everything at room conditions.

3. Test Procedure Specification

Personnel
Robert, Hamoon - Tested the MCU.

Pre-test Activities
Assemble the experiment.

Test Procedure
A full run through of the experiment will be preformed. In addition, a couple of intentional failures are implemented such as power loss and an infinite loop to see that the MCU are able to handle those.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
Hh:mm:ss	Experiment start

	Experiment Stop

5. Test Incident Report

-

6. Test Summary Report

Everything worked as intended.

Test Number	SGS.1
Test Type	Performance
Test Facility	Computer lab
Tested Item	Ground station
Test Level/procedure and duration	Connect to experiment and run, 1 day
Test campaign duration	1 day
Verifies	S.F.1, S.P.1, S.D.2
Pass/Fail	Pass

Test date: *2013-04-13*
Responsible for test and report: Björn Paulström
Participating in test: Björn Paulström, Robert Lindberg, Hamoon Shabazi

1. Test Plan

Objective
For verification of SGS that it works well with the experiment.

Applicability
Can be done as soon as there is working hardware to connect to the SGS

Items to test
SGS and UART communication is tested.

Test configuration
Solar experiment and a computer.

Test type
Performance.

Success criteria
If the experiment does a complete run through without any issues it is deemed a success. All data received must have been saved, and communication has worked without any problems.

2. Test Design Specification

Test Conditions
Test is performed in a computer lab, at indoor conditions.

3. Test Procedure Specification

Personnel

Björn did the complete runthrough with the experiment.

Pre-test Activities

Connect the experiment to the computer.

Test Procedure

Connect the experiment to the computer. Power on the experiment. Arm and de-arm the experiment. Clear and reset AVR and SD card. Arm experiment. Give LO signal. Check that the data between SD card matches received data.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	**Event**
00:00:00	Experiment start
00:01:00	ARM, DE-ARM, CLEAR, RESET, ARM, LO
00:10:00	Check SD card data
00:12:00	Experiment end

5. Test Incident Report

No incidents.

6. Test Summary Report

All systems behaved as expected and no problems were encountered.

Test Number	PDS1
Test Type	Operational
Test Facility	SRT
Tested Item	Power distribution system
Test Level/procedure and duration	Verification test. The PDS shall be connected on a bread board and measurements of current and voltage shall be made for all subsystems. 5h.
Test campaign duration	1 day
Verifies	E.F.7
Pass/Fail	Pass

Test date: *2012-09-05*
Responsible for test and report: Emil Vincent
Participating in test: Emil Vincent, Björn Sjödahl, Jens Kanje Nordberg

1. Test Plan

Objective

The test was done to verify the functionality and corrent operation of the power distribution system, to make sure all components got the power they required and that the circuit works.

Applicability

Where, what, when is the test applicable

Items to test

Power distribution system, DC/DC converters TSR-2450 and TSR-2433, and passive components.

Test configuration

The power distribution circuit set up on a breadboard, connected to a power supply.

Test type

Operational

Success criteria

The test is successful if the circuit delivers the correct power. Measurements are done over test loads.

2. Test Design Specification

Test Conditions
This test is held at SRT space campus Kiruna in the "Viking" room. The ambient temperature is 21°C and the pressure and humidity is at normal conditions.

3. Test Procedure Specification

Personnel
Emil Vincent wrote test log, Björn Sjödahl and Jens Kanje Nordberg set up test and did measurements.

Pre-test Activities
Set up the circuit on breadboard.

Test Procedure
First the system schematics was looked at, and the set up of the circuit on the breadboard was done. Then points of measurement and analysis was agreed upon, and finally test start.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	**Event**
11:04:02	Experiment start
11:04:02	Test circuit assembly started
11:21:59	Power supply was switched on at 7 V
11:22:22	Voltage measured at the 5V and 3.3V nodes, and was confirmed
11:23:25	Power supply voltage increased to 28 V
11:23:40	Voltage measured at the 5V and 3.3V nodes, and was confirmed
11:23:50	Power supply switched off
11:24:36	A multimeter was connected to the circuit at the 3V3 node
11:24:54	Current was measured at the 3V3 V Node 20mA through the 15 Ohm load.
11:25:55	Power off
11:26:19	A mm at 5v
11:28:36	Current through 680 ohm load at 5v measured to 7.2mA
11:30:36	Experiment Stop

	Experiment Stop

5. Test Incident Report

There were no incidents, test went ahead as planned and worked as expected.

6. Test Summary Report

The components used was the DC/DC converters TSR-2450 and TSR-2433, which worked perfectly. Other components used were only resistors and capacitors needed, which worked as well.

The TSR-2450 converted a voltage of 28V to 5V as expected.
The TSR-2433 converted a voltage of 5V to 3.3V as expected.

Test Number	PDS.2
Test Type	Functional
Test Facility	SRT
Tested Item	Battery pack
Test Level/procedure and duration	Verification test
Test campaign duration	2 days
Verifies	E.D.9
Pass/Fail	Pass

Test date: *2012-09-19*
Responsible for test and report: Björn Sjödahl
Participating in test: Björn Sjödahl

1. Test Plan

Objective
To make sure the charging of the battery pack works properly, and that it reaches a certain level of voltage after being discharged completely.

Applicability

Items to test
Battery pack

Test configuration
Discharging by connecting the battery pack to resistance wires during long time. Charging by connecting the pack to a charging circuit, powered by a DC source.

Test type
Functional

Success criteria
Being able to reach a voltage level of 3.6V and keep that level up during powering a load, after first being completely discharged.

2. Test Design Specification

Test Conditions
Performed at the project lab Viking at SRT. Normal indoor conditions with normal temperature, pressure and humidity.

3. Test Procedure Specification

Personnel
Björn performed the discharging, charging and post-test of the pack.

Pre-test Activities
Preparing resistance wires for easy discharging, and build a charging circuit for charging.

Test Procedure
The battery pack will be almost completely discharged using resistance wires, then the pack will be connected to the charging circuit powered by a DC source for slow charging of 16 hours. Then the pack will be tested with the resistance wires while measuring the voltage of the pack to make sure the charging is adequate.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
14:00:00	Experiment start
14:01:00	The discharging of the pack begins
14:45:00	The pack is regarded to be completely discharged.
18:00:00	The battery pack is connected to the charging circuit, being charged with a current of 0.1C ,that is approximately 400mA, and left over night.
Next day	
10:05:00	The charging is unplugged.
10:10:00	The battery pack is connected to the resistance wires, the initial voltage measured is 3.572 and slowly discharging.
10:12:00	Experiment Stop

5. Test Incident Report

6. Test Summary Report

The battery pack behaved as expected and reached the set voltage limit. The fact that the voltage level in the battery pack dropped slowly while being connected to a load at the end indicated that the pack was indeed fully charged.

Test Number	PDS.3
Test Type	Performance
Test Facility	SRT
Tested Item	Battery pack
Test Level/procedure and duration	Verification test
Test campaign duration	1 day
Verifies	E.F.8, E.P.9
Pass/Fail	Pass

Test date: *2012-08--29*
Responsible for test and report: Björn Sjödahl
Participating in test: Björn Sjödahl

1. Test Plan

Objective
To make sure the battery packs can power the resistance wires, and that the means of downscaling works.

Applicability

Items to test
Battery pack

Test configuration
The battery pack will be connected to number of downscaling power resistors in parallel and after that 3 resistance wires will be connected. A wire thermometer will be used to measure the temperature of the resistance wires.

Test type
Performance

Success criteria
By reaching the required temperature of the resistance wires, and keep that up for long enough time with a very good safety margin.

2. Test Design Specification

Test Conditions
The test was performed at the project lab Viking at SRT. There was indoor condition with normal temperature, pressure and humidity.

3. Test Procedure Specification

Personnel
Björn performed the test.

Pre-test Activities
Calculating and connecting a number of power resistors on breadboard.

Test Procedure
The battery pack will be connected to a number of power resistors that will downscale the voltage to the resistance wires. A wire thermometer will be used to make sure the required temperature is reached and kept.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
13:00:00	Experiment start
13:01:00	The battery pack was connected
13:01:15	The wires read a temperature approximately 310 degrees centigrade (it varies a little bit up and down)
13:03:00	The required temperature still holds. Voltage over the battery pack is measured to make sure that the voltage does not drop to fast. The measurements show that the voltage drops slowly.
13:03:30	Disconnecting the battery pack
13:05:00	The test is performed a number of times
13:20:00	The same test being performed but with all 6 resistance wires in parallel.
13:21:00	It is noticed that the temperature only reaches about 200 degrees centigrade, regardless of how the downscaling is varied.
13:25:00	The test is performed a number of times
13:45:00	Experiment Stop

5. Test Incident Report

The battery pack should be able to power all 6 resistance wires. When connected without any downscaling the temperature of all 6 wires reach a temperature of well above 400. But when even the smallest downscaling is being connected, we get weird results that we are unable to explain. After numerous testing we still could not get the downscaling right.
Besides the voltage drop in the battery pack when all 6 wires was connected was uncomfortable large.

6. Test Summary Report

The battery pack was able to power 3 resistance wires in parallel with very good margins and with our means of downscaling working well. The problems with trying to power all 6 wires on one pack leads us to the decision to use two packs in the experiment, one for each chamber. This will also give us more safety because it will take a lot more discharging before the battery packs are unable to conduct the experiment.

Test Number	PDS. 4
Test Type	Operational
Test Facility	SRT
Tested Item	Safety switches IPU039NL03
Test Level/procedure and duration	Verification Test. The safety system shall be connected on a breadboard and verified to shut down on request from the microcontroller. 10h.
Test campaign duration	2 days
Verifies	E.F.9, E.P.10
Pass/Fail	Pass

Test date: *2012-09-18*
Responsible for test and report: Jens Kanje Nordberg
Participating in test: Jens Kanje Nordberg, Björn Sjödahl

1. Test Plan

Objective
The test is done to determine wether the switches will work and switch on/off with a signal from the microcontroller, as expected.

Applicability
Where, what, when is the test applicable

Items to test
Safety switches IPU039NL03, passive components, microcontroller

Test configuration
The safety switches, microcontroller and additional passive components were set up on breadboard and connected to power supply of 5V. The batteries and resistance wires were connected as well, and a thermometer was set to the resistance wires to measure the temperature, to see if they heated up as expected.

Test type
Operational

Success criteria
If the switches switched the battery power on to the resistance wires, and thus heating the wires, the test passes.

2. Test Design Specification

Test Conditions

The test was performed at SRT, Kiruna, in the “Viking” classroom. The temperature was at 21 degrees Celsius, with normal pressure and humidity conditions.

3. Test Procedure Specification

Personnel

Björn Sjödahl assembled the circuit, Jens Kanje Nordberg did measurements and notes. Hamoon Shahbazi programmed the microcontroller.

Pre-test Activities

Assembly of circuit, program microcontroller to switch on and off (for test, at a 5 second interval).

Test Procedure

The circuit will be assembled on a breadboard, with switches, microcontroller and passive components, and connected to the battery circuit. A power supply of 5V will power the microcontroller. The microcontroller will switch the signal on and off at a 5 second interval, and the temperature of the resistance wires will be measured, to check if the wires gets power, i.e. if the switches switch on and off.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
13:30:00	Experiment start
13:30:00	Assembly of circuit
13:35:00	Start of test.
13:35:05	Resistance wires heating (switches switched on)
13:35:10	Resistance wires cooling (switches switched off)
13:35:15	Resistance wires heating (switches switched on)
13:35:20	Resistance wires cooling (switches switched off)
13:35:30	Experiment end

	Experiment Stop

5. Test Incident Report

Nothing unexpected happened during the test.

6. Test Summary Report

The test worked perfectly, the switches switched on and off at the 5 second interval the microcontroller was programmed to, and the resistance wires got power during 5 seconds, then cooled off (i.e. no more power supplied).

Test Number	PDS.5
Test Type	Operational
Test Facility	SRT
Tested Item	Charging Circuit
Test Level/procedure and duration	Verification test. The battery pack shall be connected to a breadboard and be verified to switch on and off as requested. 10h.
Test campaign duration	2 days
Verifies	E.O.1
Pass/Fail	Pass

Test date: *2012-09-14*
Responsible for test and report: Emil Vincent
Participating in test: Björn Sjödahl, Jens Kanje Nordberg, Emil Vincent

1. Test Plan

Objective
The objective of this test is to verify that the switching of the batteries is working as intended.

Applicability
Where, what, when is the test applicable

Items to test
Charging circuit, switches IPU039NL03, and passive components.

Test configuration
A battery pack is connected to a breadboard with the switches and a test load. +5V is then applied to the switch to simulate a signal from the Microcontroller.

Test type
Operational

Success criteria
The test will pass if the switches break the circuit when switched off, and if the circuit is complete when the switch is switched on.

2. Test Design Specification

Test Conditions
This test is held at SRT space campus Kiruna in the "Viking" room. The ambient temperature is 21°C and the pressure and humidity is at normal conditions.

3. Test Procedure Specification

Personnel
Emil Vincent: Documentation
Jens Kanje Nordberg: Measurements
Björn Sjödahl: Test assembly

Pre-test Activities
Circuit set up on breadboard, battery connected to the breadboard. Power suplly connected to switches, to simulate signal from microcontroller.

Test Procedure
A battery pack will be connected to a breadboard together with a test load and the switch. A DC power supply and a 10k Ohm resistor will then be used to simulate the signal from the microcontroller (Fig 1).

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
17:13:40	Test start
17:17:56	Voltage Readings before simulated signal is applied. The circuit was confirmed to be broken.
17:23:40	Simulated signal is applied
17:24:30	Voltage was measured across the load, and the circuit was still broken
17:30:00	The different grounds in the circuit (the battery ground and the "microcontroller" ground) was connected.
17:35:00	Voltage was applied to switches, and circuit was confirmed as functional.
17:36:30	Voltage was switched off, and switches closed the circuit.
17:45:00	Test circuit confirmed as working on a condition: the different grounds must the connected to each other. This was not as planned, but should not cause any problems. A voltage of 2.5 V was enough for the switches to switch on.
18:16:40	Test End

5. Test Incident Report

During the test it was found that the switches only work as needed when the ground from the batteries and the one from the RXSM are connected to each other.

6. Test Summary Report

Switches IPU039NL03 was tested, and found to be working on the condition that the battery ground and the RXSM ground be both connected to each other. This is not what was planned, and though it is not likely to cause any problems, it was an unforeseen complication.
With this condition, the switches was confirmed to be working, and switched on when supplied by a signal current of 5V (we also discovered that we only needed about 2.5 V) from the microcontroller, and switched off when the signal broke.

Test Number	PDS.6
Test Type	Operational
Test Facility	SRT
Tested Item	Power circuits
Test Level/procedure and duration	Verification Test The power circuit shall be connected on a breadboard where input and output voltage will be measured and verified. 10h.
Test campaign duration	2 days
Verifies	E.P.8
Pass/Fail	Pass

Test date: *2012-09-15*
Responsible for test and report: Emil Vincent
Participating in test: Emil Vincent, Jens Kanje Nordberg and Björn Sjödahl

1. Test Plan

Objective
The objective of this test is to verify that the power circuit and its components is preforming as intended.

Applicability
Where, what, when is the test applicable

Items to test
DC/DC converters, power distribution system and other passive components

Test configuration
The power distribution system was connected to a breadboard with a power supply and test loads.

Test type
Verification test

Success criteria
This test is passed if the expected values are measured across the test load.

2. Test Design Specification

Test Conditions

This test is held at SRT space campus Kiruna in the “Viking” room. The ambient temperature is 21°C and the pressure and humidity is at normal conditions

3. Test Procedure Specification

Personnel

Emil Vincent: Documentation
Jens Kanje Nordberg: Measurements
Björn Sjödahl: Test assembly

Pre-test Activities

Assembly of test circuit

Test Procedure

The whole circuit will be connected to a breadboard. Then voltage measurements will be done at a supply voltage of 7V and 28V respectively. Then current will be measured in the test load. All measurements are done using multimeters.

4. Test Log

Each step of the test procedure and any noteworthy results or incidents should be recorded on the test log.

Time	Event
10:20:35	Experiment start
10:28:17	Assembly of test circuit was assembled
10:31:02	Power supply was switched on at 7 V
10:31:10	Voltage was measured across the test load to 5V
10:31:20	Power supply voltage was increased to 28 V
10:31:25	Voltage was measured across the test load to 5V. Shortly afterwards one of the capacitors broke
10:43:40	Reassembly of the test circuit
10:46:10	Power supply switched on 7 V
10:46:50	Voltage was measured across the test load to 5V
10:47:11	Power supply voltage increased to 28 V
10:47:19	Voltage was measured across the test load to 5V
10:48:13	Power supply turned of
10:52:17	A multimeter were connected to the test circuit
10:55:52	The current through the load was measured to 7.2mA at 5 V
10:57:02	Test ended

5. Test Incident Report

During testing at 28 V one of the capacitors burned, apparently we used a capacitor rated for lower voltages. The power was cut and the capacitor replaced and then the test resumed without further incidents.

6. Test Summary Report

This test is considered successful and we now know to trust our components and design to supply the voltages intended.

APPENDIX I

Result

SOLDERING ALLOYS IN REDUCED GRAVITY

SOLAR

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ABSTRACT

Large funding is required each year for maintaining the International Space Station (ISS) due to need for replacement of components. The cost of this maintenance could be reduced by repairing equipment on site. However, the current method of soldering joints in reduced gravity generates defective connections of components, thus making the repairs insufficient in outer space. The main problem is to solder metals in reduced gravity without obtaining an increase of void fractions, which are inherent due to the lack of buoyant forces on flux and gases. Earlier tests done by NASA, in reduced gravity alone, show an increased amount of void fraction by up to three times as compared to solder created in normal earth gravity. The proposed solution for soldering in reduced gravity is to work in a low pressure environment which enables minimization of void fractions. In vacuum a repairing sequence can be simulated similar to the setting at the ISS but with a reduced pressure. This was tested in an experiment, which was able to melt three samples in vacuum environment and three samples in pressurized environment. To ensure accurate data the solder joints were melted and cooled while in milligravity. This was carried out as the REXUS experiment SOLAR (Soldering Alloys in reduced gravity) in cooperation with several space agencies throughout Europe. The SOLAR experiment was launched with a sounding rocket from Esrange Space Centre, Kiruna (Sweden) in May 2013. After the flight the samples have been analysed at the Kemi-Tornio University of Applied Sciences in Finland by using an Xray scanner to inspect the void fractions in two dimensions. The result of the reduced gravity soldering have been compared to the similar studies done in the SoRGE and CLEAR projects by NASA, and to the samples created in the pressurized environment of the SOLAR experiment. Suggestions on how to obtain improved soldering joints in space are given based on the final test results.

Introduction

Human space missions is a challenging task where there is a never ending demand for lower mass and volume solutions. However it's critical for the the mission that there are backup systems and backup instruments which can be used in case of failure. Currently (Jul-2013) astronauts on board the ISS rely on either replacing malfunctioning units altogether or living without them as the crews ability for in situ repairs is limited. After the unit is removed it is returned back to Earth for inspection and reparation[1]. In order to improve the efficiency of mass and volume, rather than replacing an instrument or using multiple systems for redundancy, the instrument can be repaired using backup components. The component that is the source of failure can then be removed and a new component can be soldered onto the same circuit board. In order to do so a soldering procedure suitable for space has to be set up in order to assure space qualified solder joints.

Previous NASA projects SoRGE and CLEAR were conducted on board parabolic flights and the ISS to research low gravity effect on solder joints. The result indicated an increase of voids in solder joint produced in reduced gravity [1] [2]. The voids are produced by a chemical reaction when the flux in the alloy is heated producing oxygen[1]. Other sources such as water vapour from the printed circuit board is also a possible suppliant of of voids.

Voids can also be found in most solder joints created in the standard gravitational pull at ground level on Earth. In order to diminish the voids in the solder joints, vacuum soldering has been used for decades to produce high quality joints for special high demanding applications. The vacuum provides a pressure difference between the voids within the solder and the outside environment which ultimately allows the gas bubbles in the solder to escape giving a uniform density of the alloy.

As vacuum soldering can be used for reducing the number of voids on Earth it is also an interesting aspect to investigate for reduced gravity soldering in order to improve the solder joints enough for space applications. This could resolve the issues experienced in the SoRGE and CLEAR projects.

[1]Soldering in a Reduced Gravity Environment (SoRGE) - John W. Easton, National Center for Space ExplorationResearch

[2]Component-Level Electronic-Assembly Repair (CLEAR) System Architecture - Richard C. Oeftering, Martin A. Bradish, Jeffrey R. Juergens, Michael J. Lewis, and Daniel R. Vrnak Glenn Research Center, Cleveland, Ohio

Experimental Set-up

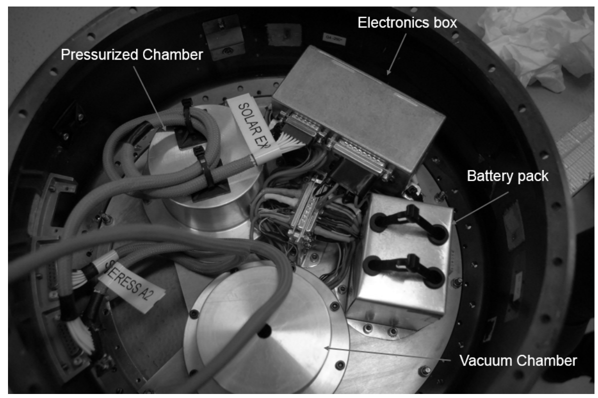

Figure 1: Experimental set-up

To investigate the effect of vacuum on solder joints produced in milligravity an experiment was set up which could be flown on a sounding rocket where the soldering procedure would take less than 30 seconds and in which the samples should be melted and hardened. In order to see whether the result is improved in comparison to specimens produced in a pressurized environment, two sets of samples were produced at the same time where the difference could then be investigated. To compare the result with the result from vacuum soldering on Earth the experiment was run under normal Earth gravity at ground level.

Table 1: Sample environment set-up of the four test scenarios

Test scenario	**Pressure** (Bar)
1G Pressurized	1
1G Vacuum	5μ
Low-gravity Pressurized	1
Low-gravity Vacuum	10μ

As the experiment had to be fully autonomous due to the lack of an uplink from the ground station, the melting process was calibrated in advance and carried out by a timer counting from lift off. This was controlled by the electronic circuits shown in Figure 1. In addition the two chambers where the samples are created can be seen. The vacuum chamber has a venting hole in it to allow for a quick transition from pressurized to vacuum environment as the rocket rapidly gains height. The pressurized chamber was sealed using an between the connection between the hat and the base of the chamber. Silicon adhesive was used to seal the feed through of the cables. All electronics and sensors were powered by the service module of the REXUS rocket. However, the resistance wires used for melting the samples were powered by an internal battery pack to accommodate for the large power consumption during the melting phase. Throughout the whole flight the system was recording the temperatures in the chambers and of the resistance wires. In addition pressure sensors were used to monitor the pressure in the vacuum and pressurized chamber. For an overview of the set-up within the experimental chambers please refer to Fig 2. The samples are prepared such that soldering wire is wrapped around a component pin carried out according to a predetermined procedure. The resistance wire is then wrapped around the component pin and soldering wire. Finally the resistance wire is connected to the battery pack through switches controlled by the on board data handling unit. The samples are numbered from one to three where three is closest to the feed through of the cables.

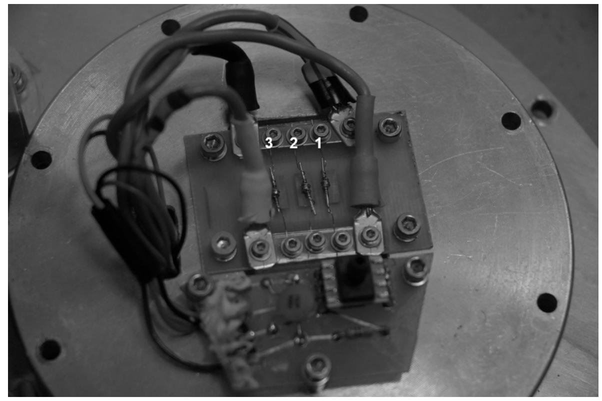

Figure 2: Close up of samples, post flight

Result

Retrieving the samples post flight, the specimens were subjected to a visual inspection which confirmed that none of the samples were damaged at impact and that all the solder had been melted in flight. They were then taken to the Kemi-Tornio University of Applied Science to be analysed with microscope and X-ray scans. Microscopic images were only taken for sample 2 in each test scenario. The resulting images can be seen in Fig 3

To investigate the voids X-ray scans were done individually for each of the twelve samples. The internal images produced could then be used to estimate the void population.

In order to calculate the void fraction in each specimen the software ImageJ was used to determine for each pixel if it belongs to a void or not. This is then compared to the total area of the void which finally yields an estimate of the void to solder ratio. The result from this can be seen in Tab 2.

Table 2: Void to solder ratio

Sample ID	**1**	**2**	**3**	Average
1G, 1 Bar	3.2%	2.4%	0.9%	2.2%
1G, 5μ Bar	3.6%	0%	0.3%	1.3%
mG, 1 Bar	0.9%	4.6%	0.2%	1.9%
mG, 10μ Bar	16.4%	4.8%	11.9%	11.0%

Discussion

As the data in Tab 2 shows, there is a significantly increased void to solder ratio when, in reduced gravity, soldering is applied in vacuum compared to the test scenario in a pressurized environment. This is the opposite of what was expected. Results of the two reference test scenarios at normal gravity were on average similar to each other and to the results from low-gravity in pressurized environment. The variations in the void to solder ratio between the different samples were quite large, so that it remains unclear if any of these three test

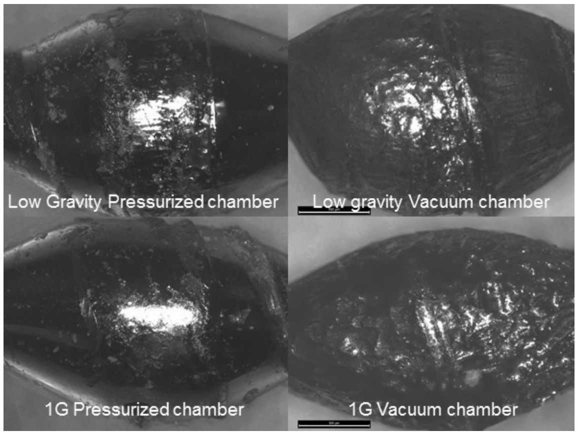

Figure 3: Microscope images of selected samples

scenarios performed better. However, the test scenario with normal gravity in vacuum seems to have produced slightly better solder joints, as expected. The cause of the unexpectedly low quality of solder joints in reduced gravity and vacuum is still not completely understood. One possible reason may be related to the lack of gas around the solder and missing interactions between the liquid lead and the gas in a pressurized environment. At ground level the external force is achieved by gravitation causing the bubbles to be pressed out by buoyancy.

Furthermore the the cooling process of the solder joint proves difficult in a vacuum environment due to lack of convection between the air and the soldering lead. This can be seen in Figure 3 where the solder joints produced in pressure have a smooth shiny surface with a nice wetting angle while the vacuum samples are rough and have a tendency of balling. To control the cooling a gas flow could be implemented into the system where the gas would not only cool the samples but also create an internal flux which could potentially reduce the number of voids.

Qualifying the solder joints for space applications with respect to the void fraction proves difficult as the ECSS documentation lack clear directions for the maximum allowed void population. However judging from the current ECSS documentation the samples produced in pressurized environment in millgravity can be considered acceptable[3].

Conclusion

The vacuum environment produces the best and worst soldering joints in terms of voids count. Combining vacuum with low gravity clearly produces the largest population of voids where normal gravity combined with vacuum causes the lowest void fraction. When the solder joints were produced in a pressurized environment the gravitation had little to no influence. Due to the low sampling statistics of three samples no conclusions could be drawn if the low-gravity environment produces better or worse solder joints.

Further Studies

As mentioned in the "Discussion" section a future project aimed at investigating the effect of a gas flow around the melted solder joints is a relevant subject which could possibly further increase the quality of solder joints in space. It would also give a chance to replicate the result of SOLAR using a soldering technique closer related to a practical and applicable soldering procedure for space use.
Furthermore new studies should be conducted looking at pressures between atmospheric and vacuum environment where a critical pressure could be determined giving the maximum quality of the solder joints.

[3] ECSS Secretariat ESA-ESTEC Requirements & Standards Division Noordwijk, The Netherlands

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References

[1] - Soldering in a Reduced Gravity Environment (SoRGE) - John W. Easton, National Center for Space ExplorationResearch.

[2] - Component-Level Electronic-Assembly Repair (CLEAR) System Architecture - Richard C. Oeftering, Martin A. Bradish, Jeffrey R. Juergens, Michael J. Lewis, and Daniel R. Vrnak Glenn Research Center, Cleveland, Ohio

[3] - ECSS Secretariat ESA-ESTEC Requirements & Standards Division Noordwijk, The Netherlands