SED

Student Experiment Documentation

Document ID: RX14_CERESS_SEDv2.1_31Jul12.doc

Mission: REXUS 13/14

Team Name: CERESS

Experiment Title:

CERESS (Compatible and Extendable REXUS Experiment Support Bus)

Team	Name	University
Student Team Leader:	Daniel Bugger	TU München
Team Members:	Sebastian Althapp	TU München
	Christoph Friedl	TU München
	Alexander Schmitt	TU München

Version:	Issue Date:	Document Type:	Valid from:
3.0	**14 December 2012**	**SED**	**14 October 2012**

Issued by:

D. Bugger

Approved by:

D. Bugger, S. Althapp, C.Friedl, A.Schmitt

Change Record

Version	Date	Changed chapters	Remarks
0	2012-01-12	New Version	Blank Book 2010
1	2012-02-13	all	PDR
1.01	2012-02-14	Header, 6.2, 6.3, 7	
1.02 – 1.11	2012-05-25	1, 3.5, 4.7, 4.10.2, 5.1, 6.2, 4.6, 4.9, Appendix C	Updated
1.12	2012-06-07	All	Updated, Rearranged
1.13	2012-06-09	8,9	Added Chapter 8, Shifted old Chapter 8 to Chapter 9
2.0	2012-11-06	All, Appendix A-D	CDR
2.01	2012-31-07	All, 4.10	Added Chapter 4.10, reduced amount of Abbreviations
2.1	2012-31-07	2, 4.21, 4.22, 4.4, 4.5, 5, 6.14	CDR Comments worked
3.0	2012-10-09	3.1, 4.8.1, 4.8.3, 4.8.4 inserted,4.8.7, 4.1.1.8, 4.5, 4.1.2.7 updated, 4.1.1.3, 4.1.1.6, removed	Added 4.84, shifted following chapters
3.1	2012-12-13	4.2.1, 4.4, 4.5	Updates due to design changes

ABSTRACT:

The analysis of previous REXUS projects at the Institute for Astronautics at TU Munich has shown that an entire infrastructure had to be designed and built for every new experiment. The requirements of these experiment infrastructures are in general very similar; Including a regulated power supply, onboard data handling, command and control of the experiment, real-time communication as well as interfacing the REXUS systems on the rocket and on ground. Besides these basic functions many teams wish to have a real-time visualization of the flight.

The main goal of the CERESS project is the development of a standard platform providing the most important functionalities, allowing future teams at TUM to concentrate more on their scientific objectives. Once verified on the first flight, all used hardware (e.g. Sensors) can be directly applied to future experiments. After recovery the onboard stored data, the telemetry data from CERESS and from REXUS are merged into one data file for distribution, analysis and outreach.

In addition to acceleration, angular rate, temperature and pressure sensors, a camera documents the progression of the experiment. Monitoring and control software on the ground enables a thorough surveillance of the experiment during the entire mission. Functions like remote control of the experiment, sensor- or time- based actions are provided. A visualization tool illustrates the rocket's trajectory in a 3D simulation in near real-time and as post flight replay. This complements the "CERESS" project with a widely requested feature that allows the general public to access the fascination of REXUS experiments.

Keywords: REXUS, SED - Student Experiment Documentation, CERESS, Compatible and Extendable REXUS Experiment Support Bus

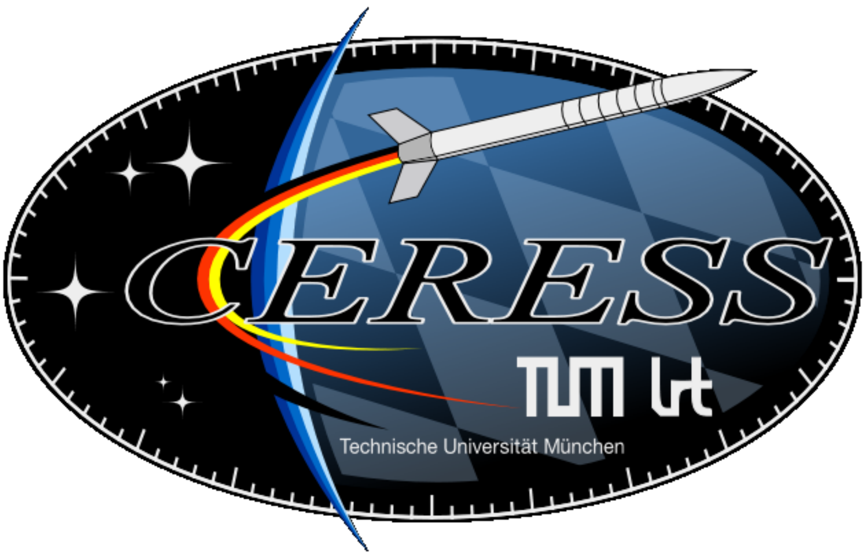


Figure 1: CERESS Mission Patch

CONTENTS

List of illustrations

List of tables

1 INTRODUCTION

1.1 Scientific/Technical Background

Teams participating in the REXUS program are facing similar challenges in order to perform their experiment: Power supply, on board data handling and telemetry are examples for tasks to be taken care of to perform the actual experiment.

Talking to former REXUS team members at LRT, namely T-REX (RX03), VERTICAL (RX04), VECTOR (RX08) and FOCUS (RX10) identified a profound interest in a platform providing the tasks mentioned. This allows teams to focus more on the scientific experiment itself. The lack of data concerning the experiment flight environment and the documentation of disturbing influences on milli-gravity was mentioned as well by previous Teams. Providing these values allows a more detailed design of the experiment and a more profound analysis of the experiments data.

The CERESS project aims to provide both: A support infrastructure, including a power supply, hard- and software for OBDH and Command and Control as well as flight environment characterisation tasks, using a variety of sensors, e.g. accelerometers, gyroscopes, vibration-, temperature- and pressure sensors. Another goal is to enhance the teams' situational awareness during the mission by providing a near real-time visualisation of the rocket's flight.

The acronym CERESS is meant to catch the universal design approach of the CERESS Project as "Compatible and Extendable REXUS Experiment Support Bus"

1.2 Experiment Objectives

The primary objectives have to be archived in order to consider the experiment. Any additional objectives are secondary objectives.

Primary objectives of CERESS:

- Develop an REXUS Experiment Support Bus for future TUM REXUS teams, consisting of a space- and a ground module
- Functional verification of the system at its first flight

Secondary objectives of CERESS:

- Intuitive data visualization for situational awareness and universal outreach purposes
- Characterization of the experiments' flight environment
- Distribution of collected data to interested parties
- Flight verification of often used key components which are not part of the in-flight functional verification.

1.3 Experiment Overview

The CERESS System consists of the following major subsystems:

The space segment is defined as the CERESS Rocket Module which performs the typical infrastructure tasks and the CERESS Verification Module which is used to verify the functionality of CERESS. The CERESS Verification Module is replaced by the scientific experiment in later missions.

The ground segment consists of the CERESS Ground Module, the Visualization Tool (ViTo) and the Service Computer.

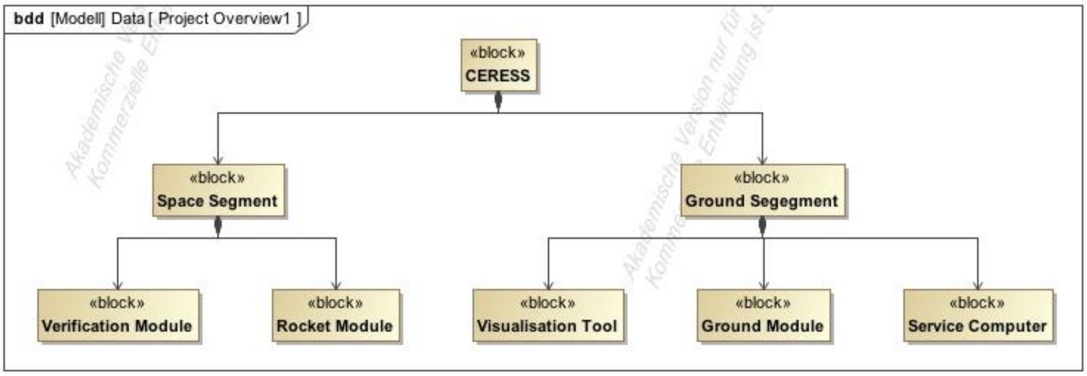


Figure 2: CERESS System Overview

1.3.1 CERESS Rocket Module

The CERESS Rocket Module retrieves data from included sensors and those of the attached CERESS Verification Module. The CERESS Rocket Module stores and processes the data on board and communicates with the CERESS Ground Module, by which it is can be controlled. Furthermore it provides regulated power to the CERESS Verification Module and is capable to invoke actions on the CERESS Verification Module. The CERESS Rocket Module is designed for reusability in future experiments and is the key component of the CERESS Space Segment.

1.3.2 CERESS Verification Module

The CERESS Verification Module contains melting wires as simple actuators, which are used to verify the different control chain provided by CERESS. A variety of sensors is used to characterize the experiment's flight-environment. The sensors include temperature, pressure and a camera. The arrangement of the sensors and their purposes are explained in chapter 4. The CERESS Verification Module is replaced by the actual experiment in future REXUS missions from TU Munich.

1.3.3 CERESS Ground Module

The CERESS Ground Module consists of desktop computers running custom software. It interacts with the space segment via Telemetry and Telecommand in order to communicate with the CERESS Rocket Module. Furthermore it merges the data from the CERESS Rocket Module and the REXUS telemetry stream. Position and measurement data is processed at the CSGM and forwarded via Internet to multiple end-user clients running the 3D flight visualization tool (ViTo). The Internet connection from the CERESS Ground Module to the Internet is governed by the ESRANGE Internet access.

1.3.4 Visualization Tool (ViTo)

The ViTo displays the position and orientation of the CERESS Rocket Module and therefore the altitude and attitude of the REXUS rocket in near real-time during flight and as replay in post-flight. Furthermore, data from the CERESS Rocket Module and CERESS Verification Module sensors can be displayed. During the flight the ViTo receives data from the CERESS Ground Module via Internet. In post-flight the needed data is obtained by processed data of the on-board data storage.

1.3.5 Service Computer

The Service Computer is needed for programming and maintaining the CERESS Rocket Module's Main Computation Unit (MCU) during development, testing, after integration and launch preparation.

1.4 Team Details

1.4.1 Contact Point

Address:	CERESS (Rexus) % Claas Olthoff
	Technische Universität München
	Lehrstuhl für Raumfahrttechnik
	Boltzmannstraße 15
	85748 Garching, Germany
Email:	team.ceress@googlemail.com
Phone:	+49 176 23585826 (Team Leader)

1.4.2 Team Members

The team consists of students from the TU München studying aerospace engineering. The project is not part of any university course.

Daniel Bugger

12th Semester Aerospace Engineering (Dipl. Ing.) at TU Munich

Functions:

- Project Leader
- Project Coordination
- Mechanical Design
- Data Processing
- Outreach

Experience:

- Internship at Amir Kabir University / Tehran / Iran
- “Microsat Engineering” at TU Delft/Netherlands
- Working with a Thermal-vacuum test chamber at LRT

Sebastian Althapp

5rd Semester Aerospace Engineering (B.Sc.) at TU Munich

Functions:

- Ground Segment
- Visualization
- Outreach

Experience:

- Former tutor for microcontroller programming at the "Begabtenförderung Physik, GE-Hennef" (scholarship for gifted in physics)
- Member of the WARR (Scientific Workgroup for Rocketry and Spaceflight)
- 2^{nd} .place at the national competition "Jugend Forscht" (Youth Researches) with the paper: "Entwicklung und Erforschung eines Hybridraketentriebwerks" (Development and study of a Hybrid Rocket Engine)
- Fraunhofer-Talent-School for Micro-Mecha-tronics
- Internship at DLR Cologne

Christoph Friedl

11th Semester Aerospace Engineering (Dipl. Ing.) at TU Munich

Functions:

- Electrical Design
- Data Processing
- Outreach

Experience:

- CubeSat Workshop at LRT
- Internship at EADS, Division Cassidian Air Systems

	**Alexander Schmitt** ***11th Semester Aerospace Engineering (Dipl. Ing.) at TU Munich*** *Functions:* • On-Board Data Handling • Outreach • Minute Taker Experience: • Tutor for practical courses in the programming languages C/C++ at institute for information technologies of TU Munich • Seminar “Team formation and group leading” (Teambildung und Gruppenleitung) at ITQ • TUTOR (soft skill program) at TU Munich • Second Place in the engineering competition “CAR-toffel” at TU Munich • Internship at EADS, Division Cassidian Air Systems

Table 1: CERESS Team Members

2 EXPERIMENT REQUIREMENTS

2.1 Requirements CERESS Rocket Module

1	Req. Rocket Module	
1.1	Req. Electrical	
1.1.1	[Functional] Provide Power	The system shall provide regulated electrical power.
1.1.1.1	[Performance] Power to Meltingwires	The Power Supply shall provide the power to melt the wires
1.1.1.2	Deleted	Deleted
1.1.1.3	Deleted	Deleted
1.1.1.4	Deleted	Deleted
1.1.1.5	[Design] SM to EPS	The electrical power system shall accept unregulated power from the REXUS SM
1.1.1.6	[Performance] Perf. provided power	The electrical power system shall be able to provide 30W of power.
1.1.3	[Design] Receive Power from RXSM	The Rocket Module shall use the power provided by the RXSM
1.1.3.1	[Performance] 28V DC Input	The electrical power supply shall accept input voltages of 28V DC
1.1.3.2	[Performance] 3A DC Peak Input	The power supply shall accept Peak currents of 3 Amps
1.1.3.3	[Performance] 1A DC current Input	The power supply shall accept 1A continuous current
1.1.4	Deleted	Deleted
1.1.4.1	[Performance] max feed back	The experiment must make provisions to limit voltage ripple fed back to the RXSM over the power line to a maximum of 500 mV. (p. 37)
1.2	Req. Sensors	
1.2.1	[Functional] Acceleration	The system shall measure acceleration in all 3 axes.
1.2.1.1	[Performance] Acc.Range	The acceleration sensor shall cover the range from 10mg (µg flight state) to 25g
1.2.1.2	[Performance] Acc. Accuracy	The acceleration sensor shall have an accuracy of 10mg (µg flight state).
1.2.1.3	[Performance] Acc. measurement frequency	The acceleration sensor shall take 1000 measurements every second.
1.2.2	[Design] withstand rocket environment	All Sensors shall withstand the environment condition within a REXUS launch campaign.
1.2.2.1	[Design] withstand Thermal loads	The sensors shall withstand the thermal load cases

1	Req. Rocket Module	
1.2.2.2	[Design] withstand acceleration loads	The sensors shall withstand the acceleration load cases
1.2.2.3	[Design] withstand pressure. loads	The sensor shall withstand the pressure load cases
1.2.3	[Functional] Angular Rate	The system shall measure angular rate in all 3 axis
1.2.3.1	[Performance] AR Range	The angular rate sensor shall be able to measure up to 5Hz
1.2.3.2	[Performance] AR Accuracy	The angular rate sensor shall have an accuracy of 10mHz.
1.2.3.3	[Performance] AR measurement frequency	The angular rate sensor shall take 1000 measurements every second.
1.2.4	[Functional] Ambient pressure	The system shall measure the ambient pressure
1.2.4.1	[Performance] Amb. pres. range	The ambient pressure sensor shall cover the range from 0mbar to 1013mbar
1.2.4.2	[Performance] Amb. pres. accuracy	The ambient pressure sensor shall be able to measure pressure with an accuracy of +/-1mbar
1.2.4.3	[Performance] Amb. pres. measurement frequency	The ambient pressure sensor shall make 1 pressure measurement every second.
1.2.5	[Functional] Internal Temperature	The system shall measure the temperature inside the inside the CSRM
1.2.5.1	[Performance] Int. Temp Range	The internal temperature sensor shall be able to measure temperatures between -40 and 200°C
1.2.5.2	[Performance] Int. Temp Accuracy	The internal temperature sensor shall be able to measure temperatures with an accuracy of +/- 1°C
1.2.5.3	[Performance] Int. Temp measurement frequency	The internal temperature sensor shall make 1 temperature measurement every second.
1.3	Req. Software	
1.3.1	[Functional] Data from int. Sensors	The rocket module shall retrieve data from intern sensors
1.3.10	[Functional] Perform Operations	The rocket module shall be capable to perform operations on the verification experiment
1.3.11	[Operational] Execute commands	The rocket module shall be capable to execute received commands
1.3.2	[Functional] Data from CSVM Sensors	The rocket module shall retrieve data from verification module sensors

1	**Req. Rocket Module**	
1.3.3	[Functional] Store sensor data	The rocket module shall store retrieved data from sensors
1.3.3.1	[Performance] Data save rate	The rocket module shall store the retrieved data from the sensors with 1000Hz
1.3.4	[Functional] Interpret received data	The rocket module shall be capable to interpret the received data
1.3.8	[Design] Self-test	The rocket module shall be capable to be self-tested
1.3.8.1	[Design] Malfunction detection	The rocket module shall be capable to detect malfunctions
1.3.8.2	[Design] Counteractive measures	The rocket module shall be capable to perform counteractive measures if an malfunction is detected
1.3.9	[Operational] Radio Silence	The CSRM shall accept a request for radio silence at any time while on the launch pad
1.4	**Req. COMS**	
1.4.1	[Functional] Receive ground data	The rocket module shall be capable to receive information from the ground module through the whole flight of the rocket.
1.4.1.1	[Performance] Specs receive data	The rocket module shall meet the transmission specs of the Service Module for receiving data
1.4.2	[Functional] Sent data to ground	The rocket module shall send information to the ground module through the whole flight of the rocket
1.4.2.1	[Design] Specs send data	The rocket module shall meet the transmission specs of the Service Module for sending data
1.5	**Design Requirements**	
1.5.1	[Design] Withstand vibrations	The mechanical and electrical components shall withstand the vibration loads during nominal operation of the rocket
1.5.2	[Design] Withstand shock	The mechanical and electrical components shall withstand the shock loads during launch of the rocket
1.5.3	[Design] Withstand acceleration	The mechanical and electrical components shall withstand the acceleration loads during nominal operation of the rocket
1.5.4	[Design] Withstand	The mechanical and electrical

1	Req. Rocket Module	
	pressure	components shall withstand the pressure loads during nominal operation of the rocket
1.5.5	[Design] Withstand temperature	The mechanical and electrical components shall withstand the thermal loads during nominal operation of the rocket
1.5.7	[Design] Temperature durability	The temperature of the experiment box shall be kept between -40°C and 30°C
1.6	Req. Topology	
1.6.2	[Design] Fit in Box	The Rocket Module shall fit in a standard REXUS-Module (max_height = 85mm)
1.6.3	[Design] Plug on Hatch	The hatch shall provide a plug for programming and Checking
1.7	Req. Processing Unit	
1.7.1	Deleted	-
1.7.2	[Design] Connection to Gyros	
1.7.3	[Design] Connection to Verification Module	
1.7.4	[Functional] Processing speed	The Processing Unit shall be capable to perform the logging actions within near-real-time
1.8	Req. Structural	
1.8.1	[Design] Position of CoG	Maximum: X ± 20 mm Y ± 20 mm Z ± 20 mm
1.8.2	[Design] Moment of Inertia	Maximum: Ix ± 0.1 kg·m2 Iy ± 0.1 kg·m2 Iz ± 0.1 kg·m2
1.8.3	[Design] Total Mass	Shall not deviate more than +-0.5kg
1.8.4	[Design] Mass distribution	Around 0.25kg per 100mm

Table 2: CERESS Rocket Module Requirements

2.2 Requirements CERESS Verification Module

2	Req. Verification Module	
2.1	[Functional] Sensors	
2.1.1	[Functional] Temperature	The system shall measure the temperatures inside the VE
2.1.1.1	[Performance] Temp range	The temperature sensor shall be able to measure temperatures between -40 and 200°C
2.1.1.2	[Performance] Temp accuracy	The internal temperature sensor shall be able to measure temperatures with an accuracy of +/- 1°C
2.1.1.3	[Performance] Temp measurement frequency	The internal temperature sensor shall make 1 temperature measurement every
2.1.2	Deleted	-
2.1.2.1	Deleted	-
2.1.2.2	Deleted	-
2.2	[Functional] Video	The system shall record a video of the flight (resp. of VE)
2.2.1	[Performance] Video frame rate	The video camera shall have a frame rate between 25fps and 50fps.
2.2.2	[Performance] Video resolution	The video camera shall have a resolution of fullHD 1920x1080px.
2.3	[Operational] Actions	The Verification Module shall show that an Action triggered by the rocket module is performed

Table 3: CERESS Verification Module Requirements

2.3 Requirements CERESS Ground Module

3	Req. Ground Module	
3.1	Data Handling GM	
3.1.1	[Functional] Data from live link	The Ground Module shall receive telemetry data from the ESRANGE ground networks
3.1.2	[Functional] Data from CSRM	The Ground Module shall receive data from the CSRM via the REXUS downlink
3.1.2.1	[Functional] Save received data	The Ground Module shall store the received data stream
3.1.2.2	[Functional] Decode received data	The Ground Module shall decode the received data streams into the usable data sets
3.1.3	[Functional] Data to CSRM	The Ground Module shall send data to the CSRM via the REXUS uplink
3.1.3.1	[Functional] Store send data	The Ground Module shall store the received data stream
3.1.3.2	[Functional] Code data for sending	The Ground Module shall code the data, that is to be sent, into the send data stream
3.1.4	[Functional] Process data near-real-time	The Ground Module shall be able to process down linked data from the CSRM in near-real-time
3.1.5	[Functional] Process data post flight	The Ground Module shall be able to process stored data of the CSRM in post flight
3.1.6	[Functional] Condition data for visualization	The Ground Module shall condition the data for visualisation
3.1.6.1	[Functional] Merge conditioned data	The Ground Module shall merge all conditioned data into a single file
3.1.6.2	[Functional] update frequently the data	The Ground Module shall update the data frequently
3.1.6.3	[Functional] Distribute data near-real-time	The Ground Module shall provide access to the conditioned data via the Internet during flight
3.1.7	[Functional] Distribute data post flight	The Ground Module shall provide access to the conditioned data post flight
3.1.8	[Operational] Interface for sending control data	The Ground Module shall provide a interface to send control data to the CSRM
3.1.9	[Functional] Handle loss of	The tool shall be capable to handle

3	Req. Ground Module	
	contact	a lost contact to the data stream
3.2	General Req. GM	
3.2.1	[Operational] Operational during flight	The Ground Module shall be operational during all flight phases of the rocket module
3.2.2	[Operational] Operational during countdown	The Ground Module shall be operational during the countdown phase
3.2.3	[Operational] Detecting Malfunctions	The Ground Module shall be capable of detecting malfunctions
3.2.4	[Operational] Display GM status	The Ground Module shall display the GM status
3.2.5	[Operational] Display CSRM status	The Ground Module shall display the CSRM status

Table 4: CERESS Ground Module Requirements

2.4 Requirements Visualization Tool

4	Requirements Visualization Tool	
4.1	Display during flight	The VT shall display data during flight
4.1.2	Display REXUS Rocket trajectory	The VT shall display the trajectory of the REXUS Rocket
4.1.3	Data refresh frequency	The data shall be updated once per second
4.1.4	use GM data	The VT shall use the data from the GM via the internet
4.2	Display during post flight	The VT shall display CERESS data during post flight
4.2.1	Display REXUS Rocket trajectory	The VT shall display the trjectory of the REXUS Rocket
4.2.3	Display CSRM data	The VT shall display the data collected by the CSRM in post flight

Table 5: CERESS Visualization Tool Requirements

2.5 Requirement satisfaction

The CERESS system and subsystems are designed to fulfill the Requirements. The system components are therefore validated against the above requirements-tables.

3 PROJECT PLANNING

The CERESS team consists of four aerospace engineering students from the Technical University of Munich (TUM). The organization is divided into five different groups: Project Coordination, Mechanical Design, Electrical Design, Software Development and Ground Support. The responsible person of each part is shown in Table 6: Working field mapping. Because of the small team size, the hierarchy is flat with strong interactions between all fields of activities.

Task	Responsible person
Project coordination	Daniel Bugger
Software Design	Alexander Schmitt
Electrical Design	Christoph Friedl
Mechanical Design	Daniel Bugger
Ground Segment	Sebastian Althapp

Table 6: Working field mapping

3.1 Project plan: Long term

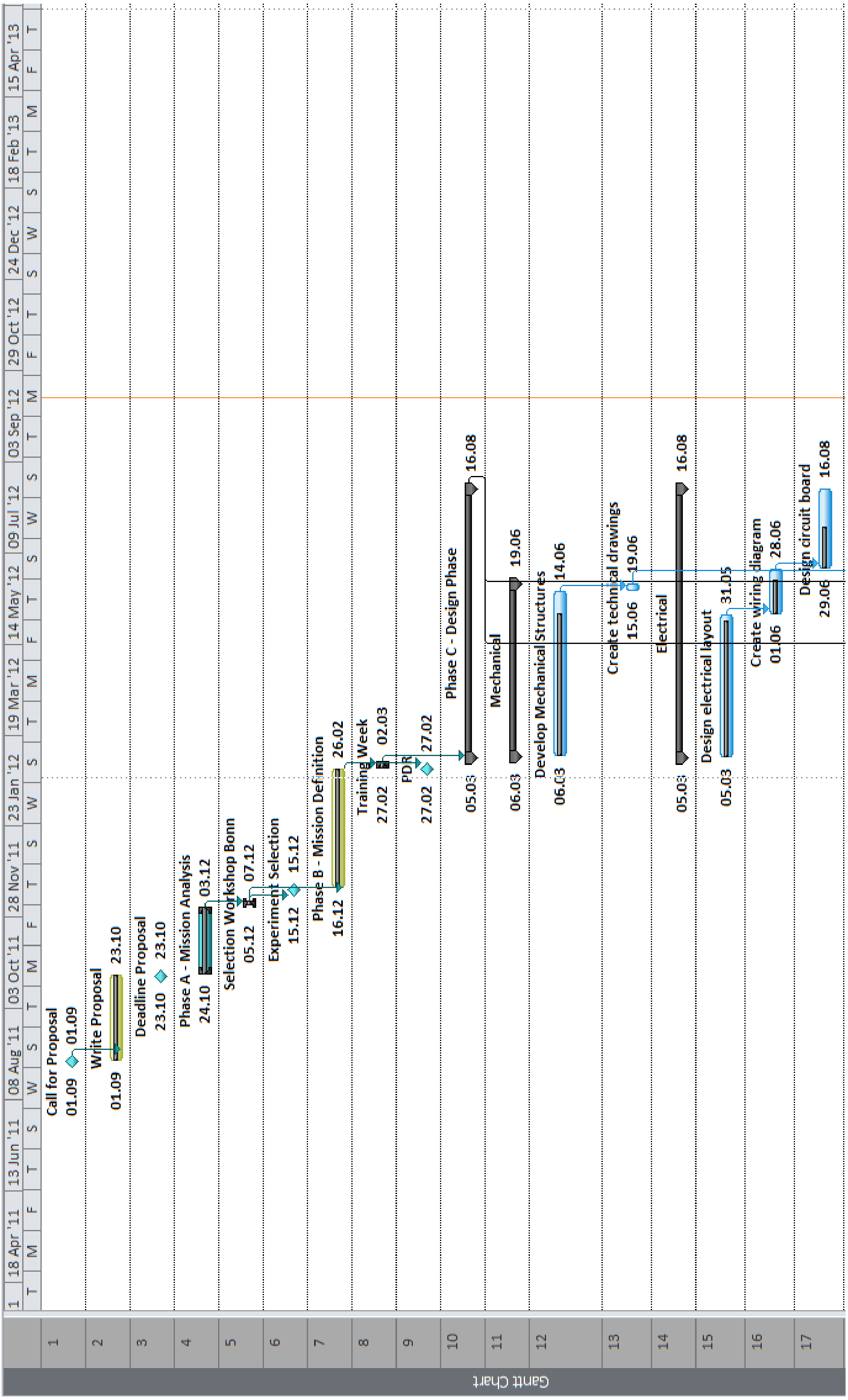
The long term planning is done with the “MS Project” software. In Table 7 : Project Plan the main phases and development steps are shown. For better time understanding the same data is shown in Figure 3: Gantt Chart in a Gantt-chart.

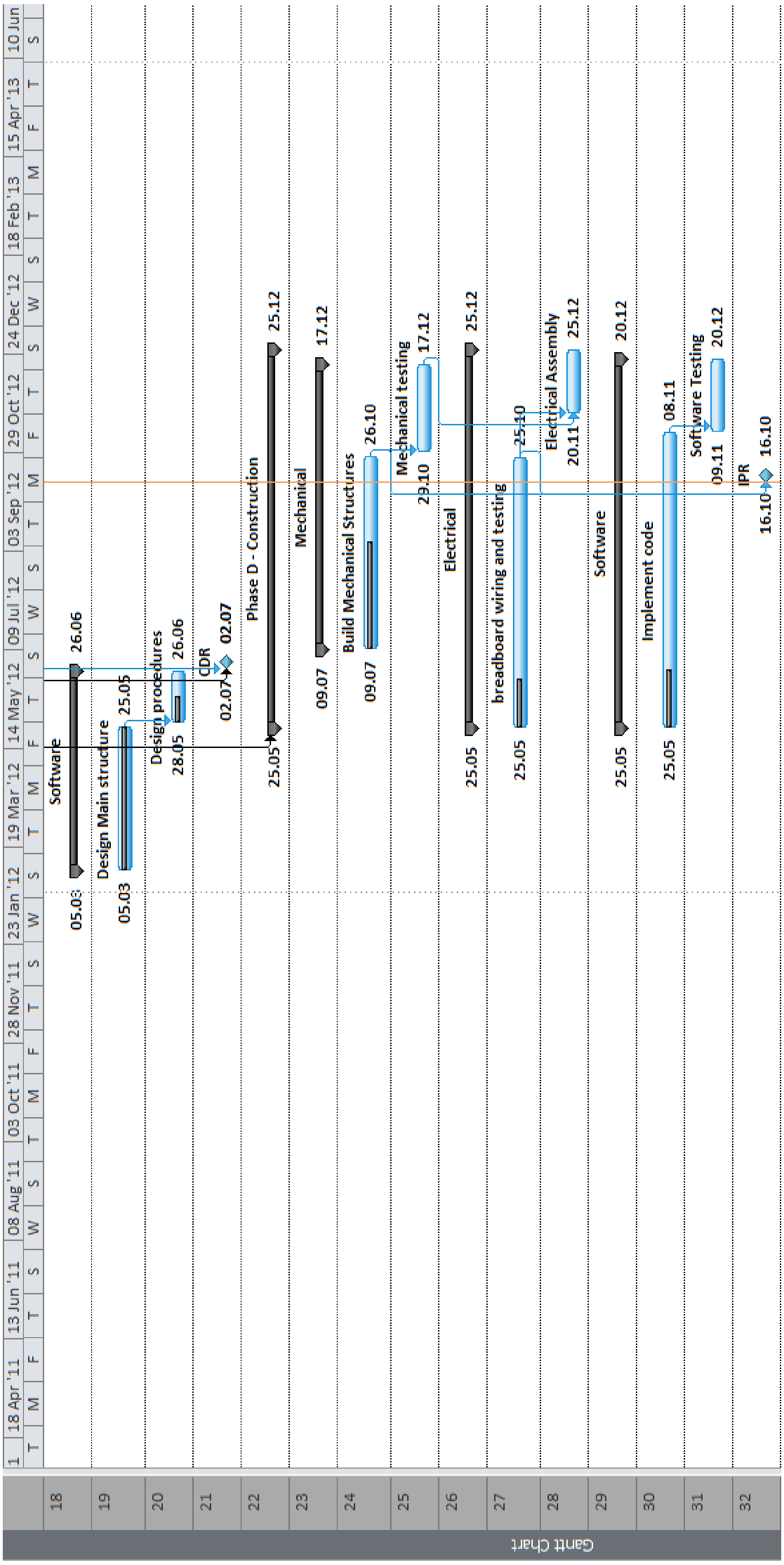
Task Name	Duration	Start	Finish	Resource Names	Predecessors	WBS
Call for Proposal	0 days	Thu 01.09.11	Thu 01.09.11			1
Write Proposal	38 days	Thu 01.09.11	Sun 23.10.11		1	2
Deadline Proposal	0 days	Sun 23.10.11	Sun 23.10.11			3
Phase A - Mission Analysis	31 days	Mon 24.10.11	Sat 03.12.11			4
Selection Workshop Bonn	3 days	Mon 05.12.11	Wed 07.12.11		4	5
Experiment Selection	0 days	Thu 15.12.11	Thu 15.12.11		5	6
Phase B - Mission Definition	52 days	Fri 16.12.11	Sun 26.02.12		5	7
Training Week	5 days	Mon 27.02.12	Fri 02.03.12		7	8
PDR	0 days	Mon 27.02.12	Mon 27.02.12		7	9

Phase C - Design Phase	**119 days**	**Mon 05.03.12**	**Thu 16.08.12**		**8**	**10**
Mechanical	**76 days**	**Tue 06.03.12**	**Tue 19.06.12**	**Daniel Bugger**		**10.1**
Develop Mechanical Structures	73 days	**Tue 06.03.12**	Thu 14.06.12	Daniel Bugger		10.1.1
Create technical drawings	3 days	Fri 15.06.12	Tue 19.06.12	Daniel Bugger	12	10.1.2
Electrical	**119 days**	**Mon 05.03.12**	**Thu 16.08.12**	**Christoph Friedl**		**10.2**
Design electrical layout	64 days	Mon 05.03.12	Thu 31.05.12	Christoph Friedl;Sebastian Althapp		10.2.1
Create wiring diagram	20 days	Fri 01.06.12	Thu 28.06.12	Sebastian Althapp	15	10.2.2
Design circuit board	35 days	Fri 29.06.12	Thu 16.08.12	Christoph Friedl	16	10.2.3
Software	**82 days**	**Mon 05.03.12**	**Tue 26.06.12**			**10.3**
Design Main structure	60 days	**Mon 05.03.12**	Fri 25.05.12	Alexander Schmitt		10.3.1
Design procedures	22 days	Mon 28.05.12	Tue 26.06.12	Alexander Schmitt	19	10.3.2
CDR	0 days	Mon 02.07.12	Mon 02.07.12		10;13	11
Phase D - Construction	**153 days**	**Fri 25.05.12**	**Tue 25.12.12**		**10FS-60 days**	**12**
Mechanical	**116 days**	**Mon 09.07.12**	**Mon 17.12.12**	**Daniel Bugger**		**12.1**
Build Mechanical Structures	80 days	**Mon 09.07.12**	Fri 26.10.12	Daniel Bugger		12.1.1
Mechanical testing	36 days	Mon 29.10.12	Mon 17.12.12	Daniel Bugger	24	12.1.2
Electrical	**153 days**	**Fri 25.05.12**	**Tue 25.12.12**			**12.2**
breadboard wiring and testing	110 days	**Fri 25.05.12**	Thu 25.10.12	Christoph Friedl		12.2.1
Electrical Assembly	26 days	Tue 20.11.12	Tue 25.12.12	Christoph Friedl;Sebastian Althapp	27;25FS-20 days	12.2.2
Software	**150 days**	**Fri 25.05.12**	**Thu 20.12.12**			**12.3**

Implement code	120 days	**Fri 25.05.12**	Thu 08.11.12	Alexander Schmitt		12.3.1
Software Testing	30 days	Fri 09.11.12	Thu 20.12.12	Alexander Schmitt;Daniel Bugger	30	12.3.2
IPR	0 days	Tue 16.10.12	Tue 16.10.12		24;27	12.4
EAR	0 days	Sat 01.12.12	Sat 01.12.12			13
Integration Week	5 days	Mon 14.01.13	Fri 18.01.13			14
System Testing	5 days	Mon 18.02.13	Fri 22.02.13			15
Launch Campaign	10 days	Mon 29.04.13	Fri 10.05.13			16
Experiment Results Symposium	5 days	Mon 03.06.13	Fri 07.06.13			17
Project Coordination	**462 days**	**Thu 01.09.11**	Fri 07.06.13	**Daniel Bugger**		**18**
Project Management	462 days	Thu 01.09.11	Fri 07.06.13	Daniel Bugger		18.1
Project Scheduling	462 days	Thu 01.09.11	Fri 07.06.13	Daniel Bugger		18.2
Documentation	462 days	Thu 01.09.11	Fri 07.06.13	Alexander Schmitt		18.3
Outreach	462 days	Thu 01.09.11	Fri 07.06.13	Christoph Friedl;Sebastian Althapp		18.4

Table 7 : Project Plan


Gantt Chart
18 Apr '11
13 Jun '11
08 Aug '11
03 Oct '11
28 Nov '11
23 Jan '12
19 Mar '12
14 May '12
09 Jul '12
03 Sep '12
29 Oct '12
24 Dec '12
18 Feb '13
15 Apr '13
Call for Proposal
01.09
01.09
Write Proposal
01.09
23.10
Deadline Proposal
23.10
23.10
Phase A - Mission Analysis
24.10
03.12
Selection Workshop Bonn
05.12
07.12
Experiment Selection
15.12
15.12
Phase B - Mission Definition
16.12
26.02
Training Week
27.02
02.03
PDR
27.02
27.02
Phase C - Design Phase
05.03
16.08
Mechanical
06.03
19.06
Develop Mechanical Structures
06.03
14.06
Create technical drawings
15.06
19.06
Electrical
05.03
16.08
Design electrical layout
05.03
31.05
Create wiring diagram
01.06
28.06
Design circuit board
29.06
16.08


Software
Design Main structure
Design procedures
CDR
Phase D - Construction
Mechanical
Build Mechanical Structures
Mechanical testing
Electrical
breadboard wiring and testing
Electrical Assembly
Software
Implement code
Software Testing
IPR
Gantt Chart

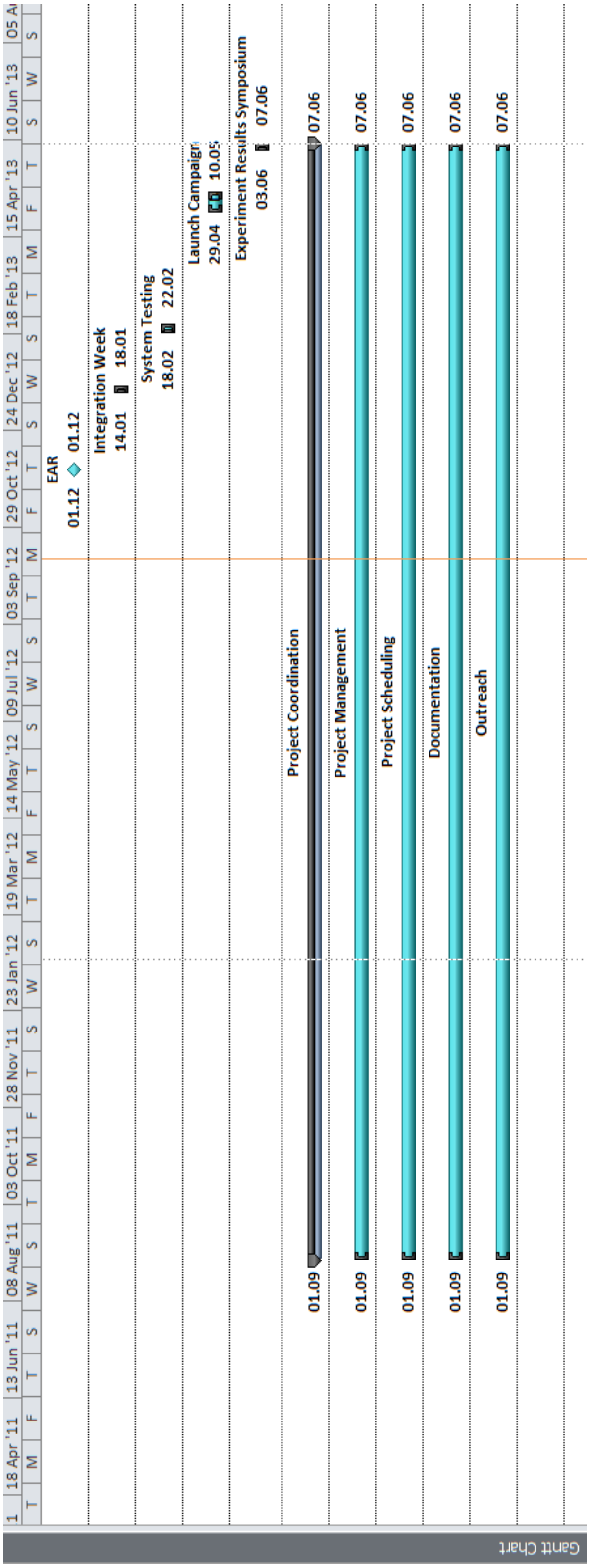


Figure 3: Gantt Chart

3.2 Project plan: Short term

For short term coordination VBA-Excel Sheet is used where every subtask is shown. These Tasks have a nominal deadline within the next 2 weeks. Each task has priority between 1 and 5 (extreme urgent to “do it later”). Done tasks get marked as complete and are tagged with the date. The list is cleared of all completed task frequently. Completed tasks are saved for records. Figure 4: Short Term Action Items shows a part of the list as an example:

Priorität	Task Nr.	Task	Deadline	Kommentare	Erledigt	Erledigt am
Christoph						
2	CF008	SED: Kap. 4.7 Power System	06. Jun	First Draft Power Board kontrollieren lassen		
4	CF009	Test für jeden eurer Teile überlegen und in SED Kap. 5.2 einfügen	20. Mai	delayed		
4	CF010	SED: Kap. 6 (mit Sebastian) Launch Campaign Preparation	06. Jun	delayed		
2	CF013	Adapterplatinen festlegen	27. Mai			
1	CF014	SED: Kap. 4.2 Elektical Interfaces	06. Jun			
2	CF015	SED : Kap. 4.5 (mit Sebastian ?) El. Design	06. Jun			
2	CF016	Requirements auf entprechende Systemlevels verteilen	27. Mai		x	27.05.2012
4	CF017	Auf HP bei Alex , "Protokolant " einfügen	10. Jun			
1	CF018	Rocket Module- Schaltpläne machen	04. Jun			
1	CF019	Verification Module- Schaltpläne machen	04. Jun			
Alex						
3	AS005	Test für jeden eurer Teile überlegen und in SED Kap. 5.2 einfügen	20. Mai	delayed		
4	AS006	Nochmals bei Jan Kniewasser melden	22. Mai	delayed		
3	AS012	Analyse Software konzipieren	01. Jun	erst nach Task SA010		
1	AS013	Software Flowchart erstellen/erweitern	06. Jun	in progress		
3	AS014	Höhn wegen Vibrationssensor cooperation mit LRT fragen	10. Jun			
4	AS015	Bei Vektor nach Test Procedure des Rios fragen	13. Jun			
Sebastian						
5	SA002	Sponsoring : Conrad (Gutscheine für Ware)	16. Mai	delayed		
3	SA003	SED: Kap. 4.1 bearbeiten Exp. Setup	06. Jun	delayed		
5	SA005	Bei Markus Wilde / Andi Fleischner sich Infos über das GM-Front-End einholen	19. Mai	Wir müssen uns überlegen, welche Daten wir brauchen, nicht welche interessant sein könnten. Wir brauchen z.B. ein Kriterium, wann wir den Meltingwire Command schicken. Außerdem brauchen wir den Status unseres Experiementes, nicht die Zahlenwerte der Sensoren. Ein ganzer Bildschirm voller Zahlen ist sinnlos. Ein Bildschirm mit grünen Lämpchen schon besser. KISS: So einfach wie möglich.	x	30.05.2012
3	SA007	SED: Kap. 4.6 4.6 Thermal Design	06. Jun	Heaters igendwie nachrechnen		
3	SA008	Test für jeden eurer Teile überlegen und in SED Kap. 5.2 einfügen	20. Mai	erst nach reorganisation der requirements möglich		

Tabelle1 Tabelle2 Tabelle3

Figure 4: Short Term Action Items

3.3 Resources

3.3.1 Manpower

The CERESS team consists of four members with about 8 hours per week available for the project. In normal case that creates 32h/week manpower in total. If the need arises, additional time on weekends can be allocated.

3.3.2 Budget

Type	Cost [€]
OBDH	- 3100
EPS	- 300
Structure	- 1800
Sensors	- 1000
Test equipment	- 1000
Overall costs	- 7200
Studienbeiträge (from University)	+ 5200
DLR (Hardware)	+ 2000
Overall funding	+ 7200
Total	0

Table 8: Budget Overview

Additional funding in form of (sensor-) hardware is intended.

3.3.3 External Support

The Institute of Astronautics (LRT) supports CERESS:

- The employees contribute know-how to the project. Experts are at hand for sensor selection, system engineering, programming, project management and industry contacts.
- The Institute allocates resources like the Clean Room, the Workshop, Student Laboratory, IT Infrastructure and a thermal / vacuum chamber.
- Software licenses are provided for LabView, MatLab, CATIA, STK and MagicDraw.

REXUS Alumni at our Univerity:

- Fellow students at our institution, who have already participated in the REXUS program help us in critical situations and design decisions.

Oerlikon Leybold Vacuum GmbH:

- We managed to get sponsoring by “Oerlikon Leybold Vacuum GmbH”. They provide us with Pirani sensors for low air pressure measurements.

National Instruments:

- National Instruments already supported us with an “ask the expert” session and additional sponsoring is in the pipe.

3.3.1 Facilities

At the department Institute of Astronautics access to different laboratories, a thermal / vacuum chamber and an integration room (clean room) is provided. Material resources at the laboratories and workshops such as simple raw materials like bolts and electronics can be used. Smaller hardware components can directly be manufactured there.

3.4 Outreach Approach

The CERESS project's outreach focuses on two main pillars: Online media and print media.

Currently the focus is on online outreach to raise public interest towards CERESS and the REXUS programme in general. This includes our homepage, (http://ceress.de) which is updated continuous with the work in progress, giving detailed information on the goals, project definition and project progress. To reach an even broader community of interested people, our outreach programme relies heavily on social networks, including Facebook (http://facebook.de/Team.Ceress), Twitter (http://twitter.ceress.de) and YouTube (http://www.youtube.com/user/CeressRexus). Facebook is used to provide status updates on the project's progress, as well as sharing pictures of our team at work and at REXUS related events, e.g. selection workshop or training week. Twitter is used to distribute news of the project and promote changes of the homepage in a fast way. YouTube is used for uploading videos of work and project related events.

The print media outreach is intended to start later on in the project. It involves distribution of press releases to various newsletters, local newspapers and even local TV stations about our participation in the REXUS programme. Posters and flyers distributed at TU Munich are also planned, mainly in the engineering faculty, but also in other faculties as well.

The CERESS Team is going to join "Dr.-Ing. Andreas Stamminger" from MORABA on his presentation about MORABA at the TU Munich.

In addition to these commonly used outreach approaches, the CERESS project has one that is unique: The visualization tool allows people around the globe to experience the rocket flight in near real-time as well as replay it afterwards with additional information. Combined with the on-board camera's recordings, we intend to get people more interested in spaceflight in general and the REXUS programme in particular.

Date	Media	Publisher	Content
-	Homepage	CERESS	Detailed project information http://ceress.de/
-	Facebook	CERESS	Status updates and photographs http://facebook.ceress.de
-	Twitter	CERESS	Status updates http://twitter.ceress.de/
-	YouTube	CERESS	Videos http://www.youtube.com/user/CeressRexus
To be released	Press release	CERESS	General project information
Feb. 2012	Press release	FSMB	Article about CERESS and the use of university funding.

Table 9: Outreach media

3.5 Risk Register

The following table shows all identified risks to the project and the experiment.

For Explanation of Risk Register see Appendix D

ID	Risk & Consequence	P	S	P x S	Action
TC10	Critical component is destroyed in testing	B	3	Low	Order spare components and keep them available
TC20	Short circuit in electrical system	B	3	Low	Use resistors and redundancies
TC30	Experiment fails thermal, vacuum or vibration testing	C	2	Low	Test early and thoroughly
TC40	Experiment is damaged in transport	B	2	Very Low	Handle with care, package softly
TC 50	Test Infrastructure fails	E	2	Medium	Repair
MS10	Software programme in microcontroller fails during flight	C	3	Low	Heartbeat checks for crashes and resets if necessary.
MS20	Overheating of microcontroller/ electronics	B	3	Low	Testing in vacuum conditions/ consider Heat sinks
MS30	Vibration shocks destroy electronic boards	B	4	Low	Imply bearing points closely to each other
MS40	Structure failure	B	4	Low	Adapt design of components to requirements and loads
MS50	Vibration causes damage to cable harness	B	4	Low	Implementation of robust cable routing
MS60	Acceleration Sensor fails	C	1	Very low	Acceptable due to tetrahedron configuration
MS70	Gyro fails	C	2	Low	Select suitable gyro to withstand the external environment

ID	Risk & Consequence	P	S	P x S	Action
MS80	Pressure sensor fails	C	2	Low	Select suitable sensor to withstand the external environment
MS90	Camera fails	C	2	Low	Select suitable camera to withstand the external environment
MS100	(removed)				
MS110	Loss of up-/downlink	C	2	Low	Write software to be able to handle temporary and continuous loss of connection, Redundancy due to onboard data storage
MS120	System fails to store data on sd-card	B	4	Low	Downlink data, test functionality
MS130	Electrical connectors unplug due to vibration or acceleration	C	3	Low	Select screw-able connectors where possible or glue tight
MS140	Components detach from mounting and damage other subsystems	B	3	Low	Use several mounting points, check every component before flight
PR10	Team member has less time for project than expected	B	3	Low	For every critical system a back-up person has to be qualified to fill in/ good time management for enough buffer
PR20	Component is not delivered in time	B	2	Very low	Order early

ID	Risk & Consequence	P	S	P x S	Action
PR30	Experiment funding not sufficient	C	4	Medium	Have different sources of capital, e.g. tuition fees, sponsorings,…

Table 10: Risk Register

4 EXPERIMENT DESCRIPTION

4.1 Experiment Setup

In the following sections the different subsystems and components of the CERESS System are described multiple times from different views. (e.g. Mechanical, Electrical, Software etc.)

The CERESS System consists of a space- and a ground segment; each containing several subsystems, which themself contain several components.

The connections and interactions between the REXUS Rocket and the CERESS Rocket Module are described as the “REXUS Bus”.

The Connections and interactions between the CERESS Rocket Module and the CERESS Verification Module are described as the “CERESS Bus”.

The communications interface between the CERESS Rocket Module and the CERESS Ground Module is referred to as Telemetry (TM) and Telecommand (TC).

4.1.1 The CERESS Rocket Module, Space Segment

The CERESS Rocket Module is the key component of the CERESS Space Segment. It provides the CERESS Bus by extending the functionality of the REXUS Bus forwarded to the CERESS Verification Module.

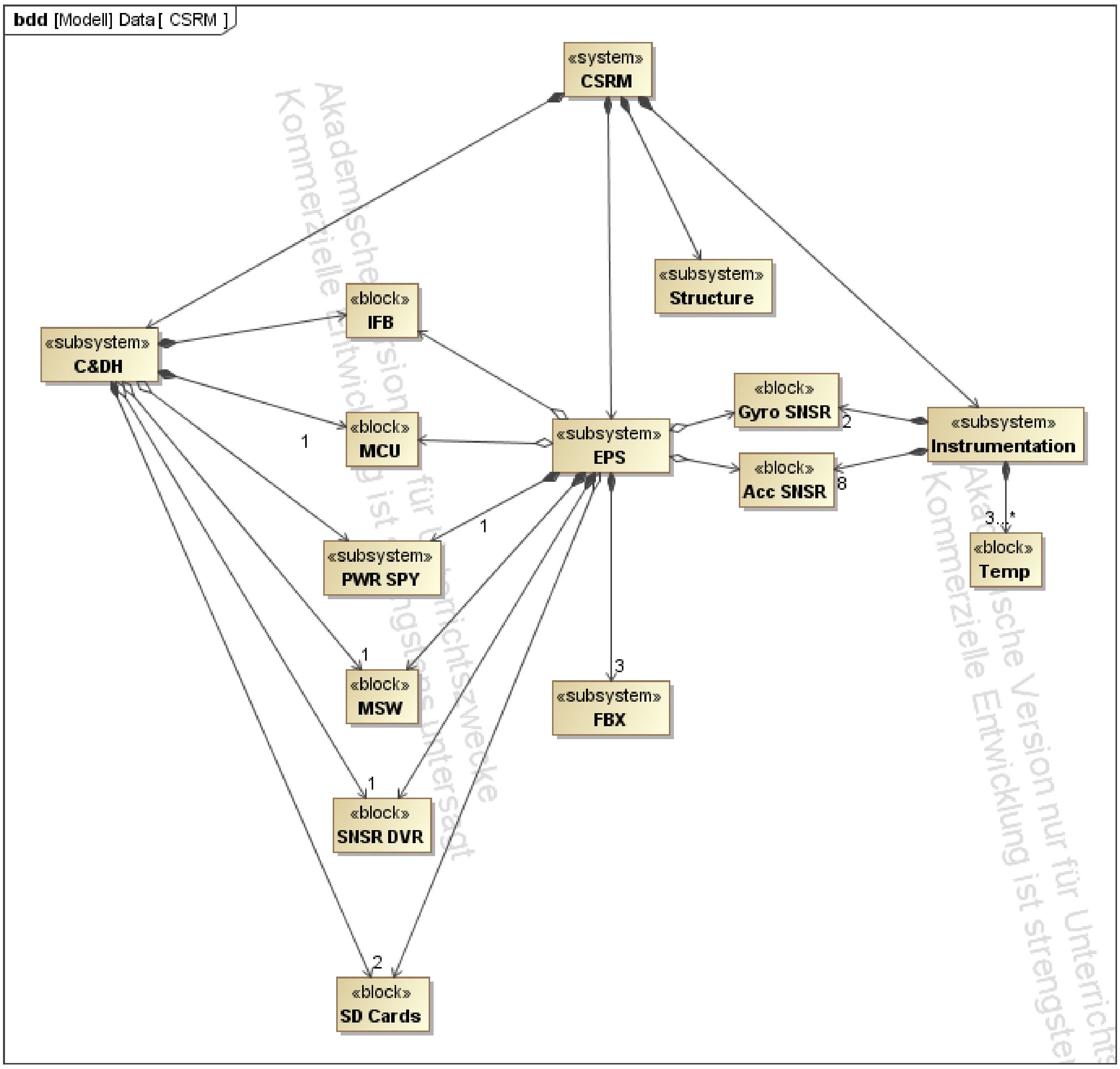


Figure 5: bdd Rocket Module

4.1.1.1 Main Computation Unit

The Main Computation Unit (MCU) is the key component of the CERESS Rocket Module and provides following operations:

- Data acquisition
- Data storage
- Command & Control of the CERESS Rocket Module and CERESS Verification Module
- TM/TC handling

The MCU is implemented by a sbRIO (see Appendix for Datasheet). The tasks of the MCU are often wrapped up as On-Board Data Handling (OBDH).

4.1.1.2 Interface Board

The Interface Board implements the signal connections of the REXUS Bus as proposed in the RX User-Manual. Major tasks are:

- Forward LO, SOE, SODS Signals
- Provide galvanic isolation

4.1.1.3 Sensor Driver Board

The tasks of the Sensor Driver Board are:

- Switch Power ON/OFF for CERESS Rocket Module Sensors
- Switch Power ON/OFF for CERESS Rocket Module Data Storage

The electrical components of the CERESS Rocket Module are powered by the CERESS Rocket Module Power Supply. To prevent high inrush currents and to protect the CERESS Rocket Module Data Storage against power fluctuations at startup and shutdown, the electrical power of these components can be switched ON/OFF.

Power switching is critical for mission success, so every switch is implemented as two Solid State Relays in parallel.

4.1.1.4 Power Supply

The CERESS Rocket Module Power Supply provides following regulated voltages:

- 3.3V
- 5V
- 24V

The Power Supply is implemented with two DC/DC converters; one for 3.3V and 5V and one for 24V.

The 28V unregulated REXUS Power is directly forwarded to the CERESS Verification Module.

The CERESS Rocket Module is floating ground. The common ground point is located at the ground connection of the Main Computation Unit.

4.1.1.5 Sensors

If necessary the sensor of the CERESS Rocket Module is implemented two times, one for course measurements during liftoff and “reentry” and one for fine measurements during free flight and vacuum.

Implemented Sensors are:

- Acceleration Sensors, mounted in an tetrahedron configuration (2 times 4)

- Rotation Rate Sensors (2 times 1)
- Temperature Sensors (3)

4.1.1.6 Data Storage

The Data Storage of the CERESS Rocket Module is implemented with a NI-9802 SD-Card Module. It provides a full file-system access on file level. The two slots are capable of 2GB each. For Event-Logging the non-volatile onboard storage of the sbRIO is used.

4.1.2 The CERESS Verification Module, Space Segment

The CERESS Verification Module is replaced by the actual experiment in future missions. For the CERESS Mission, the CERESS Verification Module is used for verification of the CERESS System and is used for flight environment characterisation with several sensors. It is fully controlled and supplied by the CERESS Rocket Module over the CERESS Bus.

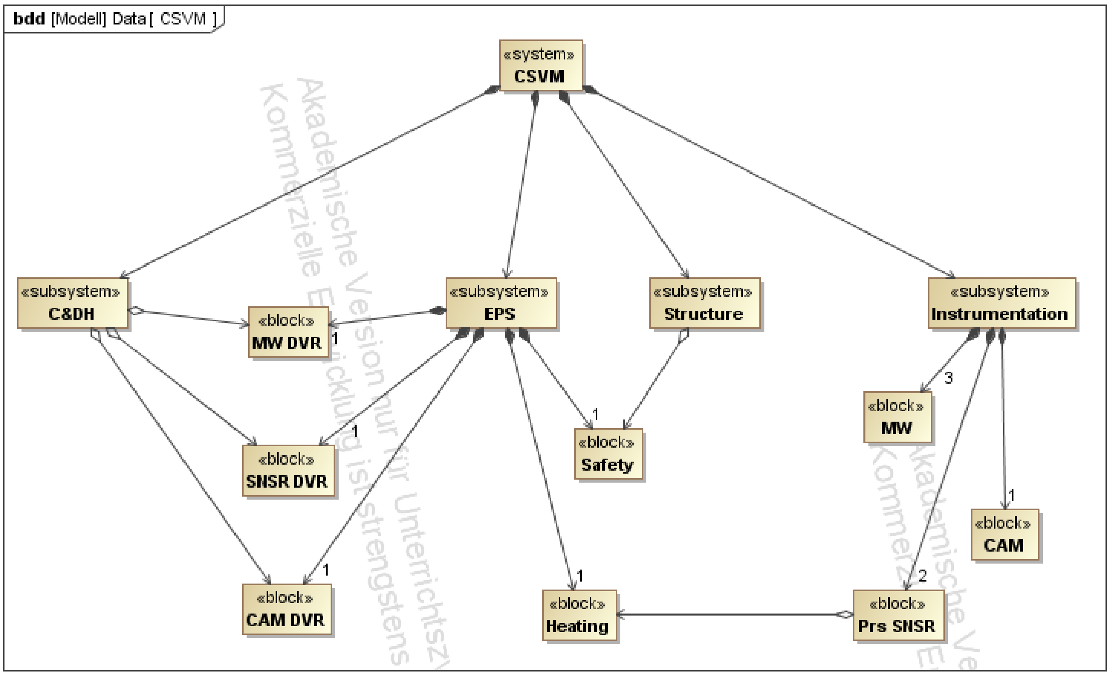


Figure 6: bdd Verification Module

4.1.2.1 Sensor Driver Board

Task of the CERESS Verification Module Sensor Driver Board is to switch the power for the CERESS Verification Module sensors ON/OFF:

- Switch Power ON/OFF for Fine Pressure Sensor
- Switch Power ON/OFF for Fine Pressure Sensor Heating
- Switch Power ON/OFF for Coarse Pressure Sensor

The signals to trigger the power switching actions are generated by the MCU of the CERESS Rocket Module.

4.1.2.2 Sensors

Following Sensors are implemented in the CERESS Verification Module:

- Fine Pressure Sensor
- Coarse Pressure Sensor
- Temperature Sensors

4.1.2.3 Camera

The Camera is pointing radial outwards of the REXUS Rocket. A Camera window is implemented for this purpose.

The Camera is implemented by the GoPro 2 Hero HD.

4.1.2.4 Camera Driver

The Camera Driver switches the power of the Camera ON/OFF and provides signals and signal feedback from and to the Camera for operations like power up, record, shut down and delete.

4.1.2.5 Melting Wires

Three Meltingwires are implemented in the CERESS Verification Module to verify the different control chains of the CERESS System:

- Meltingwire 1, burned by an time triggered command
- Meltingwire 2, burned by an event triggered command
- Meltingwire 3, burned by an TC triggered command

Each Meltingwire provides a feedback signal, if the Meltingwire is burned or not to enable successful verification even in case of no recovery of the CERESS Verification Module.

The Meltingwires are implemented by a modified melting-wire-mechanism developed and verified for the TU Munich CubeSat “MOVE”.

4.1.2.6 Melting Wire Driver

The Meltingwire Driver switches the high currents needed to burn the Meltigwires. The used voltage for this device is 3.3V.

Furthermore the Meltingwire Driver provides feedback, if current flows through the Meltingwires or not.

4.1.2.7 Safety Pin

The Safety Pin is implemented as a “Insert Before Flight”-Pin that forms a connection between the 3.3V power source and the melting wires. For transport and situations when activation of the melting wires is not permitted, the plug can be removed, therefore disconnecting the power source and the wires. For testing there will be a different plug available, still isolating power source and melting wires. The power will instead flow through LED lights to indicate that the command has been received successfully.

4.1.3 The CERESS Ground Module, Ground Segment

The CERESS Ground Module is divided into Ground Module Servers and Ground Module Clients.

It is not yet determined on how many computers the servers and clients are running. The theoretical minimum is one desktop computer running the server- and client software.

4.1.3.1 CERESS Ground Module Server

The CERESS Ground Module Server provides following tasks:

- Handle the RS-232 interface of the ESRANGE Ground Station
- Handle TM/TC from and to the CERESS Rocket Module
- Store TM/TC data stream
- Command and Control of CERESS Rocket Module and payload (the CERESS Verification Module)
- Merge Data from ESRANGE Ground Station (Antenna tracking angles and ranges)
- Merge Data from REXUS Telemetry (GPS)

The CERESS Ground Module Server utilizes the CERESS TM/TC protocol.

The received data is checked for limits and validity depending on the mission phase and flagged in case of limit violations or errors.

The different data sources are merged into a unified data structure, backed up at the local data storage and forwarded to the CERESS Ground Module Clients in near real-time.

4.1.3.2 Visualization Tool Server

The REXUS Telemetry is used by the Visualization Tool Server to generate the 3D flight visualization data. The ESGANGE Internet Connection forwards this data to the CERESS Internet Server located in the Internet.

For post flight, the Visualization Tool Server generates a flight visualization data file for replay with additional scientific data.

4.1.3.3 CERESS Internet Server

The CERESS Internet Server distributes the 3D flight simulation data to the CERESS Flight Simulation Clients located worldwide over the internet.

4.1.3.4 CERESS Flight Simulation Clients

The CERESS Flight Visualization Client is implemented as a Google Earth plugin. Using free and extendable software enables the broad public to get involved with the REXUS programme.

4.1.3.5 CERESS Ground Module Clients

These CERESS Ground Module Clients are running on local CERESS desktop computers located at ESRANGE. They include:

- Control Console for the CERESS Rocket Module
- Control Console for Payload (CERESS Verification Module)
- Display of the CERESS Mission (Events & time)
- Display of the CERESS Rocket Module Status
- Display of the CERESS Verification Module Status
- Display of the CERESS Ground Segment Status
- Display of Scientific Data

Each CERESS Ground Module Client caches the data provided by the CERESS Ground Module Server in order to display it or in order to send a TC request to the CERESS Rocket Module Server.

Multiple Clients can be running on a single desktop computer. An impression of a joined display- and control panel is given in Figure 7: CERESS Ground Segment Client

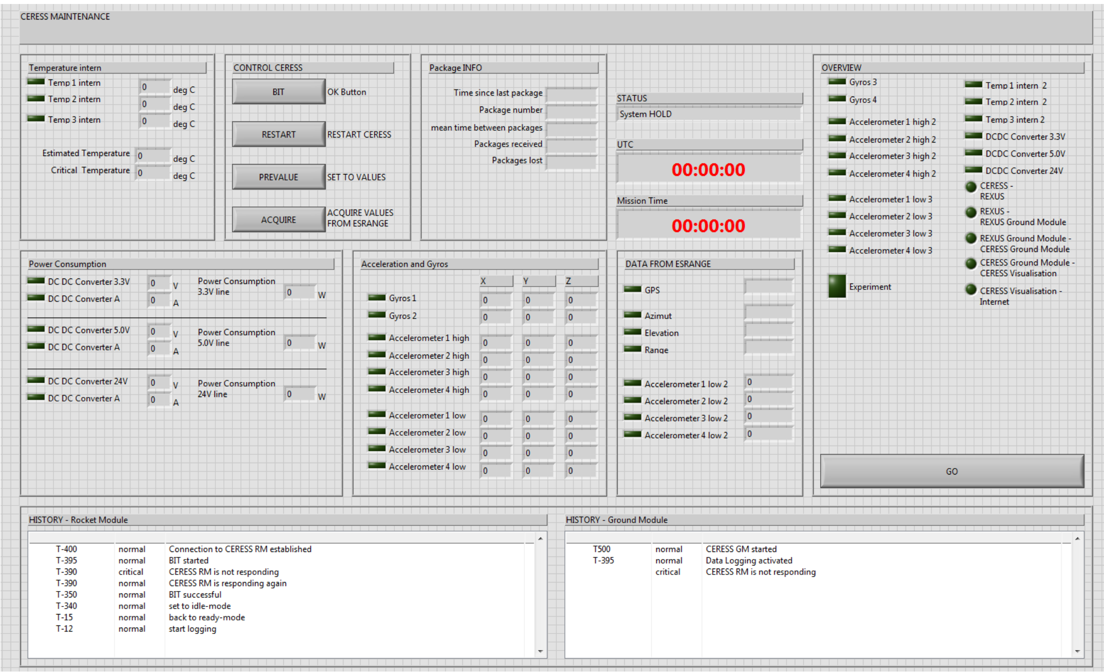


Figure 7: CERESS Ground Segment Client

4.1.3.6 Visualisation Tool

- Displays 3D-Flight Visualization.

A local instance of the ViTo can run as a CERESS Ground Module Client without the need of the ESRANGE Internet connection if no Internet connection is applicable.

4.2 External Experiment Interfaces

The main Interfaces of the CERESS system are shown in Figure 8: CERESS Interfaces

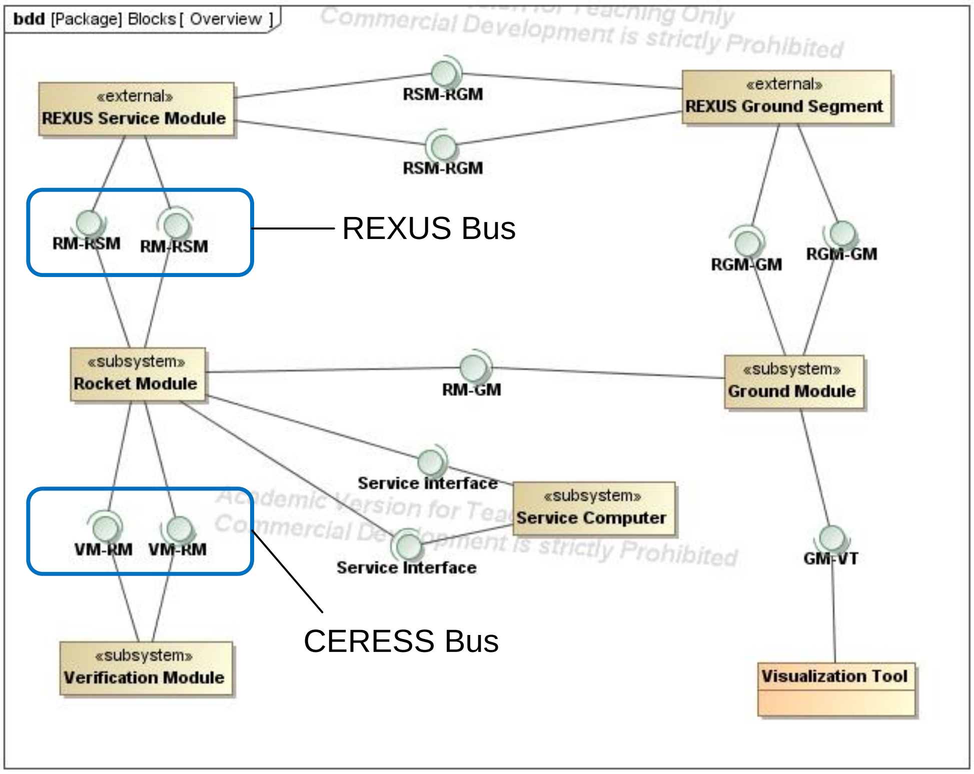


Figure 8: CERESS Interfaces

4.2.1 Mechanical Interfaces, REXUS Bus

4.2.1.1 On Bulkhead

On top of the bulkhead, the rocket module and the fine air pressure sensor are mounted (seeFigure 9: Top view of the bulkhead). The carrier structure is fixated with 14 screws of the size M4. The fine air pressure sensor is mounted with 4 screws of size M4. The sbRio is mounted directly on the Bulkhead with 12 screws of size M3 (see Figure 10: sbRio on Bulkhead). Below the bulkhead, the 6 accelerometers, two times the bottom triangle of the tetrahedron, are mounted to protect the sensors and the wiring a protection sheet plate is attached (see Figure 11 : Bottom view bulkhead). For details see technical drawings at attachments.

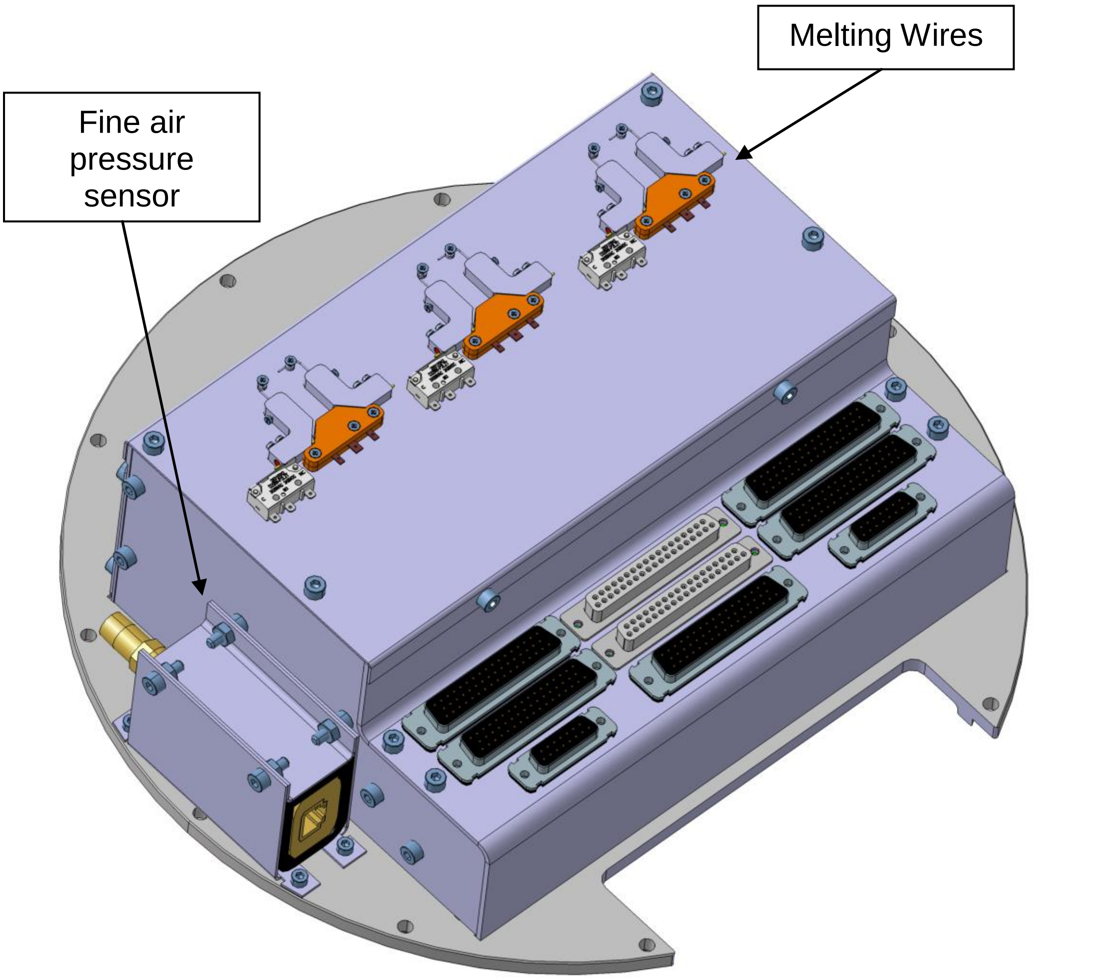


Figure 9: Top view of the bulkhead

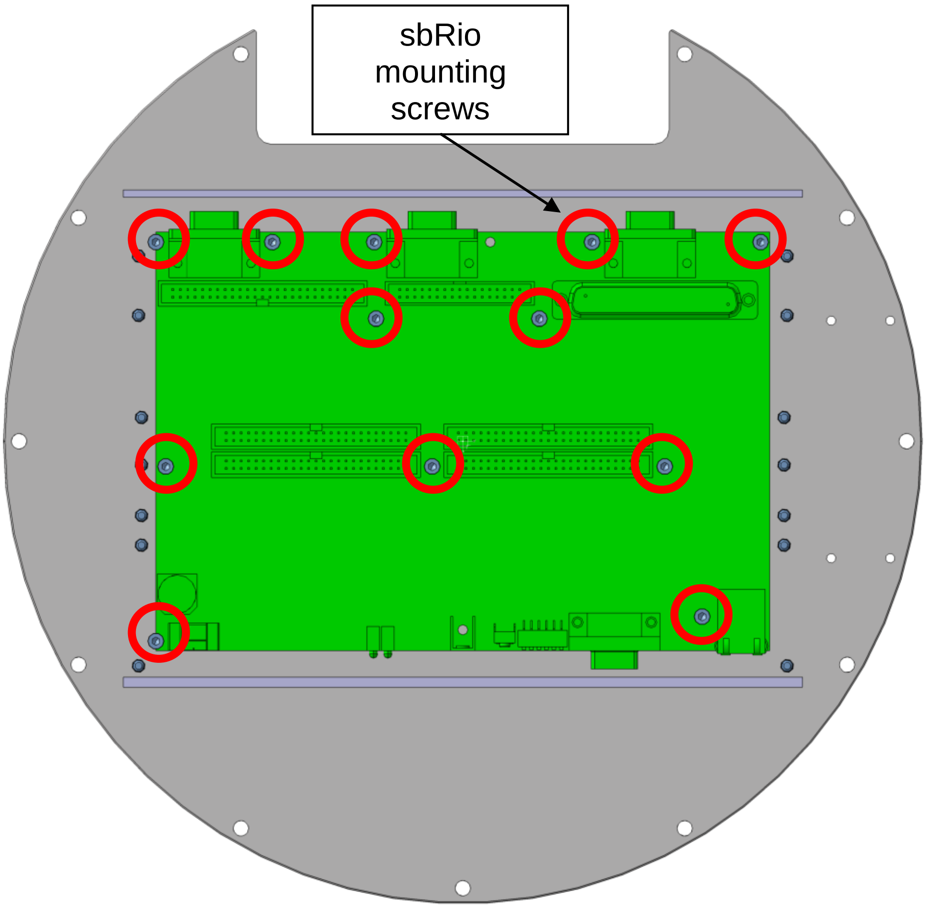


Figure 10: sbRio on Bulkhead

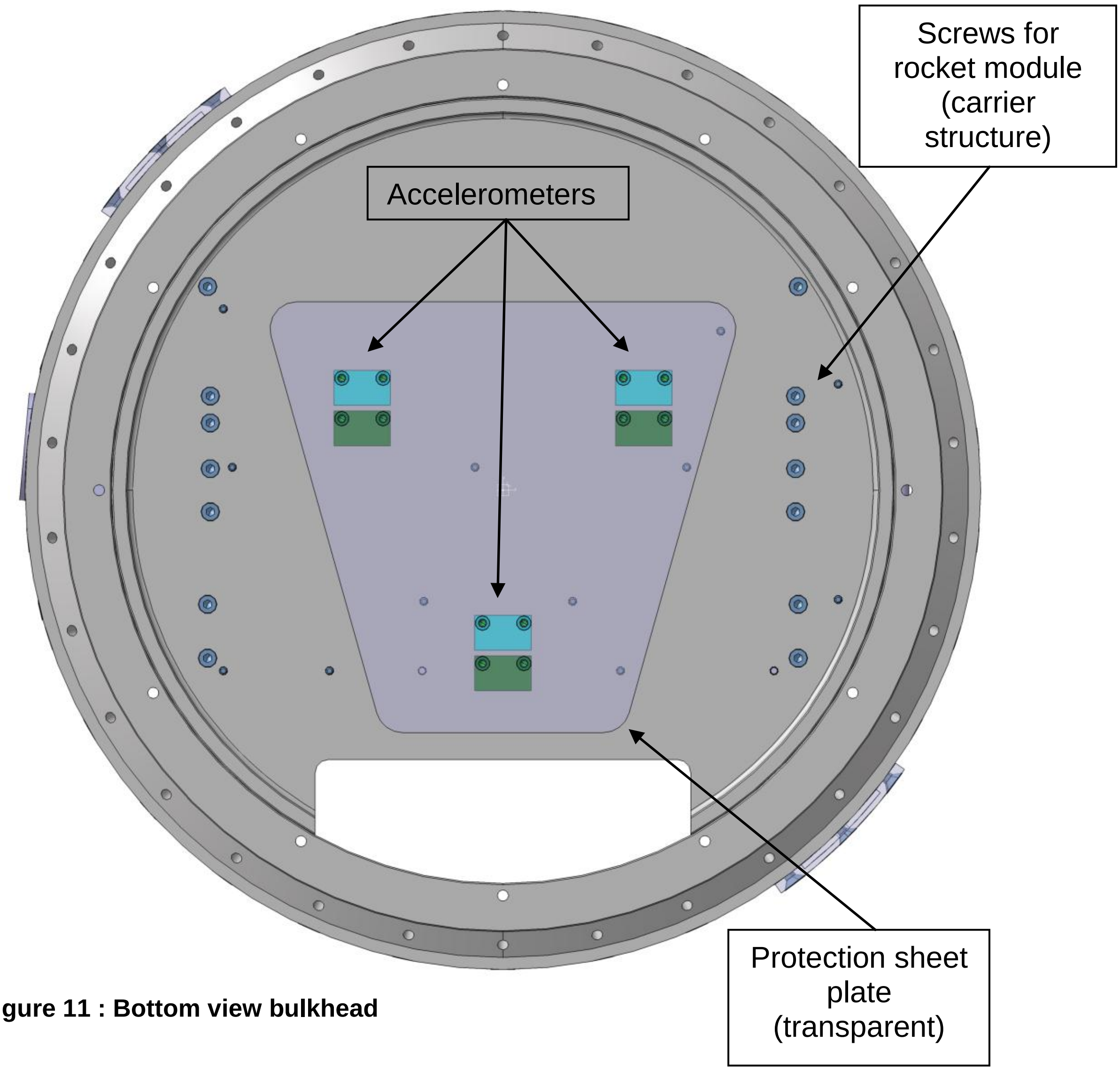


Figure 11 : Bottom view bulkhead

4.2.1.2 At hull

The Camera is mounted directly at the hull structure with 4 screws of size M4 (see Figure 12 : Camera clamp). Furthermore in front of the camera lens there is a glass window including fixation structure (see Figure 13: Camera window and Figure 14: Camera window cross section).

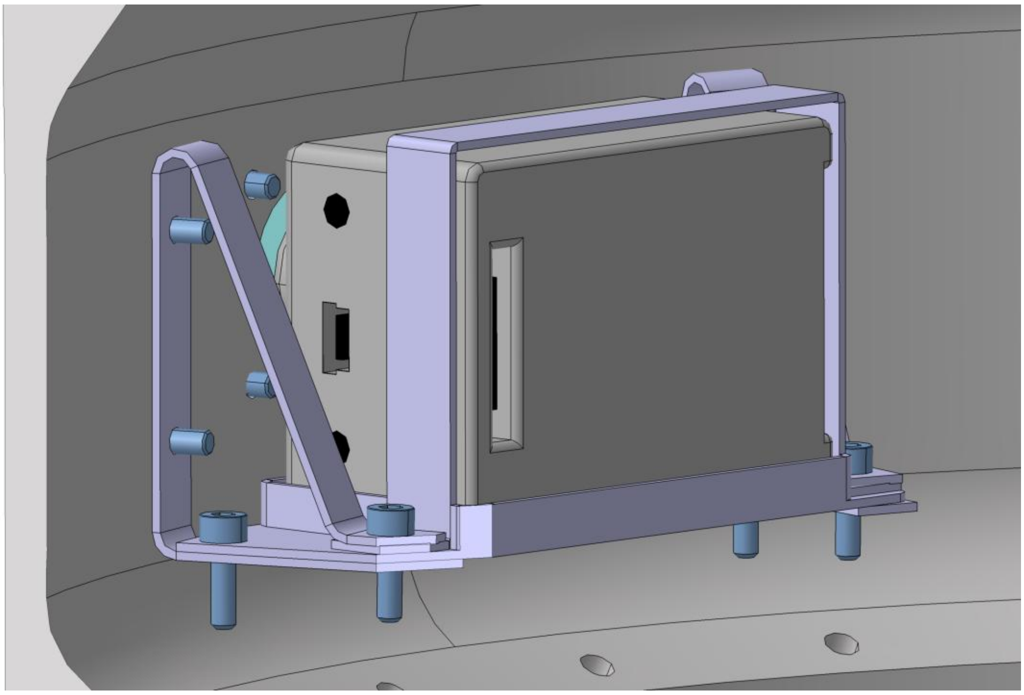


Figure 12 : Camera clamp

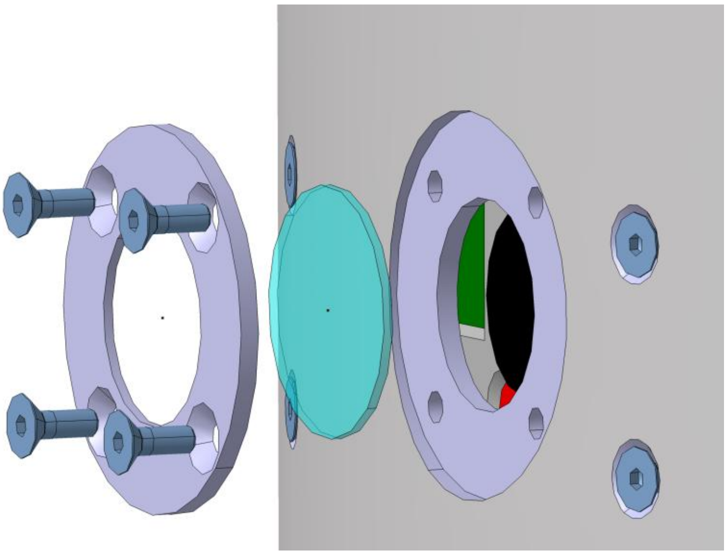


Figure 13: Camera window

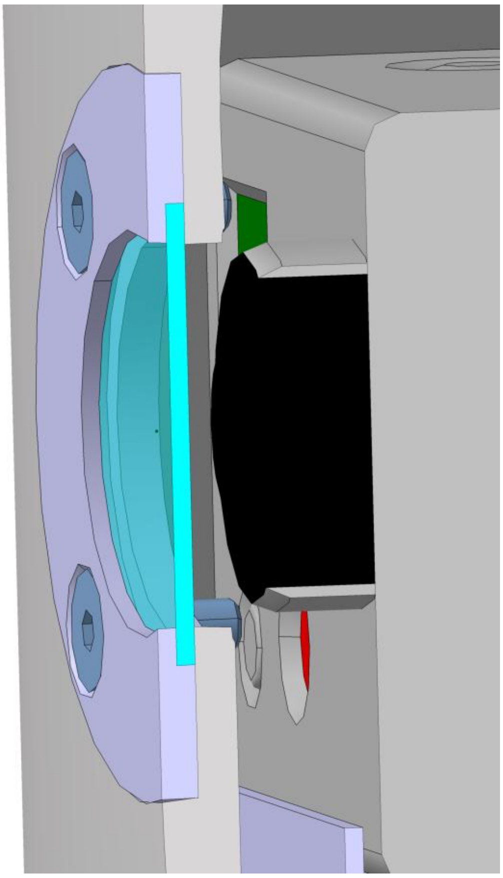


Figure 14: Camera window cross section

4.2.1.3 Venting Hole

In order to get better measurements of the ambient air pressure, two venting holes at the outer structure are required. As described in the RX User Manual (v7-3) “one hole of 10mm diameter is needed for each 15 dm^3 of evacuated air volume”. Since the complete rocket module has a volume of approximately 5.7dm^3, only one venting hole would be required, but since other modules don’t have their own venting holes, we have to evacuate them as well. To protect the inner construction from hot gas flows, there is a protection cap on the outside of the venting hole (see Figure 15: Venting hole and protection cap).

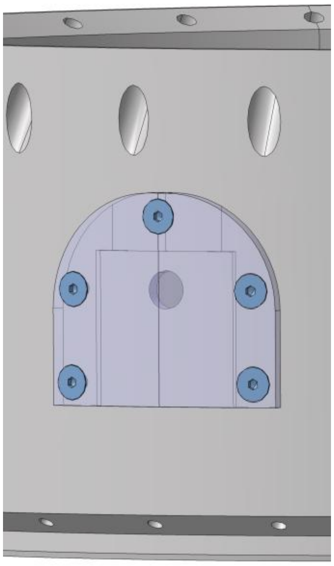


Figure 15: Venting hole and protection cap

4.2.1.4 Hatch

For late access possibility to the Main Computation Unit a hatch is designed. The hatch is covered by a removable cap which is fixed via 6 bold connections of the size M4 (see Figure 16: Outer hatch).

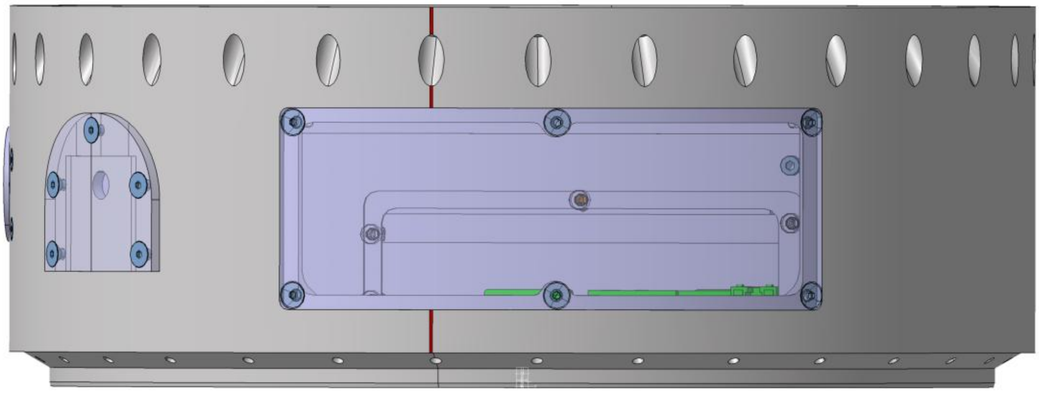


Figure 16: Outer hatch

For better understanding of the positions see Figure 17: Angels of the hull modifications

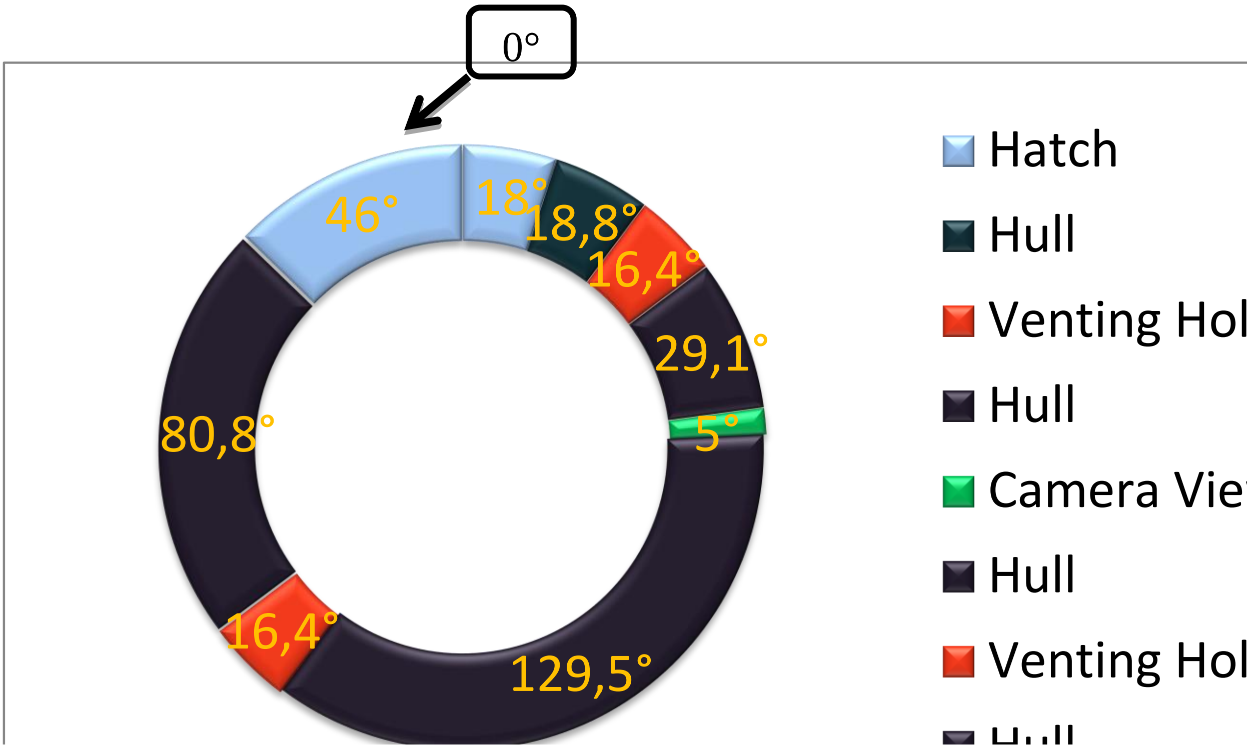


Figure 17: Angels of the hull modifications

For details see technical drawings at 9.2Appendix C or attachments.

4.2.2 Electrical Interfaces

Due to its design, Ceress has a variety of interfaces both internal and external. The following figure gives an overview of these interfaces and the connectors that are used.

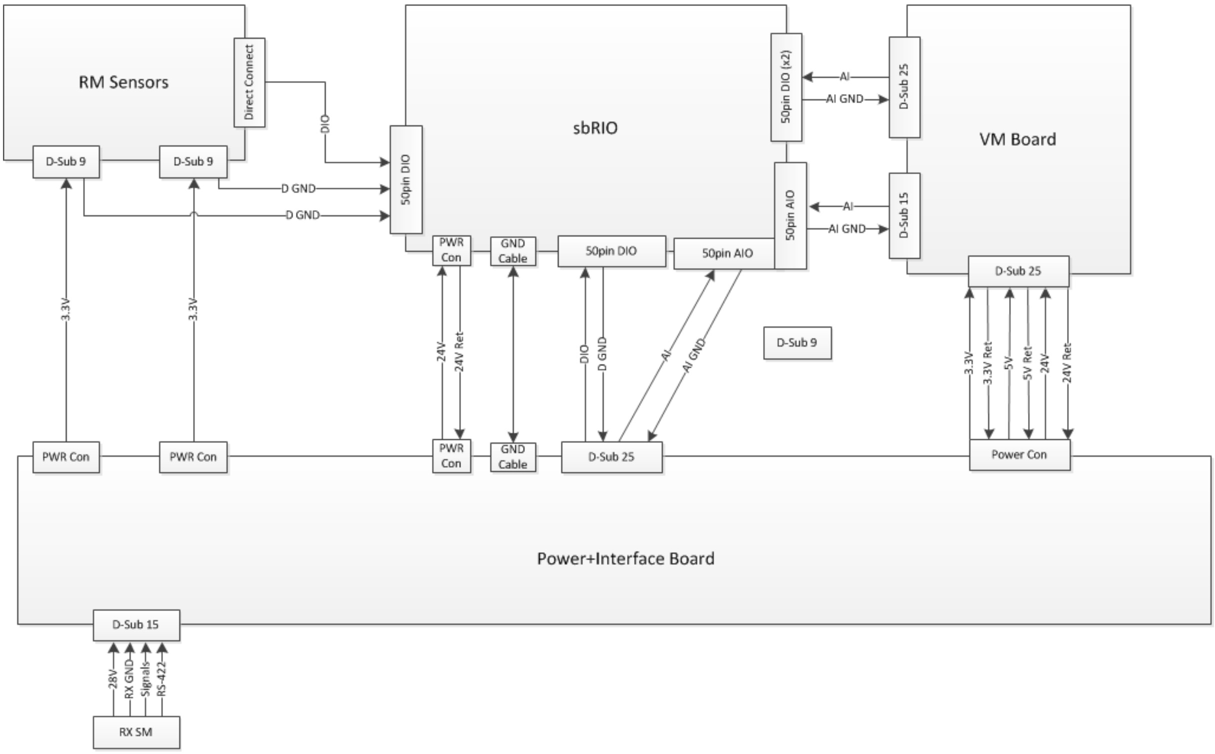


Figure 18: Electrical interface overview

The following subchapters will further detail these interfaces. See 9.2Appendix C for even more detailed signal, connector and pin definitions.

4.2.2.1 REXUS Bus

The CSRM uses the Power- and Control-Interface of the RXSM. The control-interface uses the RS-422 (EXP in/out). Both interfaces are implemented as D-SUB Connector:

Pin	Name	Specification	Usage
1	+28V	RXSM Power, 24-36 V unregulated, I_{peak} < 3 A	Power the CSRM and CSVM via DC/DC converters on the power board
2	spare		
3	SODS	Start/Stop of data storage, open collector to GND or high impedance	Trigger CSRM data storing
4	SOE	Start/Stop of experiment, open collector to GND or high impedance	Startup / Shut down the CSRM and CSVM
5	LO	Lift off, open collector to GND or high impedance	Synchronization of CSRM and ViTo, data timestamp

Pin	Name	Specification	Usage
6	EXP out+	Non-inverted experiment data from CSRM to RXSM, RS-422	Transmit data from CSRM to RXSM
7	EXP out-	Inverted experiment data to from CSRM to RXSM, RS-422	Transmit data from CSRM to RXSM
8	28V GND	Power GND	Ground connection of CSRM and CSVM
9	+28V	Battery Power, 24-36 V unregulated, $I_{peak} < 3A$	Power the CSRM and CSVM via a DC/DC converter
10	28 V Charging Power	Experiment battery charging power	Not used
11	spare		
12	UTE	not available	Not used
13	EXP in+	Non-inverted data from RXSM to CSRM, RS-422	Receive CSRM control data
14	EXP in-	Inverted data from RXSM to CSRM, RS-422	Receive CSRM control data
15	28 V GND	Power GND	Ground connection of CSRM and CSVM

Table 11: RXSM Electrical Interface

The SOE, SODS and LO signals are transferred by optocouplers as recommended as in the RX User-Manual V7-3. The electrical layout of this interface can be seen below.

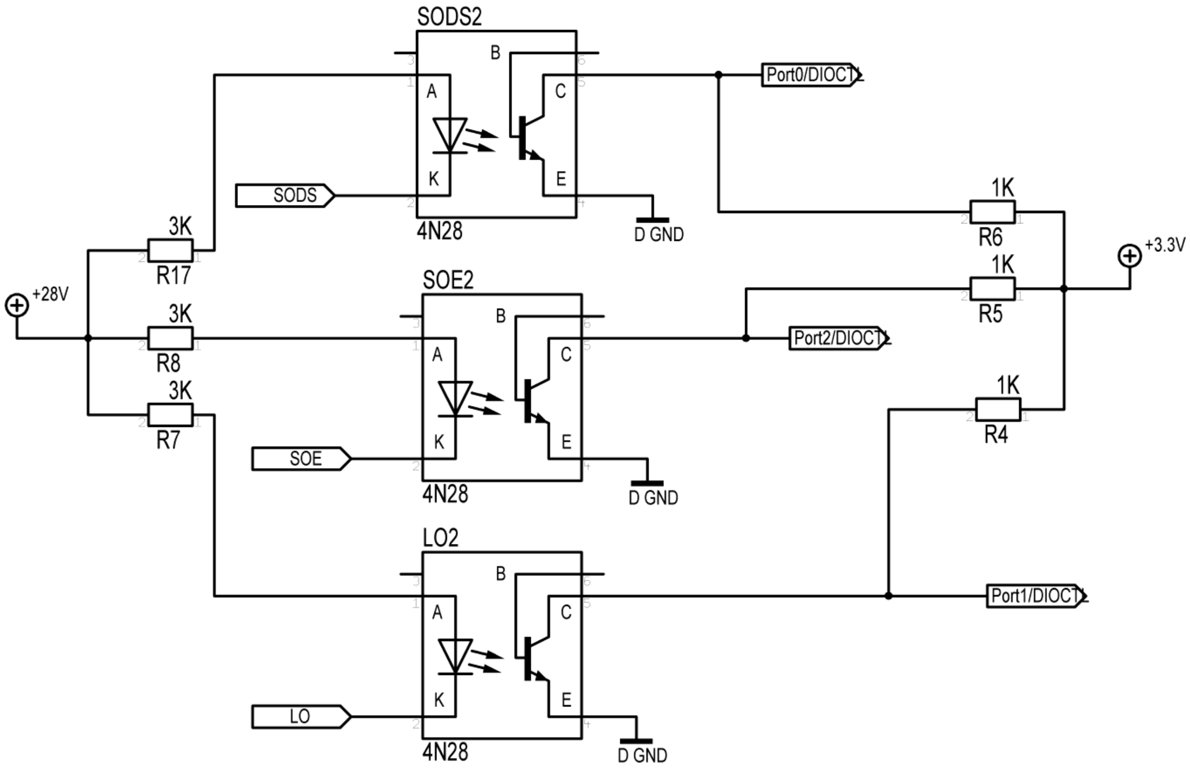


Figure 19: Optocoupler schematic

Experiment data is exchanged using the RS-422 protocol. Therefore a RS-422 converter chip is used as shown below.

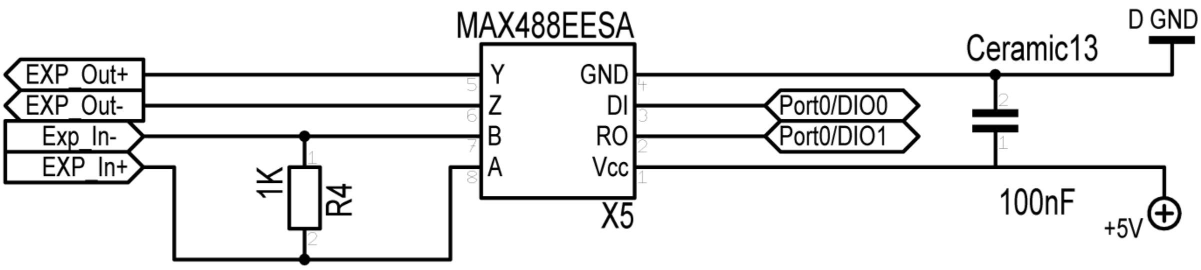


Figure 20: RS-422 implementation

4.2.2.2 CERESS Bus

The connection for power and command & control between the CSRM and the CSVM is divided into several connections:

- SGP, the single ground point (CERESS is floating ground)
- 3.3V Digital I/O 1

- 3.3V Digital I/O 2
- 3.3V Digital I/O 3
- 3.3V Digital I/O 4
- 24V Digital In
- 24V Digital Out
- Analogue I/O
- PWR, providing 3.3V, 5V, 24V.

The power connector must be able to accommodate the three input voltages. For each voltage there should be three pins for voltage and three pins for ground. This adds up to a total of 18 pins, the connectors used will therefore be a 25 pin power connector on rocket module side and a D-Sub-25 connector on verification module side.

Pin	Signal	Pin	Signal
1	+3.3V PWR	2	3.3V Ret
3	+3.3V PWR	4	3.3V Ret
5	+3.3V PWR	6	3.3V Ret
7	Spare	8	Spare
9	+5V PWR	10	5V Ret
11	+5V PWR	12	5V Ret
13	+5V PWR	14	5V Ret
15	Spare	16	Spare
17	+24V PWR	18	24V Ret
19	+24V PWR	20	24V Ret
21	+24V PWR	22	24V Ret
23	Spare	24	spare
25	Spare		

Table 12: Power Connector Layout

The main computing unit provides four 50pin connectors for digital input/output and one 50pin connecter for analogue input. Two of the digital connectors and about half of the analogue connector will remain in the rocket module, while the remaining connectors and pins are forwarded to the verification module.

The digital 50pin connectors of the main computing unit are soldered to a D-Sub 50 plug that leads out of the CRM. The P4 and P5 digital connectors of the sbRIO are forwarded in this way. The pin-out can be seen in Chapter 4.3.1.1.

Not every connection is used in the CERESS Mission, but is provided for future experiments. See 9.2Appendix C for more detailed signal-, connector- and pin-definition.

4.2.2.3 CERESS Rocket Module internal interfaces

The Rocket module will consist of three PCB: One for each DC/DC convertor and one housing interface electronics, like the RS-422 chip and optocouplers.

The power boards are using separate power and data outputs. Therefore two Samtec IPL1 connectors are used per PCB. Due to volume restrictions, the interface PCB will not use any connectors, cables will be soldered directly to the board and the rocket modules interface connector to the REXUS service module.

The sbRIO's power supply is implemented using a two wire power connector that supplies +24 and 24 Ret to the sbRIO's power port.

The rocket modules instrumentation will be placed externally. Therefore a power and data interface is needed. Power is provided by the mainboard via two 9-pin power connectors that in in a D-Sub 9 connector, allowing easy cable replacement. Since the sensors are already soldered to breakout boards with connected power and digital grounds, the ground connection will be soldered directly to breakout boards and connects together with the data lines to the sbRIO's DIO connectors.

4.2.2.4 CERESS Verification Module internal interfaces

The verification module will use a main power and data distribution board. The specific interfaces will have to be defined as soon as all components interfaces, especially the GoPro's, are defined.

4.2.2.5 REXUS Bus

The CERESS Rocket Module uses the Power- and Control-Interface of the RXSM. The control-interface uses the RS-422 (EXP in/out). Both interfaces are implemented as D-SUB Connector:

Pin	Name	Specification	Usage
1	+28V	RXSM Power, 24-36 V unregulated, $I_{peak} < 3$ A	Power the CERESS Rocket Module and CERESS Verification Module via DC/DC converters on the power board
2	spare		
3	SODS	Start/Stop of data storage, open collector to GND or high impedance	Trigger CERESS Rocket Module data storing
4	SOE	Start/Stop of experiment, open collector to GND	Startup / Shut down the CERESS Rocket Module

Pin	Name	Specification	Usage
		or high impedance	and CERESS Verification Module
5	LO	Lift off, open collector to GND or high impedance	Synchronization of CERESS Rocket Module and ViTo, data timestamp
6	EXP out+	Non-inverted experiment data from CERESS Rocket Module to RXSM, RS-422	Transmit data from CERESS Rocket Module to RXSM
7	EXP out-	Inverted experiment data to from CERESS Rocket Module to RXSM, RS-422	Transmit data from CERESS Rocket Module to RXSM
8	28V GND	Power GND	Ground connection of CERESS Rocket Module and CERESS Verification Module
9	+28V	Battery Power, 24-36 V unregulated, $I_{peak} < 3A$	Power the CERESS Rocket Module and CERESS Verification Module via a DC/DC converter
10	28 V Charging Power	Experiment battery charging power	Not used
11	spare		
12	UTE	not available	Not used
13	EXP in+	Non-inverted data from RXSM to CERESS Rocket Module, RS-422	Receive CERESS Rocket Module control data
14	EXP in-	Inverted data from RXSM to CERESS Rocket Module, RS-422	Receive CERESS Rocket Module control data
15	28 V GND	Power GND	Ground connection of CERESS Rocket Module and CERESS Verification Module

Table 13: RXSM Electrical Interface

4.2.2.6 CERESS Bus

The connection for power and command & control between the CERESS Rocket Module and the CERESS Verification Module is divided into several connections:

- CGP, the common ground point (CERESS is floating ground)
- 3.3V Digital I/O 1

- 3.3V Digital I/O 2
- 3.3V Digital I/O 3
- 3.3V Digital I/O 4
- 24V Digital In
- 24V Digital Out
- Analogue I/O
- PWR, providing 3.3V, 5V, 24V, 28V unregulated REXUS power.

The power connector must be able to accommodate the four input voltages. For each voltage there should be three pins for voltage and three pins for ground. This adds up to a total of 24 pins, the connector used will therefore be a D-Sub-25 connector.

Pin	Signal	Pin	Signal
1	+3.3V PWR	2	3.3V GND
3	+3.3V PWR	4	3.3V GND
5	+3.3V PWR	6	3.3V GND
7	+5V PWR	8	5V GND
9	+5V PWR	10	5V GND
11	+5V PWR	12	5V GND
13	+24V PWR	14	24V GND
15	+24V PWR	16	24V GND
17	+24V PWR	18	24V GND
19	Spare	20	+28V unregulated PWR
21	28V unregulated GND	22	+28V unregulated PWR
23	28V unregulated GND	24	+28V unregulated PWR
25	28V unregulated GND		

Table 14: Power Connector Layout

The main computing unit provides four 50pin connectors for digital input/output and one 50pin connecter for analogue input. Two of the digital connectors and about half of the analogue connector will remain in the rocket module, while the remaining connectors and pins are forwarded to the verification module.

The digital 50pin connectors of the main computing unit are soldered to a D-Sub 50 plug that leads out of the CRM. The P4 and P5 digital connectors of the sbRIO are forwarded in this way. The pin-out can be seen in Chapter 4.3.1.1.

Not every connection is used in the CERESS Mission, but is provided for future experiments. See 9.2Appendix C for more detailed signal-, connector- and pin-definition.

4.2.2.7 CERESS Rocket Module internal interfaces

The CERESS Electric Power System (EPS) and the CERESS Command- and Data-Handling are developed with a top to down approach and are defined in the next and final iteration of the electrical systems, based on the definition of the REXUS- and CERESS Bus.

4.2.2.8 CERESS Verification Module internal interfaces

The CERESS Electric Power System (EPS) and the CERESS Command- and Data-Handling are developed with a top to down approach and are defined in the next and final iteration of the electrical systems, based on the definition of the REXUS- and CERESS Bus.

4.2.3 Thermal

The operating temperature of the pirani type fine pressure sensor needs to be above +10°C. The storage temperature of the pirani sensor shall not be below -20°C. These requirements are fulfilled by a heating for the pirani sensor, which is implemented as a heating foil. The impact of the heating to the rest of the REXUS Rocket is minimised by thermal isolation of the pirani sensor with heating.

4.3 Experiment Components

In the following section the implementation of the components of the CERESS system are described.

A summary of the mechanical properties is given in the table below:

Experiment mass (in kg):	2.98 (+4.5)
Experiment dimensions (in m):	Ø0.356 x 0.12
Experiment footprint area (in m2):	0.3982
Experiment volume (in m3):	0.04778
Experiment expected COG (center of gravity) position:	G_x: 2.8mm G_y: -0.9mm G_z: 47.9mm (from lowest surface of the hull)

Table 15: Experiment Summary

4.3.1 CERESS Rocket Module

4.3.1.1 Main Computation Unit (sbRIO-9642)

The heart of the Command and Control / OBDH system is the “National Instruments sbRIO-9642”. It is responsible for all experiment control, on-board data handling and data exchange with the REXUS service module.

This single-board Reconfigurable Input Output (sbRIO) provides a FPGA with 2 Million Gates, a real-time processor, 4 analogue outputs, 32 analogue inputs, 110 digital I/O at 3.3 V, 32 Digital Inputs at 24 V and 32 Digital outputs at 24V.

The sbRIO will be configured using LabView. The usage of blocks within the language will provide the possibility to develop a configurable system for future teams.

The used pin connectors of the sbRIO are shown in the tables below:

P2 Digital Connector					
1	D GND	Relay1 GND	2	Port0/DIOCTL	Relay1
3	Port0/DIO0	Accelerometer1 SPI SPC	4	Port0/DIO9	Accelerometer1 SPI DIN
5	Port0/DIO1	Accelerometer1 SPI DOUT	6	+5V sbRIO	No Connection
7	Port0/DIO2	Accelerometer1 SPI Enable	8	D GND	Accelerometer1 GND
9	Port0/DIO3	Accelerometer2 SPI SPC	10	+5V sbRIO	No Connection
11	Port0/DIO4	Accelerometer2 SPI DIN	12	D GND	Accelerometer2 GND
13	Port0/DIO5	Accelerometer2 SPI DOUT	14	D GND	No Connection
15	Port0/DIO6	Accelerometer2 SPI Enable	16	D GND	No Connection
17	Port0/DIO7	Accelerometer3 SPI SPC	18	D GND	Accelerometer3 GND
19	Port0/DIO8	Accelerometer3 SPI DIN	20	D GND	No Connection
21	Port1/DIO9	Accelerometer3 SPI DOUT	22	Port1/DIOCTL	Relay2
23	Port1/DIO0	Accelerometer3 SPI Enable	24	D GND	Relay2 GND
25	Port1/DIO1	Accelerometer4 SPI SPC	26	D GND	Accelerometer4 GND
27	Port1/DIO2	Accelerometer4 SPI DIN	28	D GND	No Connection
29	Port1/DIO3	Accelerometer4 SPI DOUT	30	D GND	No Connection
31	Port1/DIO4	Accelerometer4 SPI Enable	32	D GND	No Connection
33	Port1/DIO5	Gyro1 SPI SPC	34	D GND	Gyro1 GND
35	Port1/DIO6	Gyro1 SPI DIN	36	D GND	No Connection
37	Port1/DIO7	Gyro1 SPI DOUT	38	D GND	No Connection

39	Port1/DIO8	Gyro1 SPI Enable	40	D GND	Relay3 GND
41	Port2/DIO9	Data Storage1 SPI CLK	42	Port2/DIOCTL	Relay3
43	Port2/DIO0	Data Storage1 SPI DIN	44	D GND	Data Storage1 GND
45	Port2/DIO6	Data Storage1 SPI DOUT	46	D GND	No Connection
47	Port2/DIO7	Data Storage1 SPI Enable	48	D GND	No Connection
49	Port2/DIO8	No Connection	50	D GND	No Connection

Table 16: P2 Digital Connector Pin usage

	P3 Digital Connector				
1	D GND	SODS GND	2	Port0/DIOCTL	SODS Signal
3	Port0/DIO0	Accelerometer5 SPI SPC	4	Port0/DIO9	Accelerometer5 GND
5	Port0/DIO1	Accelerometer5 SPI DIN	6	+5V sbRIO	No Connection
7	Port0/DIO2	Accelerometer5 SPI DOUT	8	D GND	No Connection
9	Port0/DIO3	Accelerometer5 SPI Enable	10	+5V sbRIO	No Connection
11	Port0/DIO4	Accelerometer6 SPI SPC	12	D GND	Accelerometer6 GND
13	Port0/DIO5	Accelerometer6 SPI DIN	14	D GND	No Connection
15	Port0/DIO6	Accelerometer6 SPI DOUT	16	D GND	No Connection
17	Port0/DIO7	Accelerometer7 SPI Enable	18	D GND	Accelerometer7 GND
19	Port0/DIO8	Accelerometer7 SPI SPC	20	D GND	LO GND
21	Port1/DIO9	Accelerometer7 SPI DIN	22	Port1/DIOCTL	LO Signal
23	Port1/DIO0	Accelerometer7 SPI DOUT	24	D GND	No Connection
25	Port1/DIO1	Accelerometer7 SPI Enable	26	D GND	No Connection
27	Port1/DIO2	Accelerometer8 SPI SPC	28	D GND	Accelerometer8 GND
29	Port1/DIO3	Accelerometer8 SPI DIN	30	D GND	No Connection
31	Port1/DIO4	Accelerometer8 SPI DOUT	32	D GND	No Connection

33	Port1/DIO5	Accelerometer8 SPI Enable	34	D GND	No Connection
35	Port1/DIO6	Gyro2 SPI SPC	36	D GND	Gyro2 GND
37	Port1/DIO7	Gyro2 SPI DIN	38	D GND	No Connection
39	Port1/DIO8	Gyro2 SPI DOUT	40	D GND	No Connection
41	Port2/DIO9	Gyro2 SPI Enable	42	Port2/DIOCTL	No Connection
43	Port2/DIO0	Data Storage2 SPI CLK	44	D GND	Data Storage2 GND
45	Port9/DIO6	Data Storage2 SPI DIN	46	D GND	No Connection
47	Port9/DIO7	Data Storage2 SPI DOUT	48	+5V sbRIO	No Connection
49	Port9/DIO8	Data Storage2 SPI Enable	50	D GND	No Connection

Table 17: P3 Digital Connector Pin usage

	P4 Digital Connector				
1	D GND	No Connection	2	Port0/DIOCTL	No Connection
3	Port0/DIO0	No Connection	4	Port0/DIO9	No Connection
5	Port0/DIO1	No Connection	6	5V	No Connection
7	Port0/DIO2	No Connection	8	D GND	No Connection
9	Port0/DIO3	No Connection	10	5V	No Connection
11	Port0/DIO4	No Connection	12	D GND	No Connection
13	Port0/DIO5	No Connection	14	D GND	No Connection
15	Port0/DIO6	No Connection	16	D GND	No Connection
17	Port0/DIO7	No Connection	18	D GND	No Connection
19	Port0/DIO8	No Connection	20	D GND	No Connection
21	Port1/DIO9	No Connection	22	Port1/DIOCTL	No Connection
23	Port1/DIO0	No Connection	24	D GND	No Connection
25	Port1/DIO1	No Connection	26	D GND	No Connection
27	Port1/DIO2	No Connection	28	D GND	No Connection
29	Port1/DIO3	No Connection	30	D GND	No Connection
31	Port1/DIO4	No Connection	32	D GND	No Connection
33	Port1/DIO5	No Connection	34	D GND	No Connection
35	Port1/DIO6	No Connection	36	D GND	No Connection
37	Port1/DIO7	No Connection	38	D GND	No Connection
39	Port1/DIO8	No Connection	40	D GND	No Connection
41	Port2/DIO9	No Connection	42	Port2/DIOCTL	No Connection
43	Port2/DIO0	No Connection	44	D GND	No Connection
45	Port2/DIO1	Corse Pressure	46	D GND	Coarse Pressure

		DIN			DIN GND
47	Port2/DIO2	Coarse Pressure DOUT	48	D GND	Coarse Pressure DOUT GND
49	Port2/DIO3	Coarse Pressure SCLK	50	D GND	Coarse Pressure SCLK GND

Table 18 :P4 Digital Connector Pin usage

P5 Digital Connector					
1	D GND	No Connection	2	Port7/DIOCTL	No Connection
3	Port7/DIO0	No Connection	4	Port7/DIO9	No Connection
5	Port7/DIO1	No Connection	6	D GND	No Connection
7	Port7/DIO2	No Connection	8	D GND	Heating GND
9	Port7/DIO3	Heating	10	D GND	Activate Coarse Pressure Sensor GND
11	Port3/DIO9	Activate Coarse Pressure Sensor	12	Port3/DIOCTL	No Connection
13	Port3/DIO0	No Connection	14	D GND	Activate Fine Pressure Sensor GND
15	Port3/DIO1	Activate Fine Pressure Sensor	16	D GND	Feedback Camera P GND
17	Port3/DIO2	Feedback Camera P	18	D GND	Feedback Camera S GND
19	Port3/DIO3	Feedback Camera S	20	D GND	Activate Camera P GND
21	Port3/DIO4	Activate Camera P	22	D GND	Activate Camera S GND
23	Port3/DIO5	Activate Camera S	24	D GND	Activate Camera GND
25	Port3/DIO6	Activate Camera	26	D GND	Feedback Safety Pin GND
27	Port3/DIO7	Feedback Safety Pin	28	D GND	Activate Melting Wire 3 GND
29	Port3/DIO8	Activate Melting Wire 3	30	D GND	Activate Melting Wire 2 GND
31	Port4/DIO9	Activate Melting Wire 2	32	Port4/DIOCTL	No Connection
33	Port4/DIO0	No Connection	34	D GND	Activate Melting Wire 1 GND
35	Port4/DIO1	Activate Melting Wire 1	36	D GND	Feedback Melting Wire 3 enable GND

37	Port4/DIO2	Feedback Melting Wire enable 3	38	D GND	Feedback Melting Wire 2 enable GND
39	Port4/DIO3	Feedback Melting Wire 2 enable	40	D GND	Feedback Melting Wire 1 enable GND
41	Port4/DIO4	Feedback Melting Wire 1 enable	42	D GND	Feedback melting wire 1 burn GND
43	Port4/DIO5	Feedback melting wire 1 burn	44	5V	No Connection
45	Port4/DIO6		46	D GND	Feedback melting wire 2 burn GND
47	Port4/DIO7	Feedback melting wire 2 burn	48	5V	No Connection
49	Port4/DIO8	Feedback melting wire 3 burn	50	D GND	Feedback melting wire 3 burn GND

Table 19: P5 Digital Connector Pin usage

J7 Analogue Connector					
1	AI GND	Thermistor4 GND	2	AI0	Thermistor4
3	AI8	Thermistor1	4	AI9	Thermistor2
5	AI1	Thermistor3	6	AI GND	Thermistor5 GND
7	AI2	Thermistor5	8	AI10	Fine Pressure High
9	AI11	Fine Pressure Low	10	AI3	Thermistor6
11	AI GND	Thermistor6 GND	12	AI4	No Connection
13	AI12	HSCS1	14	AI13	DC/DC Voltage1
15	AI5	No Connection	16	AI GND	No Connection
17	AI6	HSCS2	18	AI14	DC/DC Voltage2
19	AI15	HSCS3	20	AI7	DC/DC Voltage3
21	AI GND	No Connection	22	AI16	No Connection
23	AI24	No Connection	24	AI25	No Connection
25	AI17	No Connection	26	AI GND	No Connection
27	AI18	No Connection	28	AI26	No Connection
29	AI27	No Connection	30	AI19	No Connection
31	AI GND	No Connection	32	AI20	No Connection
33	AI28	No Connection	34	AI29	No Connection
35	AI21	No Connection	36	AI GND	No Connection
37	AI22	No Connection	38	AI30	No Connection
39	AI31	No Connection	40	AI23	No Connection
41	AI SENSE	No Connection	42	AO GND	No Connection
43	AO3	No Connection	44	AO GND	No Connection

45	AO2	No Connection	46	AO GND	No Connection
47	AO1	No Connection	48	AO GND	No Connection
49	AO0	No Connection	50	AI GND	No Connection

Table 20: Analogue Connector Pin usage

4.3.1.2 Gyroscope (L3G4200D)

The Gyroscope provides the possibility to be run on different ranges. It is only necessary to switch the configuration and this gyro can be used for high rotatory velocities (around 5,5Hz) or slow ones (around 0,7Hz). Both configurations are flown for best results. For communication the SPI is used.

4.3.1.3 Accelerometer (LIS331HH)

Similar to the Gyroscope this sensor can be used. During engine-powered ascending of the rocket the +-24g mode is used (wider range, lower accuracy) using four sensors, during free-flight further four sensor provide measurements within the range of +-6g (lower range, higher accuracy). For communication the SPI is used.

4.3.1.4 Power Supply (TEN 40-2420 & TEN60-2415WI)

As a regulated power source the products of TRACO POWER are well known and already flown on other REXUS-Projects.

4.3.1.5 Structure

Structure is everything needed to keep the components in place. In this case it includes also the structure of the CERESS Verification Module for easier budgeting.

4.3.2 CERESS Verification Module

The CERESS Verification Module houses the sensors that aren’t relevant for the trajectory but useful for event detection or demonstration of the CERESS Rocket Module’s functionality.

To verify the control of the CERESS Verification Module by the CERESS Rocket Module-CERESS Verification Module Interface three melting wires are blown during flight.

4.3.2.1 Camera (GoPro HD2)

The Camera is implemented as a GoPro HD2. The batteries are removed. The power supply is realized by the 5V USB power supply of the camera. Control of the camera is implemented by switching the buttons of the camera electronically.

The “GoPro HD2” Camera’s predecessor was already flown on the REXUS-Project EXPLORE. The availability of the configuring know-how, the high shock resistance and the high-resolution video output makes this device very attractive.

4.3.2.2 Pressure Sensors (MS5534C & TTR 91)

The Altitude determination is realised by measuring the ambient pressure. Two Sensors are selected to cover the required measurement range.

MS5534C is a piezoresistive pressure sensor with a measurement range from 10 to 1100 mbar. The interface to the sbRIO is a digital three wire interface.

TTR91 is a Pirani-cold-cathode-transmitter that covers the measurement range from 5e-4 to 1000mBar with an error of 15% below 100mbar. The analogue output is proportional to the measured ambient pressure. This sensor was selected due to the limited available measurement principles at near vacuum conditions on altitudes of 100km.

4.3.2.3 Temperature Sensor (KT103J2)

The Temperature sensors are implemented as Thermistors due to the simple measurement circuit. One Thermistor of the CERESS Verification Module is located at the heating of the Pirani Sensor. Two Thermistors of the CERESS Rocket Module are located at the DC/DC converters and one is located at the sbRIO.

4.3.2.4 Meltingwires

The melting wires demonstrate the possibility to perform action on the verification module resp. the future TUM-experiment. The three wires will be blown using one of the following triggers:

- Time (pre-defined)
- Event (special values of a sensor achieved)
- Command from CERESS Ground Module (uplinked)

4.3.2.5 Meltingwire Driver

The Melting Board is supposed to forward the required Amps to the melting wires if the input from the sbRIO occurs.

4.3.3 Part Availability

Type	Exact Name	Manufacturer / Supplier	Current status of supplier
Temperature	KT103J2	US Sensors	Delivered
(high) Pressure	TTR 91	Oerlikon Leybold Vacuum	Delivered
(low) Pressure	MS5534C	AMSYS	Delivered
Acceleration (launch)	LIS331HH	sparkfun.com	Delivered
Acceleration (freefly)	LIS331HH	sparkfun.com	Delivered

Type	Exact Name	Manufacturer / Supplier	Current status of supplier
Gyro (launch)	L3G4200D	sparkfun.com	Delivered
Gyro (freefly)	L3G4200D	sparkfun.com	Delivered
Processing Unit	National Instruments sbRIO_9642	National Instruments	Delivered
Power Supply	TRACO POWER TEN 40-2420	Farnell.com	Delivered
	TRACO POWER TEN 60-2415	Farnell.com	Delivered
	TRACO POWER TEP 75-4815WI	Farnell.com	Delivered
Solid State Relais	Crycom CN024D05	Farnell.com	Delivered
High side current sensors	MAX4172ESA+	Farnell.com	Delivered
RS-422 Chip	MAX488EESA+	Farnell.com	Delivered
Small components	Capcitators, resistors,…	Various suppliers	Delivered
SD-Card Board	NI 9802	National Instruments	Delivered
Camera	GoPro HD2	camforpro.com	Delivered
Melting wires		TUM-LRT-workshop	Delivered
Structure		TUM-LRT-workshop	Delivered

Table 21: Part Availability

4.4 Mechanical Design

4.4.1 Setting

The Ceress Rocket Module is located inside the shielding. The Ceress Verification Module is mounted directly to the hull and bulkhead, see chapter 4.2.1 for details.

As well as the hull the shielding box has a hatch. The hatch is located directly behind the outer hatch. The two hatches injure the late access possibility of the sbRIO, there i.e. the RJ-45 connector, the reset button and the status LEDs (see Figure 21: Inner Hatch)

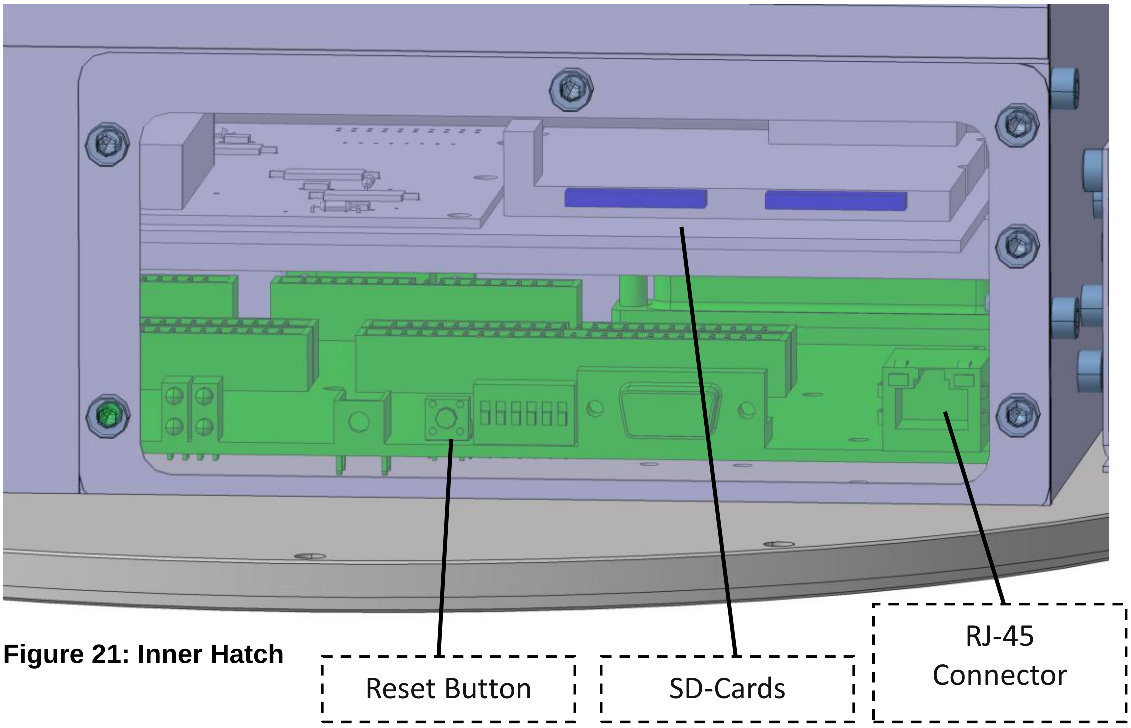


Figure 21: Inner Hatch

The shielding is designed with a frame structure, to carry the loads, and shielding plates. The front and back plate are secured against lateral oscillation with groove in the bulkhead. All other connections are done with screws.

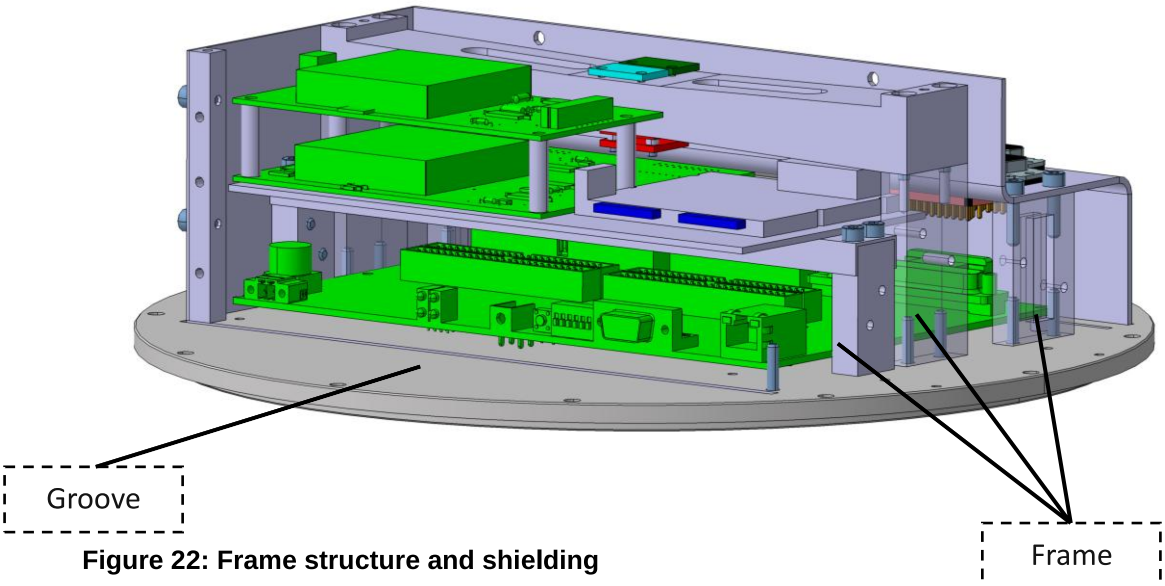


Figure 22: Frame structure and shielding

Inside the shielding are the sbRIO, two Accelerometers, two Gyros located, the SD-Card Board, the two Power Boards and the interface Board. (See Figure 23: The electronic Boards)

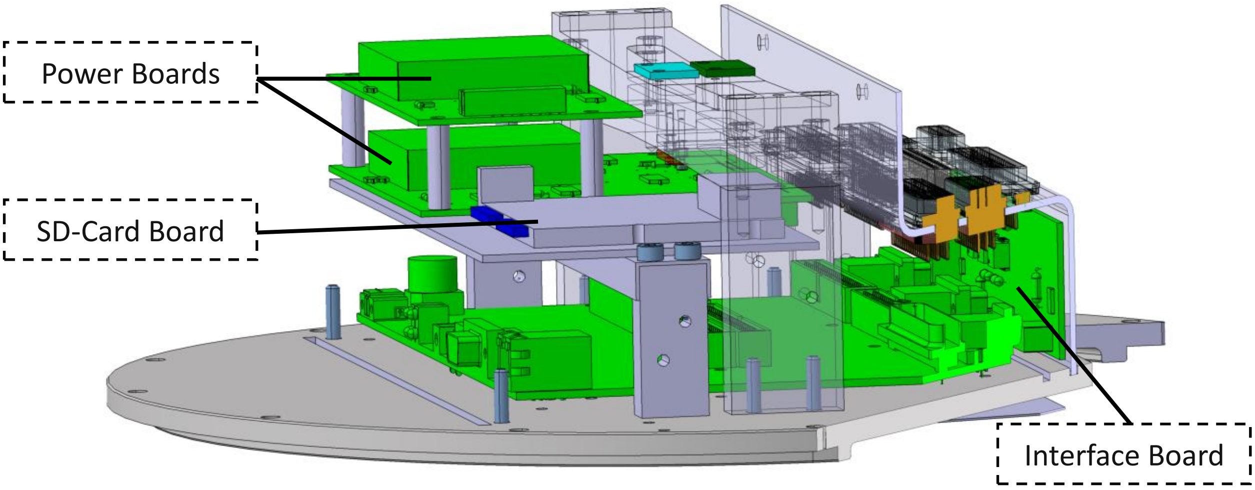


Figure 23: The electronic Boards

To be able to calculate the rotation axis just with accelerometers, they have to be placed as a triangle. And to be redundant there is a tetrahedron configuration with 4 sensors. 3 of the 4 sensors are mounted on the rear side of the bulkhead. The fourth is with the gyro placed on a crossbar at the centre of the main rotation axis (X-axis of the rocket) (see Figure 24: Crossbar with Gyro and Accelerometer)

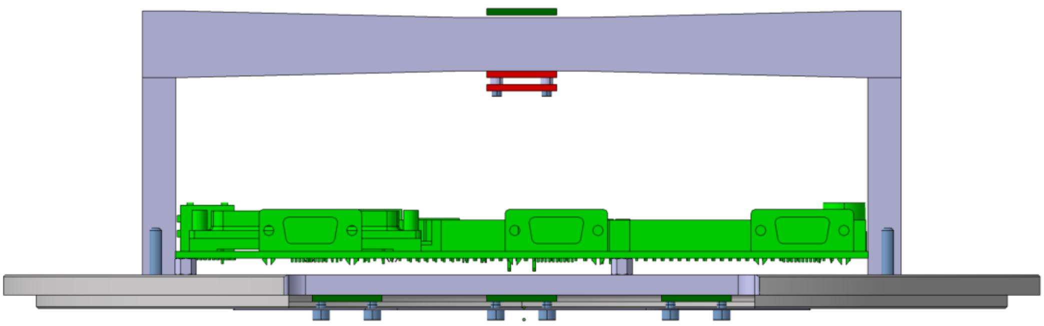


Figure 24: Crossbar with Gyro and Accelerometer

All structural components, shielding, sensor mounts etc. are made from aluminium.

Part	Mass [kg]
(Bulkhead + Hull)	(4.5)
Shielding	0.625
Sensor mounts	0.34
EPS	0.25
Sensors	0.3
Camera	0.2
sbRio	0.3
Wiring	0.3
Summed	2.315 (+4.5)
Margin (30 %)	0.665
Total (+Bulkhead & Hull)	2.98 (+4.5)

Table 22: Mass Budget

4.4.2 FE-Analysis

4.4.2.1 Hull structural analysis

A static stability analysis was carried out for the hull with special attention on the cut-out for the outer hatch.

The boarder conditions were a rigid clamping at the bottom, an overall acceleration of 20 g: 196.2 m/s² and the static force of the other modules (55kg) and the nosecone section (13 kg) with the acceleration of 20g times a safety factor of 1.5: 20012.4N at the upper contact surface (see Figure 25: boarder conditions of the hull)

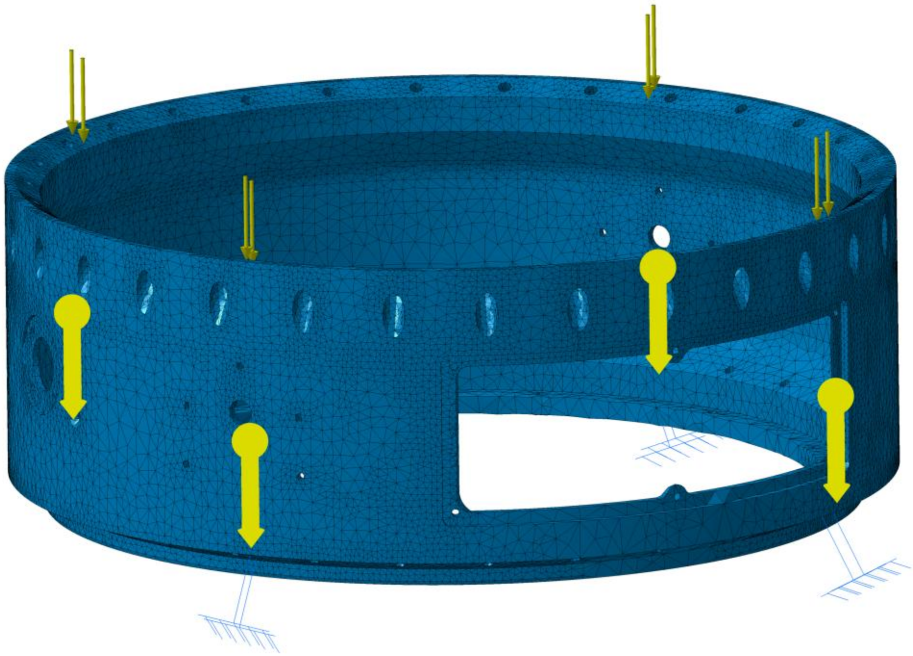


Figure 25: boarder conditions of the hull

Figure 26: Von Mises yield criterionshows the Von Mises yield criterion. The maximum occurs at the top corners of the cut-out. (see Figure 28: Detail of the cut-out corner)

The maximum is 3.47 E+008 N/m²

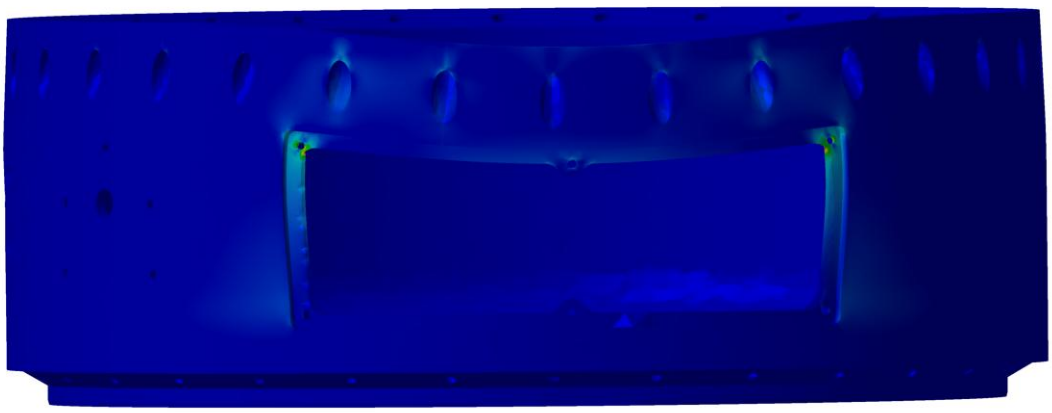


Figure 26: Von Mises yield criterion

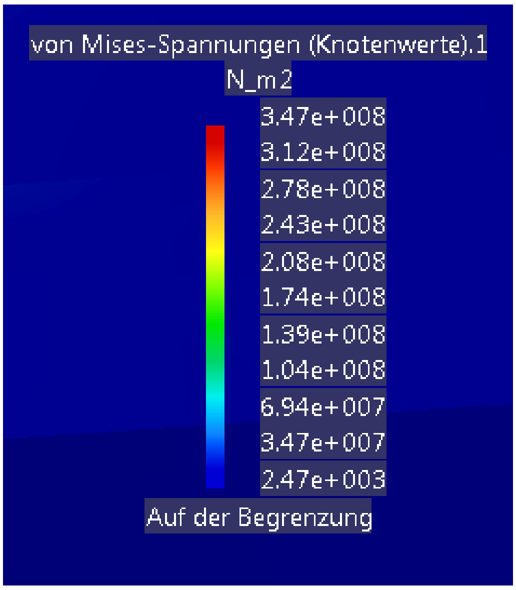


Figure 27: Scale von mises

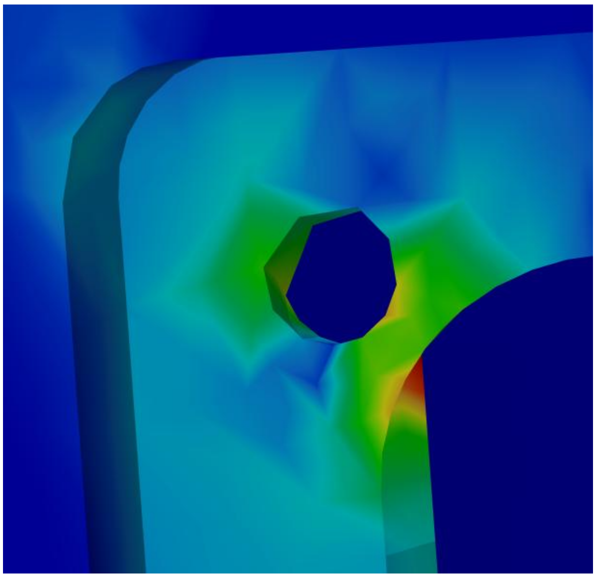


Figure 28: Detail of the cut-out corner

Figure 29: Displacement. As you can see the maximum is at the centre of the cut-out. The maximum displacement is 0.2 mm.

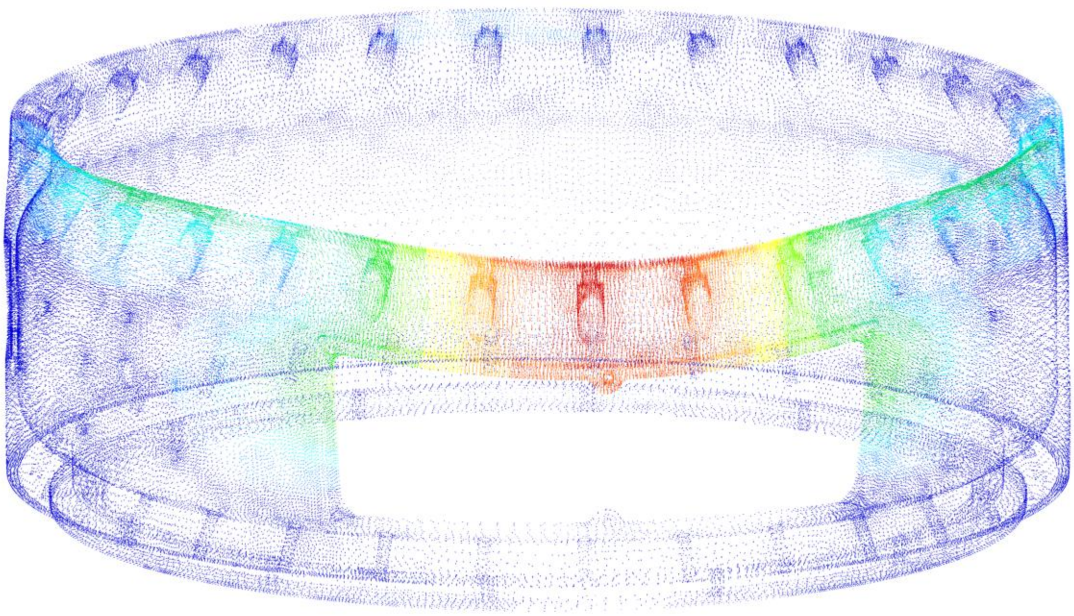


Figure 29: Displacement

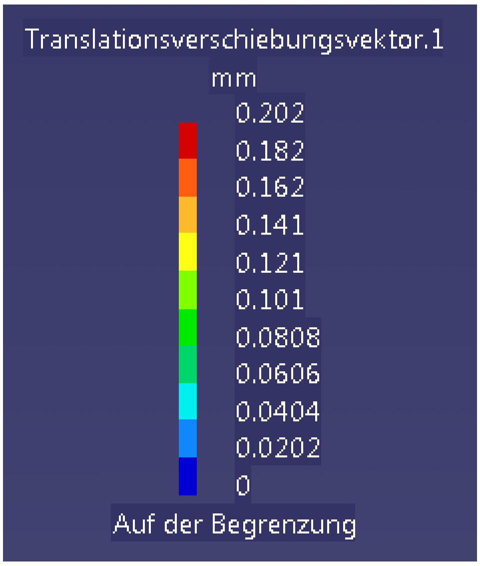


Figure 30: Scale displacement

4.4.2.2 Cross beam natural vibration analysis

A natural vibration analysis was done. The boarder condition was rigid clamping where the position of the screws (see Figure 31: boarder conditions for cross beam)

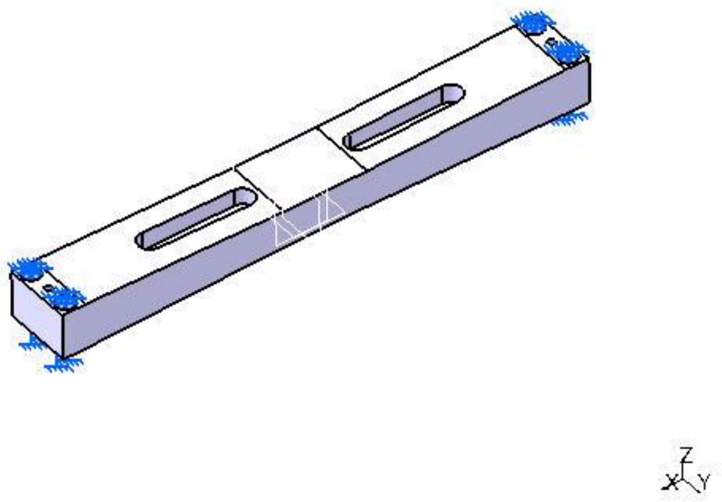


Figure 31: boarder conditions for cross beam

The result of the analysis is shown in Table 23: Natural vibrations of the crossbar. The most relevant mode is the first one; it is a pure translatory motion in z-direction (of the rocket coordinate system) (see Figure 32: 1.mode of the crossbar)

Modus	Frequenz [Hz]	Tx [%]	Ty [%]	Tz [%]	Rx[%]	Ry[%]	Rz[%]
1	2015.5	0.00	0.00	59.33	0.00	0.00	0.00
2	2884.4	0.00	58.47	0.00	0.01	0.00	0.00
3	5003.1	0.56	0.00	0.00	0.00	32.63	0.00
4	5131.0	0.00	0.02	0.00	31.66	0.00	0.00
5	7841.0	0.00	0.00	0.00	0.00	0.00	37.32
6	8946.9	0.00	0.00	15.62	0.00	0.00	0.00
7	11303	0.00	0.00	0.00	0.00	0.00	0.05
8	11433	0.01	18.75	0.00	0.00	0.00	0.00
9	11639	67.73	0.00	0.00	0.00	1.26	0.00
10	13829	5.61	0.00	0.00	0.00	15.55	0.00

Table 23: Natural vibrations

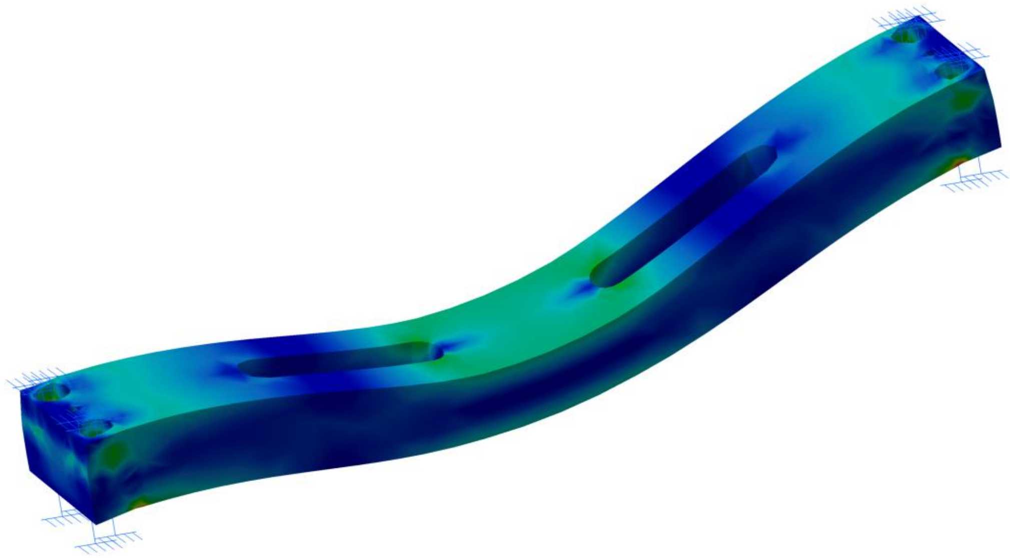


Figure 32: 1.mode of the crossbar

4.5 Electronics Design

This chapter details the electronic design ranging from circuit schematics to printed circuit boards.

4.5.1 System Overview

The electrical system includes the sbRIO, two DC/DC converters, one camera, pressure sensors, temperature sensors, accelerometers, gyros, and melting wires as well as additional components like cabling, connectors and other electrical components.

It can be subdivided into two segments:

- Power system (EPS)
- Command and control / OBDH (C&DH)

An overview of the electrical system can be found below:

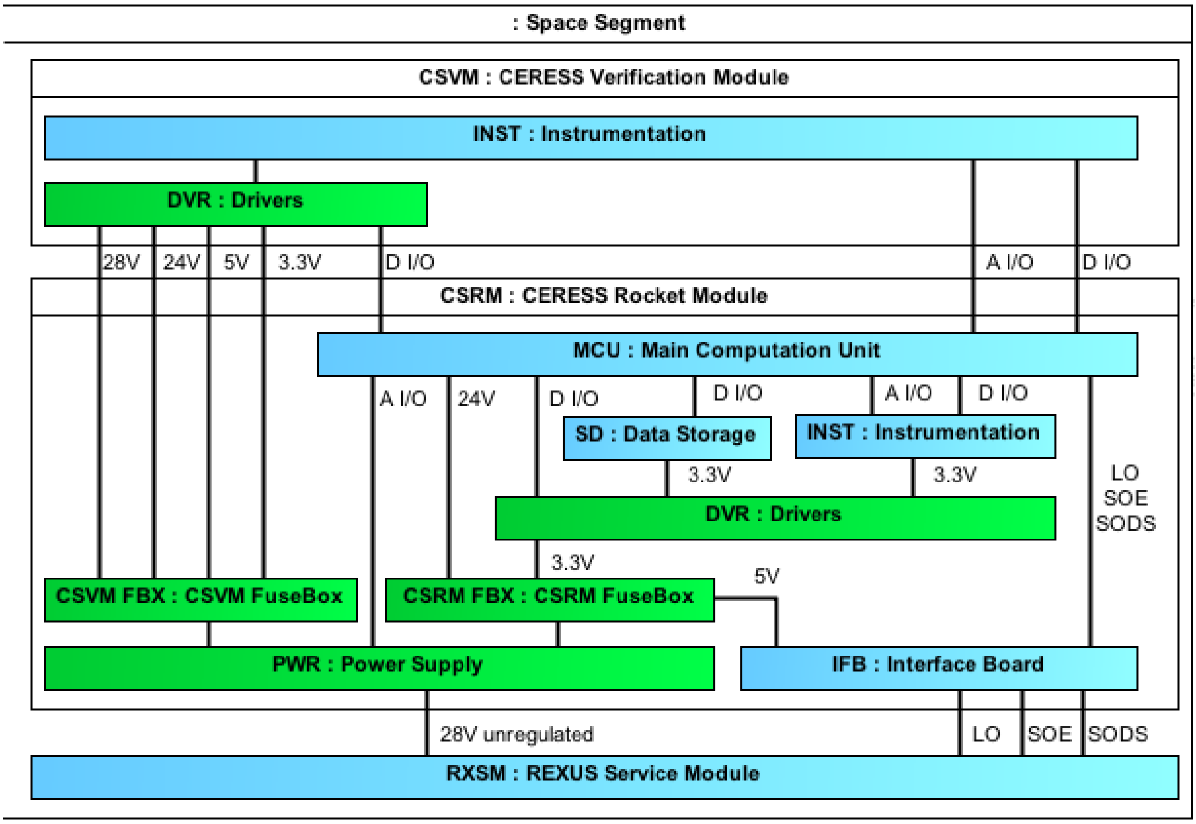


Figure 33: Overview Electrical System

4.5.2 Power System

The electrical power for the CERESS Rocket Module as well as the CERESS Verification Module is supplied by the REXUS service module in the form of unregulated electrical power with a typical voltage of 28VDC. This unregulated power source is converted in the CERESS Rocket Module to provide regulated power for itself and the verification module, as shown below.

In the CERESS Rocket Module, is protected by a PTC self-resetting fuse to prevent overvoltage from the service module to the DC/DC convertors and vice versa. Incoming power is then converted to 3.3VDC, 5VDC and 24VDC in two DC/DC convertors. Directly after the DC/DCs the voltages are split in to two lines each. One line goes together with its respective GND line to the power interface to the verification module. The other line stays in the board for powering components of the rocket module. In each of these lines there is a shunt resistance connected to a high side current sense chip to allow measurement of output current. The 3.3V are used to power the accelerometers and gyros of the rocket. The 3.3V are also connected to the optocouplers in order to allow the experiment to use the 28V signal lines. 24V output is used to power the sbRIO.

The CERESS Verification Module receives its power from the CERESS Bus. 3.3V and 24V run over the sensor drivers. The 3.3V powers the coarse pressure sensor and the heating coils of the melting wire devices, while the 24V bus connects to the fine pressure sensor. The 5V bus is connected to the GoPro camera via the camera driver board.

The verification module also contains an arm plug for the melting wire devices. This plug consists of a D-Sub 15 male connector with two pins separating a power line of the melting wires. The arm plug is a female D-Sub 15 that will close the electrical circuit once it is in place. Therefore the melting wire devices can only be activated with the arm plug plugged in; hence no accidental melting of the nylon wire can occur. There will also be a so called test plug. This plug will also close the electrical circuit, but not via the melting wires. It will route the power over a resistance and a lamp so the command flow can be verified without actually melting the wires.

4.5.3 Command and Control – Hardware

Fehler! Verweisquelle konnte nicht gefunden werden. shows the information flow inside the CERESS rocket and verification modules as well as data protocols used.

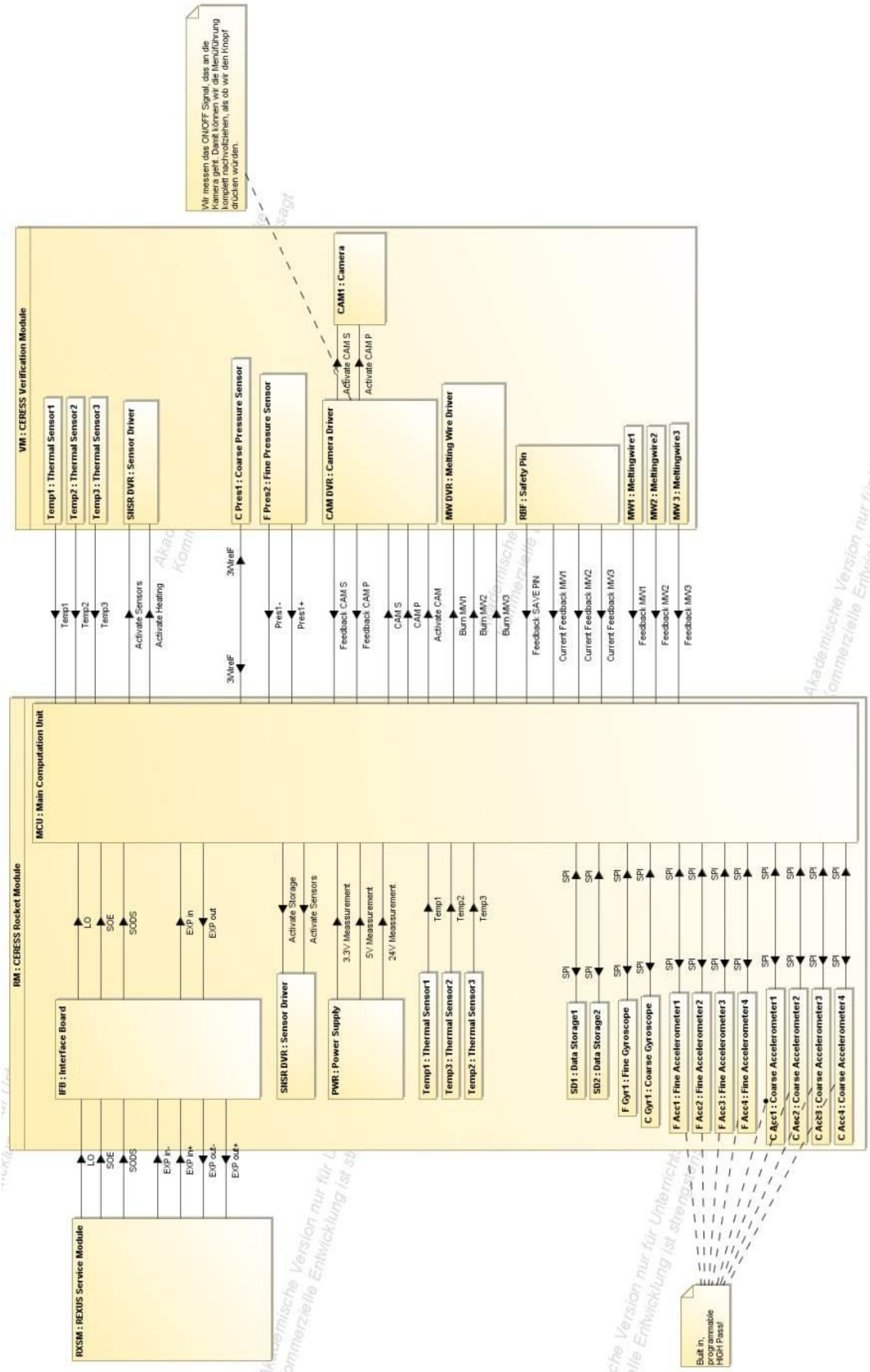


Figure 34: ibd Rocket Module

The REXUS Bus is connected to the CERESS Rocket Module by the Interface Board containing optocouplers, as galvanic isolation of the three command signals SOE, SODS and LO and a RS-422 conversion chip to allow communication with the experiment. And both ensure the floating ground of the Ceress rocket module due to the galvanic isolation.

All sensors of the rocket and service module deliver their signals to the sbRIO via digital interfaces or the analogue inputs. The data is stored in raw form by the Data Storage 1 and 2 and sent to the ground module.

The sbRIO is used to control various relays and circuits that switch sensors, heating foil, camera, melting wires ON/OFF.

The data flow within the sbRIO resp. the software is explained in Chapter4.8.

4.5.3.1 Grounding Concept

The Ceress space segment has several electrical grounds:

- 28V GND from the Rexus SM
- 3.3V Ret and 5V Ret from DC/DC1
- 24V Ret from DC/DC2
- AI GND and D GND from the sbRIO

The Rexus GND is used together with the +28V to power the two DC/DCs and is not connected to any other component of the experiment.

Ceress has a variety of devices both analogue and digital. The signal lines of these devices require a stable ground for representative measurements. They are therefore connected to the sbRIO’s analogue (AI GND) or digital ground (D GND) respectively. The connection is achieved by wiring the devices GND pins to the sbRIO’s ground pins that are located in the 50pin connectors of the board. Internally, the AI GND and D GND as well as the ground lug are connected (cf. sbRIO User Manual). Therefore the sbRIO will contain the single ground point (SGP) for the rocket module components.

The 3.3V Ret, 5V Ret and 24V Ret are forwarded to the verification module together with the corresponding voltage. By twisting these cables together, EMI should be reduced.

4.5.4 Interface Board

As the name implies this board acts as an interface between the Rexus service module and the Ceress rocket module for data, signals and power. Its main function can be broken down the three sub-functions:

- Conversion from and to RS-422 communication standard
- Interpretation and galvanic isolation of the three Rexus signals
- Distribution of 28V power lines and protection from continuous overvoltage

Derived from these sub-functions are three independent circuits that are detailed in the following chapters.

4.5.4.1 RS-422 Convertor

The function of this circuit is to convert telemetry data of the main computation unit and telecommands coming in via the Rexus service module using the RS-422 standard. Outgoing data is converted from a single bit stream to a non-inverted (Exp out+) and an inverted signal (Exp out-). Incoming data is vice-versa converted from a non-inverted (Exp In+) and an inverted signal (Exp out-) to a single bit stream. To achieve this goal, Maxim's RS-422 transceiver MAX488EESA is used.

The circuit is displayed below.

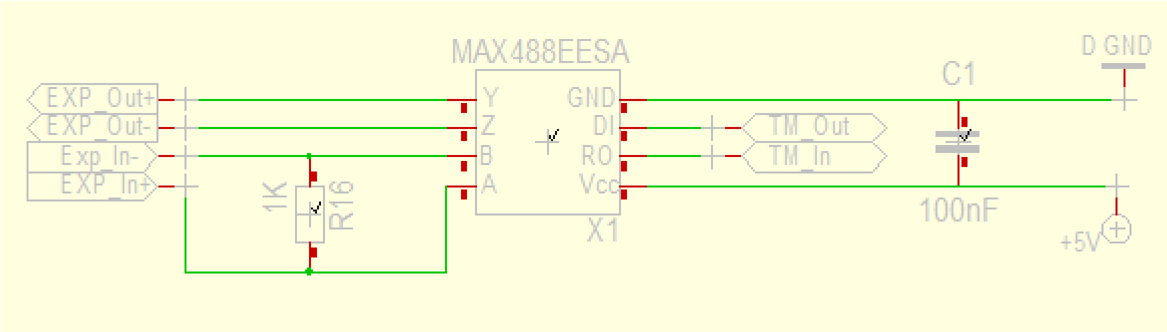


Figure 35: RS-422 Convertor Circuit

In accordance to the Rexus service module, a 1kΩ resistor is implemented between the incoming data lines. Furthermore, a 0.1µF capacitor is inserted between the 5V supply and the ground line to compensate for jitter in the supply voltage.

4.5.4.2 Signal Interpreter

The function of the signal interpreter circuit is to detect changes in the three supplied control lines, while at the same time galvanically isolating the signals in order to prevent the experiment from accidentally switching the LO signal on.

This is achieved by using three optocouplers, consisting of a light source and a phototransistor. Since only the light source can trigger the phototransistor and not the other way around, switching can only occur in one direction. Furthermore, the 28V source of the service module cannot damage any experiment components that are sensitive to overvoltage.

The circuit used is shown below.

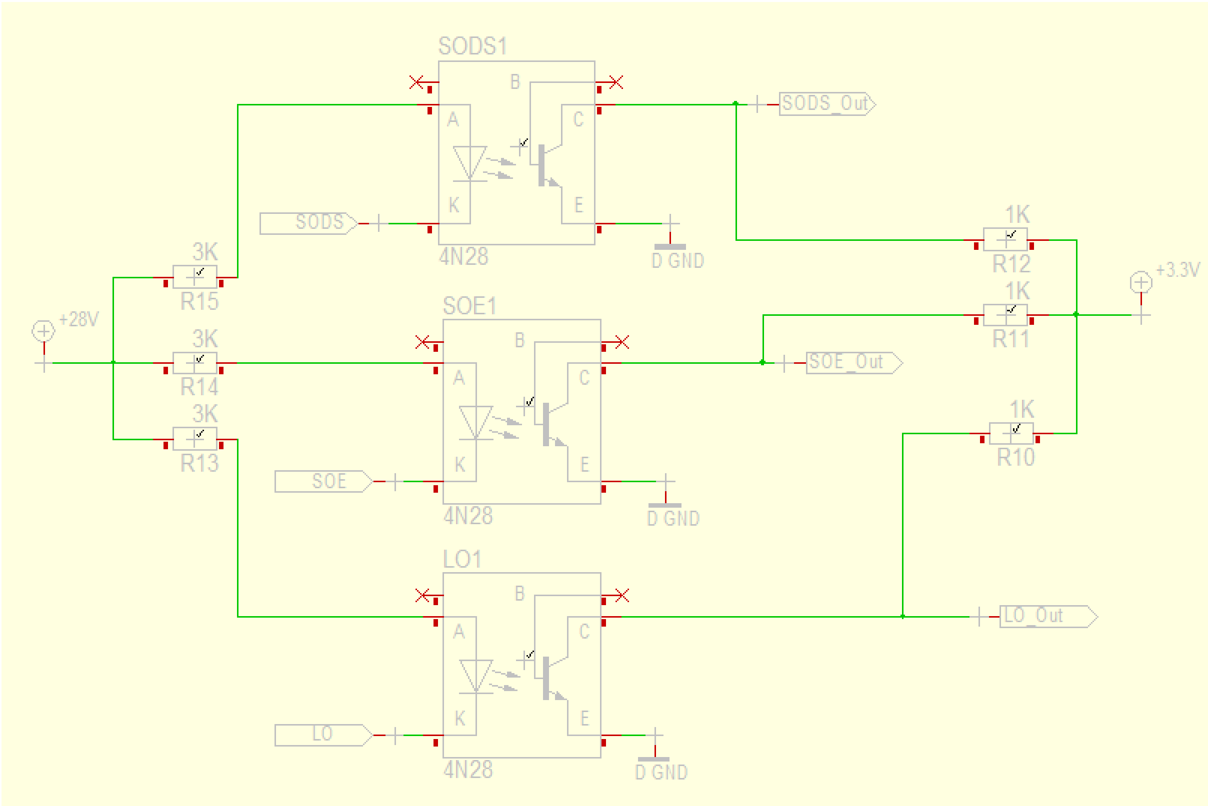


Figure 36: Signal Interpreter Circuit

The circuit is in accordance to Rexus user manual's chapter 7.6.7 with a 3kΩ resistor between the +28V and the optocouplers and a 1kΩ pull-up resistor.

4.5.4.3 PTC Fuse

The third circuit is solely to turn one 28V line into two lines in order to supply both power boards. In addition a self-resetting PTC fuse is integrated to prevent the experiment from continuously drawing too much power from the Rexus service module.

4.5.4.4 Interface Board PCB Layout

The circuits above result in a printed circuit board with the following parameter:

- Dimensions: 140x36mm
- Single layer
- 35µm copper

The relatively large dimensions are a result of the boards physical location within the rocket module.

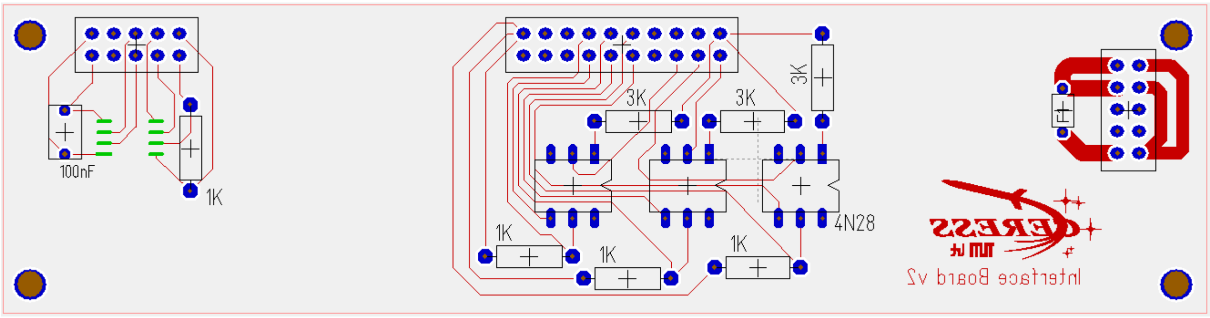


Figure 37: Interface Board PCB (Component side)

4.5.5 Power Boards

The REXUS service module provides a 28V power source. This source however is unregulated, meaning the voltage is not a constant 28V. Furthermore, most experiment components cannot be operated with 28V supply voltage. It is therefore necessary to convert the incoming voltage to correct and regulated voltages. In case of the Ceress experiment, these voltages are 3.3V, 5V and 24V. To achieve this, two DC/DC converters are used: The Tracopower TEN40-2420 provides both 3.3V and 5V, while the Tracopower TEN60-2415 is providing 24V. In addition to the converters, some more components are required for additional functionalities, like measurement of current, are required.

The functions of the Power Board are summed up below:

- Provide regulated 3.3V, 5V and 24V
- Measure level of output voltage
- Measure current usage of rocket and verification module

Due to volume restrictions it is not possible to have all power supply hardware on a single board. Therefore each DC/DC converter has its own circuit and PCB.

4.5.5.1 Powerboard 1 (24V)

The DC/DC is connected to the 28V and RX_GND lines of the Rexus service module. To increase electromagnetic compatibility, an input filter, consisting of a series of capacitors and inductors is implemented. In accordance to the converter's application notes, a 4.7µF capacitor, a TCK-048 common mode choke, consisting of two inductors and another 4.7µF capacitor and inserted between 28V and RX_GND. Between the +Vin and +Vout, as well as the –Vin and –Vout lines, a 1nF, 2kV capacitor is inserted for the same purpose. According to the application notes, this complies with EN55022 Class B conducted noise.

The TEN60-2415 has the capability to adjust the output voltage within a specified range by connecting the Trim-Pin with either +Vout or –Vout through a resistor. Connecting Trim to +Vout results in a reduction of output voltage, connecting to -Vout with an increase of output voltage. Since the output voltage should not be considerably lower than 24V, only the trim-up resistor is implemented. The possibility to use remote sensing is not used, therefore +Sense is connected to +Vout and -Sense to -Vout.

The resulting circuit can be seen below:

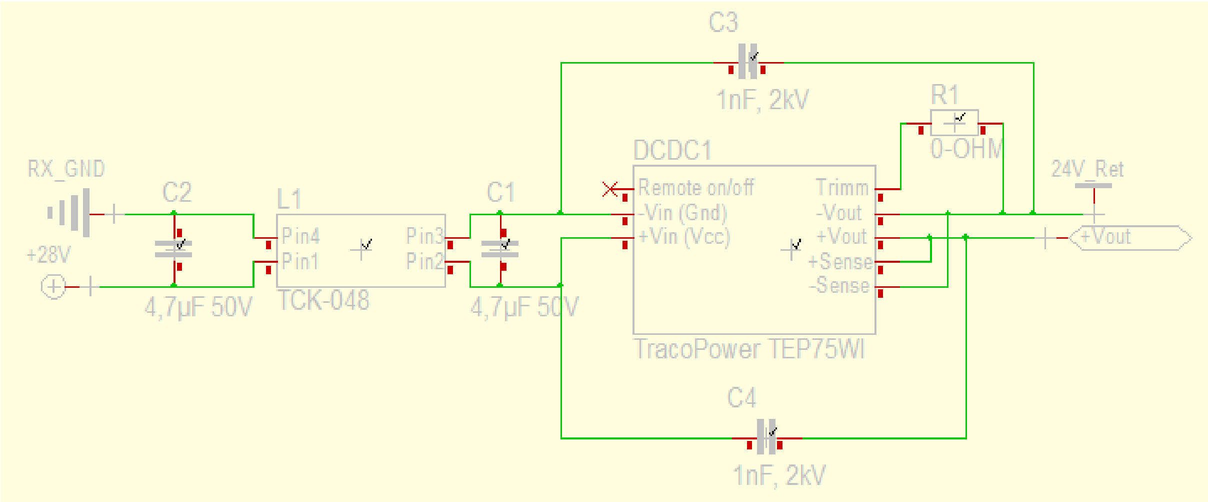


Figure 38: TEN60-2415 Circuit

To measure the current usage of rocket and service module, a shunt resistor is placed on the respective output line. By measuring the voltage drop on this shunt, the current can be calculated using Ohm's Law. A more comfortable way than measuring voltage before and after the shunt is to use a high-side current sense (HSCS) chip, like Maxim's MAX4172ESA. This chip is amplifying the voltage drop and outputting a single voltage that can be measured in comparison to ground. Therefore only one analogue input of the sbRIO is used.

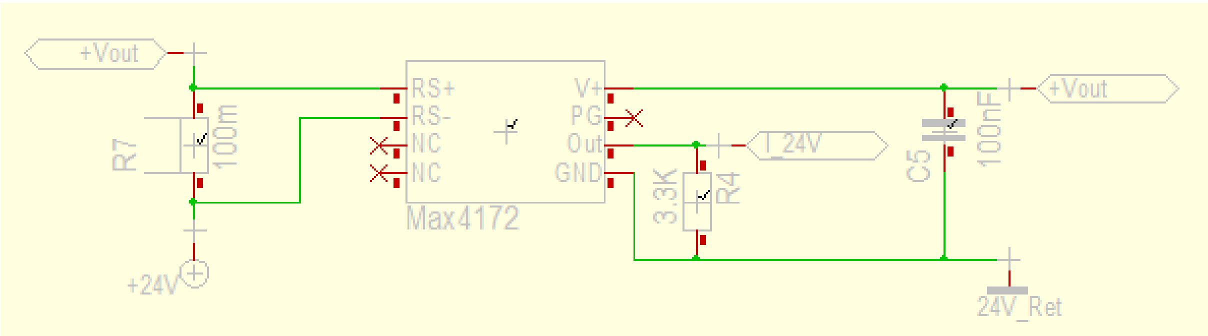


Figure 39: High side current sense circuit

The circuit above is implemented twice, once for RM and once for VM voltage output.

Between the HSCS +V and GND, a 0.1µF capacitor is implemented to reduce ripple. By connecting the measurement signal (Out) via a resistor to ground and measuring between Out and resistor, the scale of the output can be set. In principle this is a voltage divider.

The level of output voltage can be measured directly by connecting one output line the the sbRIO's analogue inputs. For 24V a voltage divider has to be used, since the sbRIO can only handle input voltages of up to 10V.

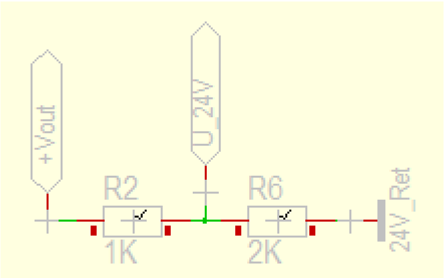


Figure 40: 24V level measurement

4.5.5.2 Powerboard 1 PCB layout

The circuits above result in a printed circuit board with the following parameter:

- Dimensions: 120x60mm
- Double layer
- 70µm copper

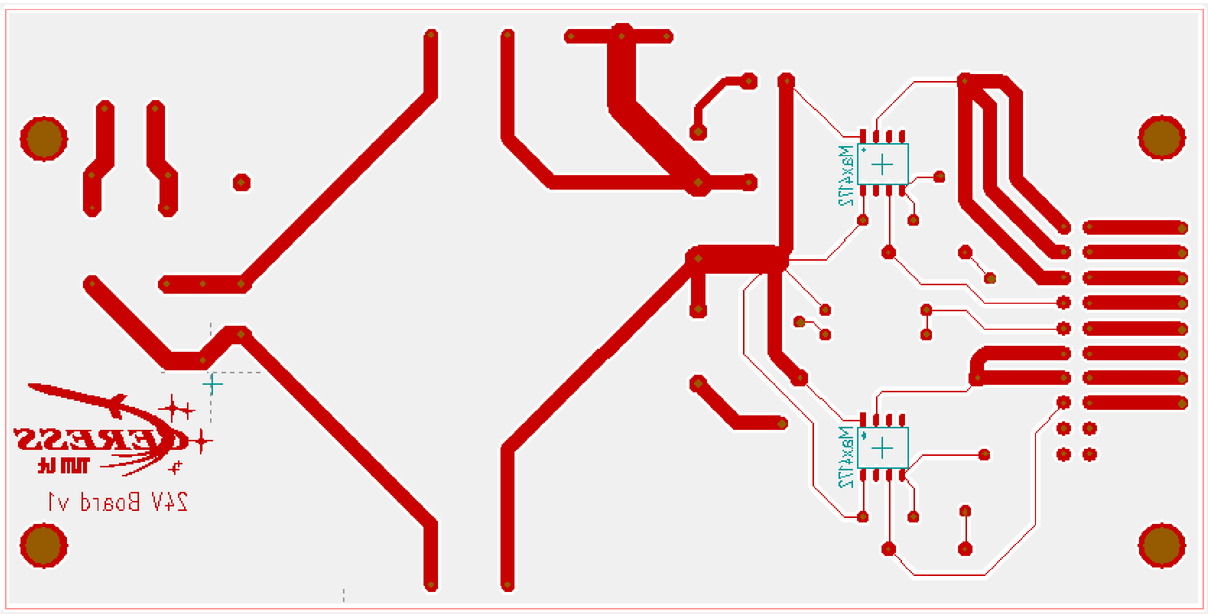


Figure 41: 24V Board Bottom (Top View)

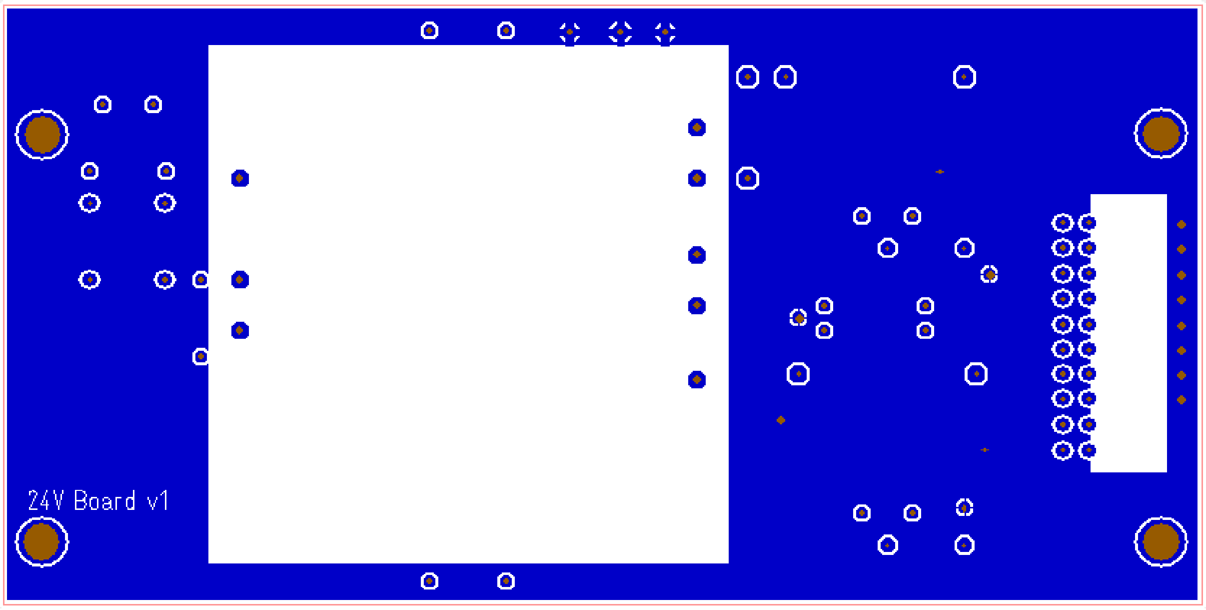


Figure 42: 24V Board Top (Top View)

The PCB's top layer is basically a ground plane for the entire board. This is due to the fact that space is very limited on the board.

4.5.5.3 Powerboard 2 (3.3/5V)

For 3.3V and 5V output, a single DC/DC converter is used. The Tracopower TEN40-2420 is able to provide both voltages with sufficient current. The input filter is equivalent to the one of the 24V converter, the difference being that not two but four 1nF, 2kV capacitors are necessary, since it has two different +Vout and -Vout. This converter does not have the capability to trim the output voltage.

The circuit for 3.3V and 5V output are shown below:

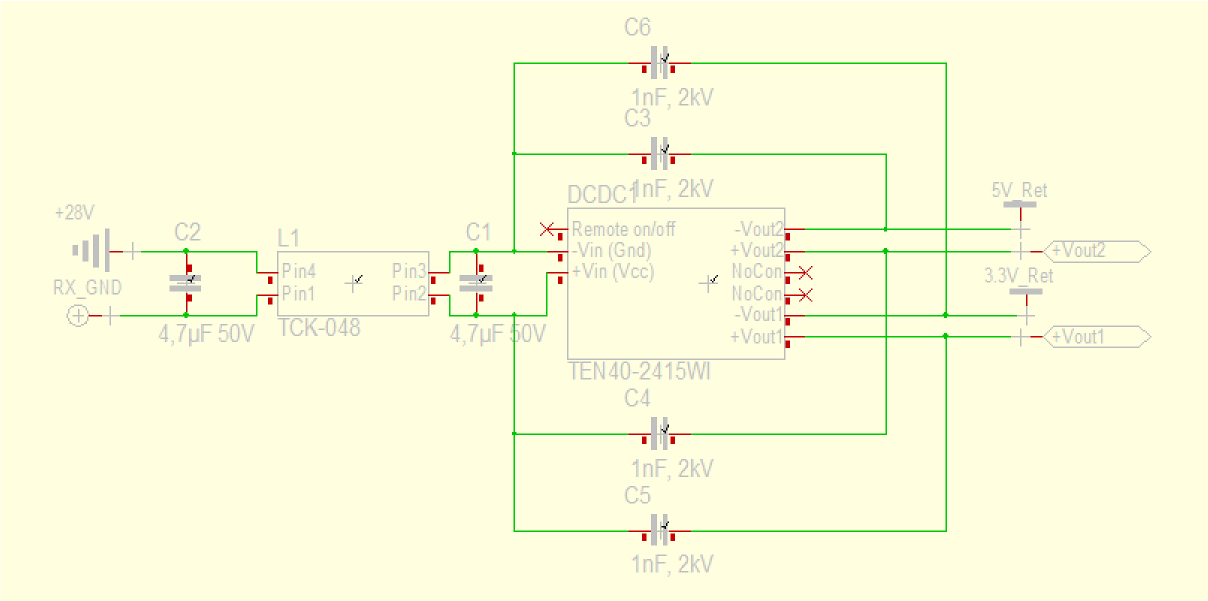


Figure 43: TEN40-2420 Circuit

The circuit to measure current is the same as for the 24V Powerboard, only the values of the shunt and output resistors vary. The circuit below is implemented four times, twice for 3.3V and twice for 5V.

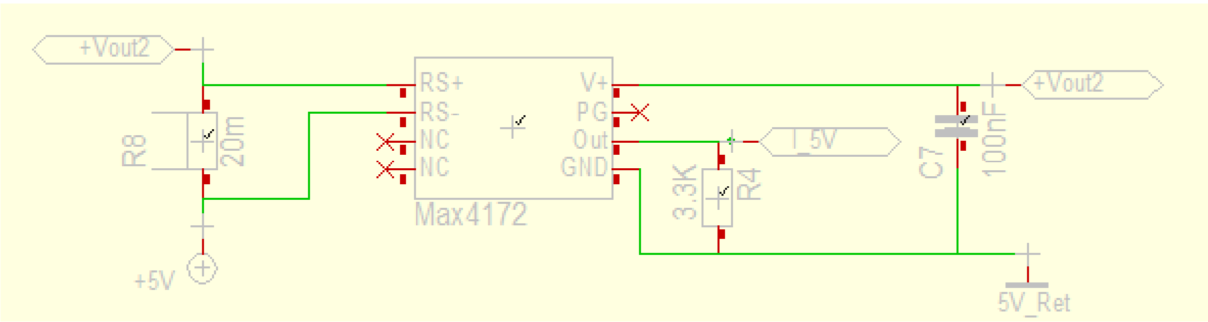


Figure 44: High side current sense circuit

Since the voltage levels are within sbRIO's analogue input range, no voltage divider is required.

4.5.5.4 Powerboard 2 PCB Layout

The circuits above result in a printed circuit board with the following parameter:

- Dimensions: 120x105mm
- Double layer
- 70µm copper

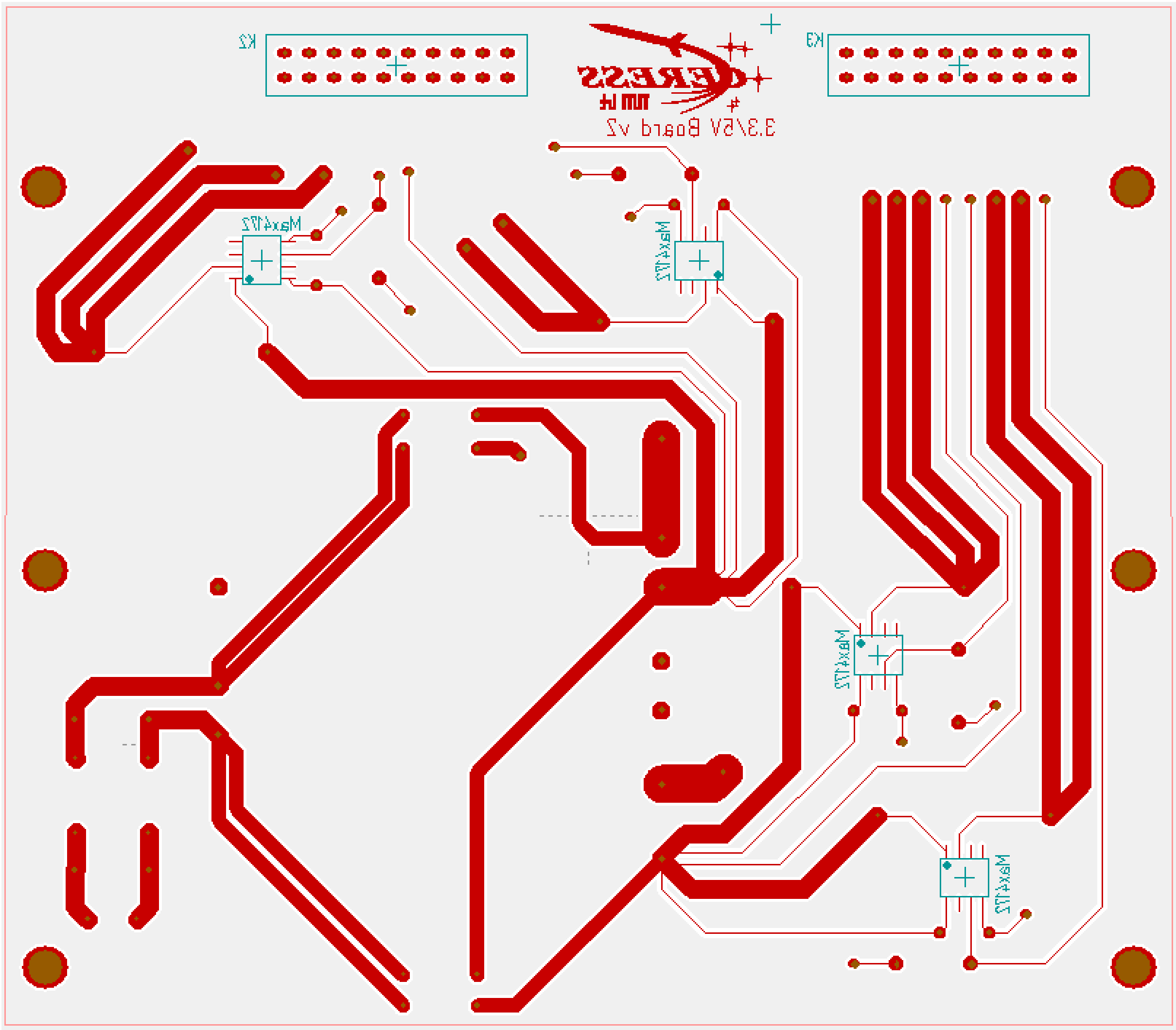


Figure 45: 3.3/5V Board Bottom (Top View)

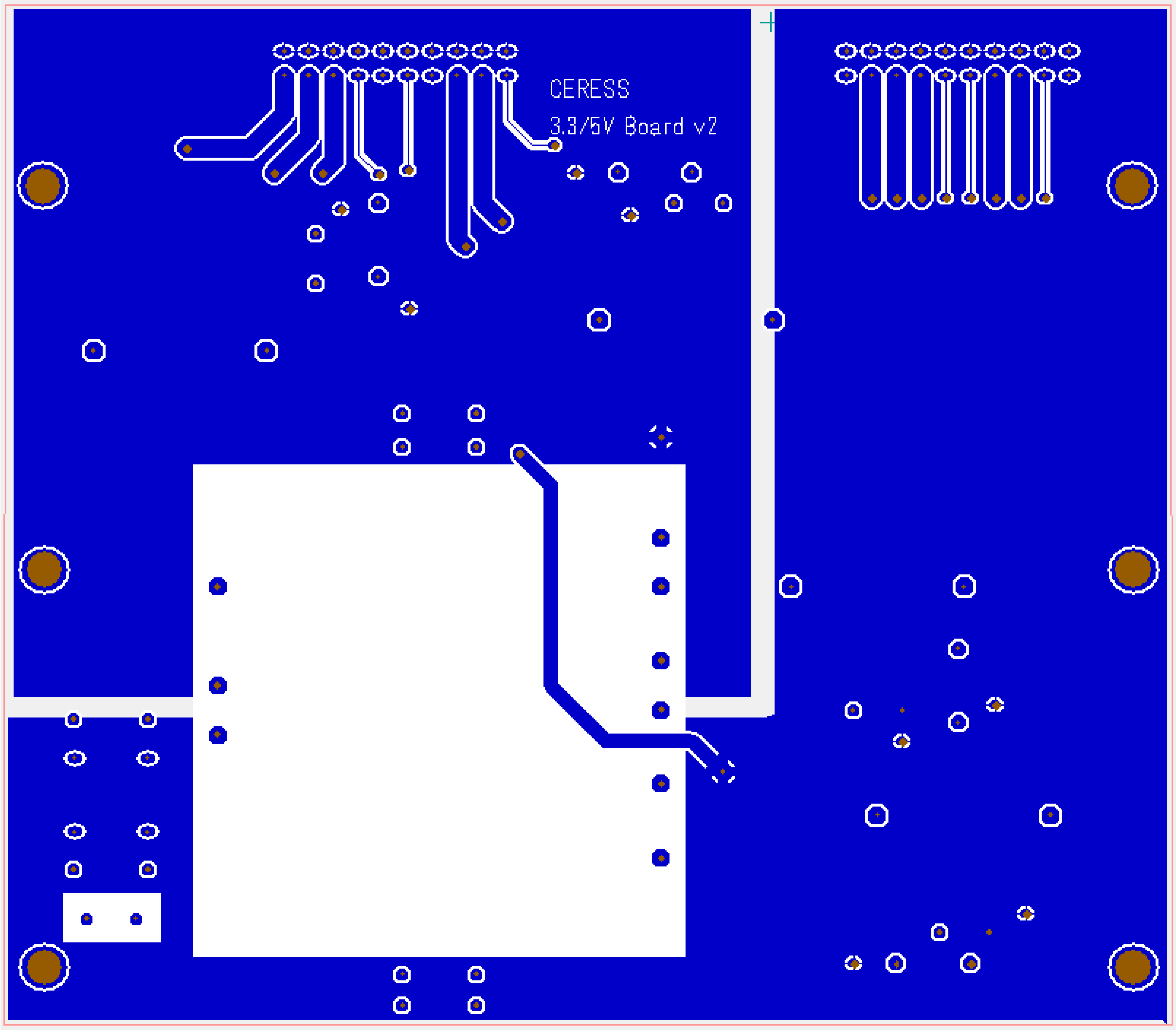


Figure 46: 3.3/5V Board Top (Top View)

4.5.6 Thermistors

To measure temperature, temperature dependent resistors (thermistors) are used. The following circuit is used for each thermistor:

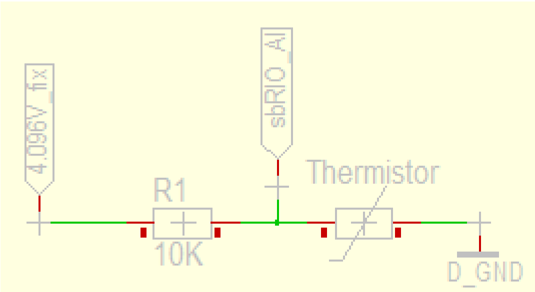


Figure 47: Thermistor circuit

This circuit is basically a voltage divider. Supply voltage goes through a 10kΩ resistor and then via the thermistor to ground. The voltage is measured between resistor and thermistor. Knowing the input voltage, value of R1 and the measured voltage, the value of the thermistors resistance can be calculated and the temperature of the sensor. In this case the supply voltage is channelled through a voltage reference therefore eliminating the need to measure the voltage.

4.5.7 GoPro Hack

To use the GoPro camera, it is necessary to provide it with power and remotely turn recording on and off. For this purpose knowledge of the 30pin connector on the back of the camera is required.

Table 24: GoPro Connector Pinout (Reference: http://chargeconverter.com/blog/?p=71)

R Video out	2	1	GND
B Video out	4	3	G Video Out
USB +5V power	6	5	USB +5V power
USB Data-	8	7	USB Data+
Audio Out Right	10	9	GND
Pwr/Mode Button	12	11	Audio Out Left
Audio In Right	14	13	Playback Mode Button
IR Input	16	15	Audio In Left
GND (?)	18	17	Trigger digital output
ID2 digital input	20	19	ID1 digital input
ID4 digital input	22	21	ID3 digital input
Aux Adapter Output	24	23	Adapter Output
VBat+	26	25	VBat+
Data Interface I²C	28	27	GND
GND	30	29	CLK Interface I²C

Since it is not advisable to use the camera's lithium ion battery on a sounding rocket, external power has to be applied. This is achieved by connecting both "USB +5V power" pins of the GoPro connector to the 5V supply of the rocket module.

To start recording, the camera is first set to one-button mode by hand. This mode means that the camera starts recording a video as soon as it is turned on. To turn it on, the "Pwr/Mode Button" pin is tied to ground for a few seconds. This is equivalent to physically pressing the power button. This is achieved by connecting “Pwr/Mode” and ground via an optocouplers which is then triggered by a sbRIO digital output.

To check if the camera is recording, “Data Interface I²C” is connected to a digital I/O of the sbRIO. This pin is low if the camera is not recording and high as soon as the recording starts.

4.6 Thermal Design

As mentioned in chapters before, the fine pressure sensor, pirani type, needs a heating. The Sensor and Heating are thermal isolated against the rest of the CERESS Verification Module.

Detailed calculations / simulations need to be done.

Figure 48: Components Temperature Ranges shows the temperature ranges of the components.

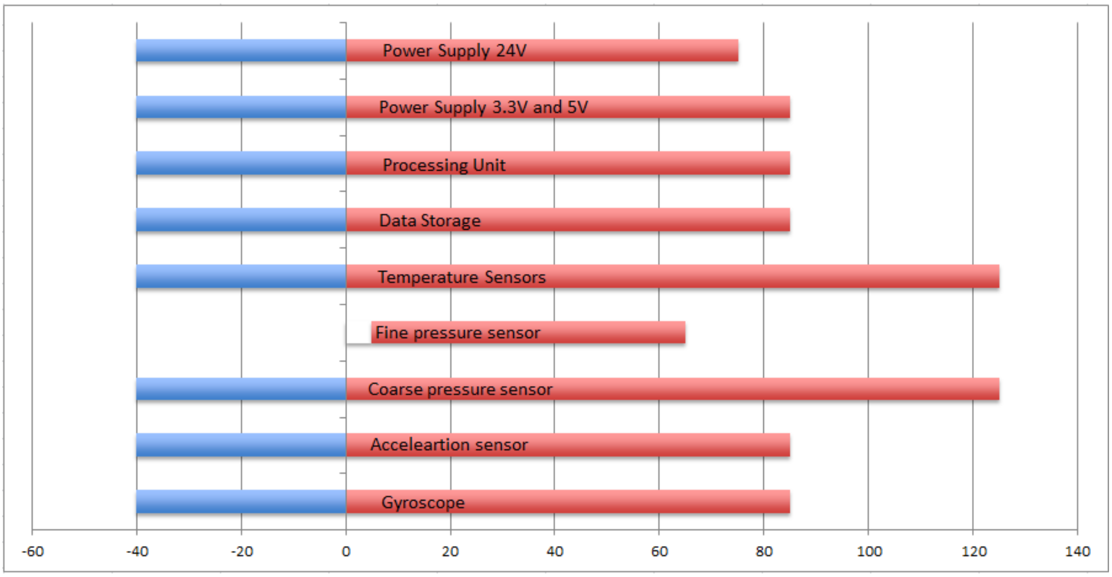


Figure 48: Components Temperature Ranges

4.7 Power System

The power system is made up of two DC/DC convertors, one providing 3.3V and 5V and the other providing 24V, four fuses to protect the experiment from to high currents, one solid state relay to turn the 24V DC/DC on, once the SOE signal comes in and three shunts and high side current sense chips to measure the output current of the DC/DCs. The schematic is included in the electrical design chapter.

The power requirement of all electrical components is listed in the table below:

Component	Voltage [V]	Current [mA]	Power [W]	Quantity	Total Power [W]
sbRIO	24	333	8.00	1	8.00
3.3/5V DC/DC	24	100	2.40	1	2.40
24V DC/DC	24	85	2.04	1	2.04
Accelerometers	3.3	0.25	0.01	8	0.08
Gyros	3.3	6.1	0.01	2	0.05
Coarse Pressure Sensor	3.3	1	0.01	1	0.01
Fine Pressure Sensor	24	42	1.01	1	1.01
Heating Foil	24	0.14	3.43	1	3.43
Thermistors	3.3	60	0.2	6	1.2
GoPro HD Hero2	5	>500	2.5	1	2.5
High Side Current Sensors	3.3	0.42	0.001	6	0.006
Meltingwire (mw) (for 5 secs)	3.3	1	3.3	1	3.33

Table 25: Power Budget of electrical components

Since not all components are powered at the same time, two different operating modes can be defined.

In Normal Mode all nominal components (sbRIO, DC/DCs, various sensors) and the heating are active.

Normal Mode			
Component	Quantity	Power [W]	Total Power [W]
sbRIO	1	8.00	8.00
3.3/5V DC/DC	1	2.40	2.40
24V DC/DC	1	2.04	2.04
Accelerometers	8	0.01	0.08

Normal Mode			
Gyros	2	0.01	0.02
Coarse Pressure Sensor	1	0.01	0.01
Fine Pressure Sensor	1	1.01	1.01
Heating Foil	1	3.43	3.43
Thermistors	6	0.2	1.2
GoPro HD Hero2	1	2.5	2.5
High Side Current Sensors	6	0.001	0.006
Total			20.7
With 50% margin			31.05

Table 26: Power Budget Heating Mode

The second mode is Wire Melting Mode. In this mode the heating is turned off, while the melting wires are powered for a five second interval.

Wire Melting Mode			
Component	Quantity	Power [W]	Total Power [W]
sbRIO	1	8.00	8.00
3.3/5V DC/DC	1	2.40	2.40
24V DC/DC	1	2.04	2.04
Accelerometers	8	0.01	0.08
Gyros	2	0.01	0.02
Coarse Pressure Sensor	1	0.01	0.01
Fine Pressure Sensor	1	1.01	1.01
Thermistors	6	0.2	1.2
GoPro HD Hero2	1	2.5	2.5
High Side Current Sensors	6	0.001	0.006
Melting Wire	1	3.3	3.3
Total			20.6
With 50% margin			30.9

Table 27: Power Budget Wire Melting Mode

4.8 Software Design–Rocket Module

4.8.1 On-Board data flow

The Main Computation Unit of CERESS is a single board Reconfigurable Input Output (sbRIO) produced by National Instrument. Figure 49 shows the data flow between function-blocks according to their allocation onto the sbRIO.

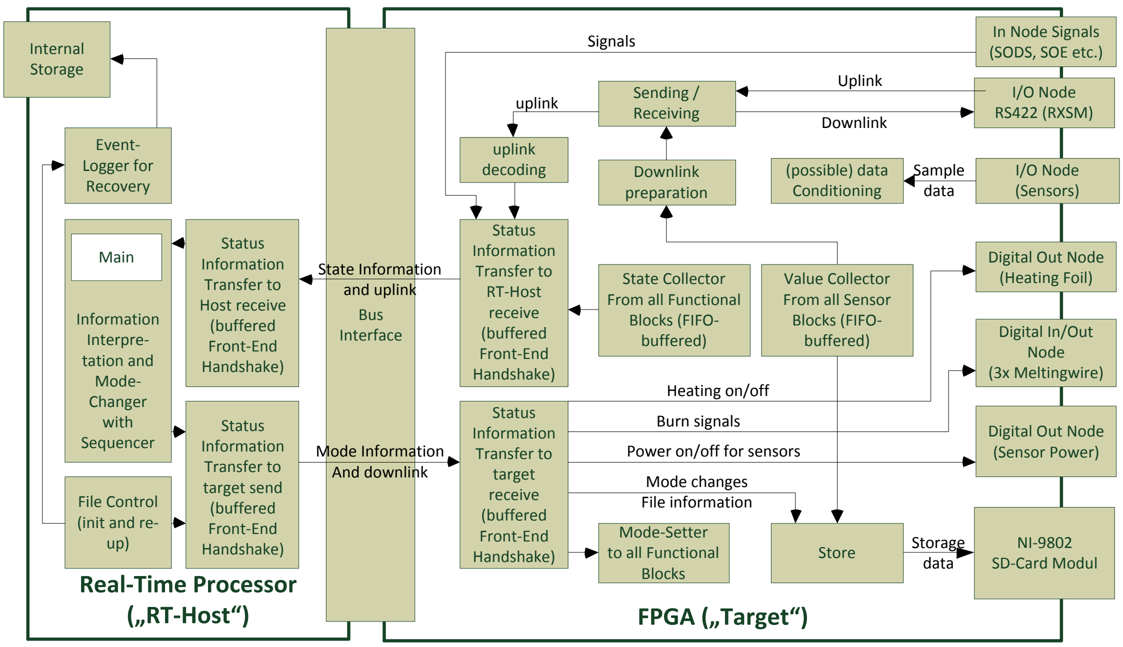


Figure 49: On-Board data flow

4.8.1.1 FPGA

The Field Programmable Gate Array provides all I/O tasks and emulation of data transfer protocols. High frequency data condition is possible. All processing on this device is deterministic. Unfortunately for every change a re-compilation, which needs time, is needed.

4.8.1.2 Real-Time Processor

The device is splitable into the several normal priority loop time critical loop. First contains the main program with different states, which are explained in the following section. For secure data exchange between loops and FPGA a buffer-principle with handshake principal is used. Normal priority does not imply that there wouldn't be "in-time" checks.

The data is logged to the Storage through the FPGA. An Event-logger with storing-cabability on the internal storage will guarantee, that the last state can be recovered after an power-loss

4.8.2 OBDH states

The OBDH has to be capable to perform appropriate tasks in different phases of the launch campaign and the flight itself. Therefore a state machine as shown in Figure 50 is used. The state changes are performed either by command, procedure or the mode has reached its predefined end (checked by the Sequencer). The Procedure is a predefined state change in order to enable an automatic full test or the mission itself.

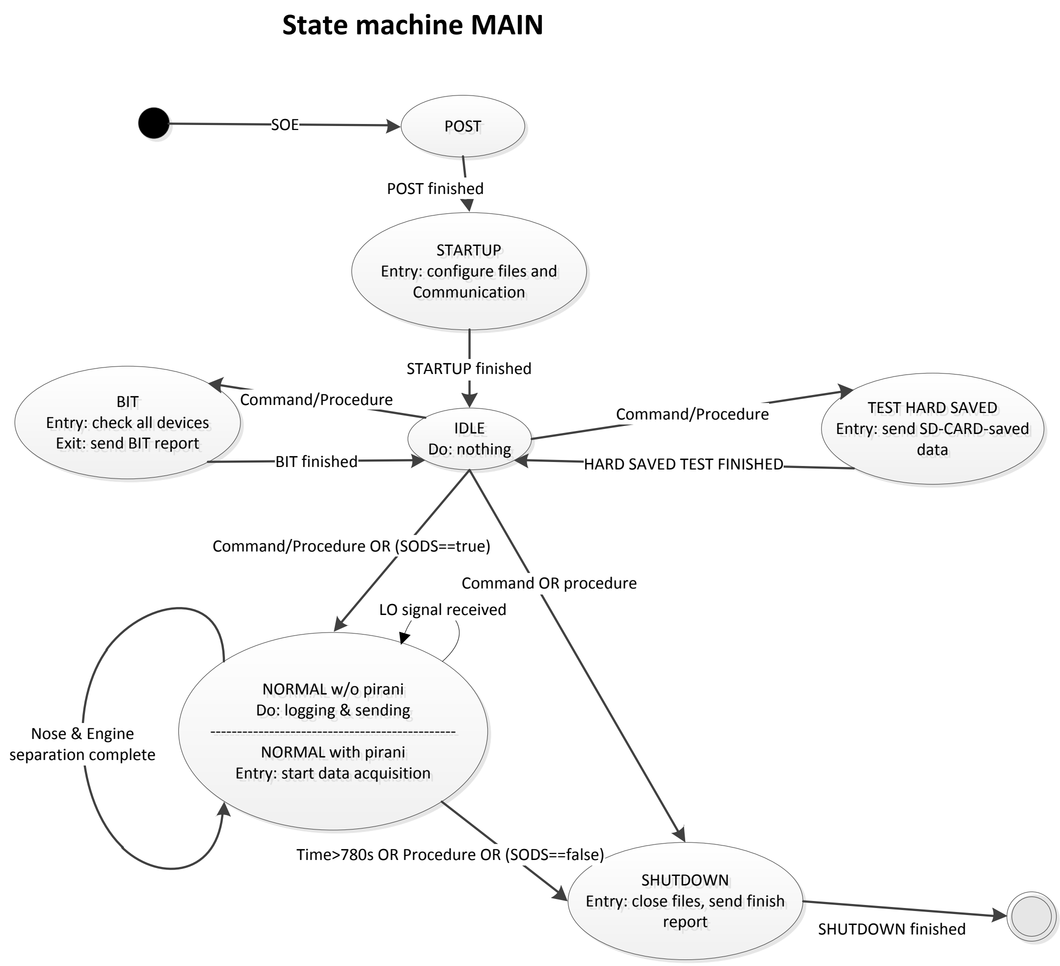


Figure 50: State Machine of MAIN

4.8.2.1 POST (Power on self-test)

POST is performed by the sbRIO itself and doesn't need any input information. The program for FPGA and Real-Time Processor is load from a non-volatile storage (build-in).

4.8.2.2 STARTUP

STARUP configures the communication channels and all Maintenance data logging.

4.8.2.3 IDLE

This state is defined for standby and as “ready-for-command” state. Useful especially for countdown holds because nearly no storage data is generated.

Furthermore some commands are available like zero-offset-acquisition and zero-offset-set. The zero-offset-acquisition command will be used before CERESS Rocket Module integration (flat bearing is necessary) and delivers the required offset values which are stored in the non-volatile storage aboard the sbRIO.

4.8.2.4 BIT (Build in self-test)

BIT runs a check on defined sensors and generates a report. Digital sensors provide some relevant check-values which declare the functionality of the device. Analogue device however don’t provide such values and as a result another interpretation of the sample data is needed:

1000 values are acquired and processed to a Mean Value, the standard deviation as well as min and max values. A comparison with typical values enables an interpretation of the functionality of the device.

For each sensor a test report is generated and downlinked.

4.8.2.5 TEST HARD SAVED

TEST HARD SAVED is part of the tests. The sbRIO doesn’t configure any sensors and sends an emulated, ideal Stream of data to the ground module. The stream therefore is stored on the storage unit for checking purposes.

4.8.2.6 NORMAL (w/o pirani – with pirani)

This state is defined to be the normal operating mode of the CERESS Rocket Module. Data will be collected, processed, saved and send. The LO Signal resets the Internal Timer. The fine-pressure-sensor PIRANI will be activated after Burn-Out of the engine because of a higher shock resistance of the sensor in off-mode.

4.8.2.7 SHUTDOWN

SHUTDOWN closes files and prepares the CERESS Rocket Module for Power shutdown and landing/impact.

4.8.3 Functional Blocks

Functional Blocks (formerly named Threads) are all program parts which are not covered in the OBDH state description. Therefore they are explained here.

4.8.3.1 State- and Value-Collector

All collected data has to be available for downlink or interpretation (e.g. time trigger event!). Therefore these functional blocks make the data available to downlink preparation as well as regular data storage. Some additional information like sample-counts of sensors or running time is prepared. The blocks buffer the data in appropriate Frequencies.

4.8.3.2 Mode Setter

This block receives the modes set by the Sequencer located on the RT-Processor through the Information Transfer blocks. It just sets for every functional block the new desired mode.

4.8.3.3 Information Transfer

The four blocks shown in Figure 49 buffer all state information and transfer them to the Target resp. buffer and transfer all mode information to the target. Due the handshake principal and its processor-blocking behaviour no sensor values are transferred.

4.8.3.4 File Control

The File Control block checks the SD-Cards for existing Files and defines new ones if necessary. Especially after a power loss the block is responsible for File-Handling.

4.8.3.5 Event Logger

The Event Logger stores all Mode-Changes and File-Information for a successful recovery after power-losses and prevents unwanted data-loss due file-overwriting or comparable occurrences. The Event Logger uses the internal non-volatile storage of the sbRIO.

4.8.3.6 Sensors and I/O Nodes

These threads communicate with their devices and provide data packets to the “Store and publish data” thread. If necessary they generate higher priority packets. Their Modes can be set from the Main thread.

4.8.3.7 Sending

This block creates a full Telemetry Data Package including Header, Data Frame and Trailer.

First the data frame is filled with packets owning the highest priorities until the frame can't take the next packet (If the first packet exceeds the Data Frame a sequence of Data Frames will be generated). Afterwards the remaining data frame is filled with packets owning lower priorities but have smaller packet sizes. Filling aborts when the remaining free space is smaller than the lowest packet size. The Trailer at the end of the package and the Header at the beginning are generated and attached like described in Section 4.8.5.3 Telemetry Data Frame definition. Then the package is released for transmitting. Untaken packets remain in the buffer and were processed in the next loop. Some Priorities cause an update of their remaining data packet (see Section 4.8.5.1 Priority).

This procedure enables a very high load factor for Telemetry and guarantees a quick transmitting of high priority packets like error reports or comparative events. Furthermore additional packets are easy to integrate into the telemetry stream.

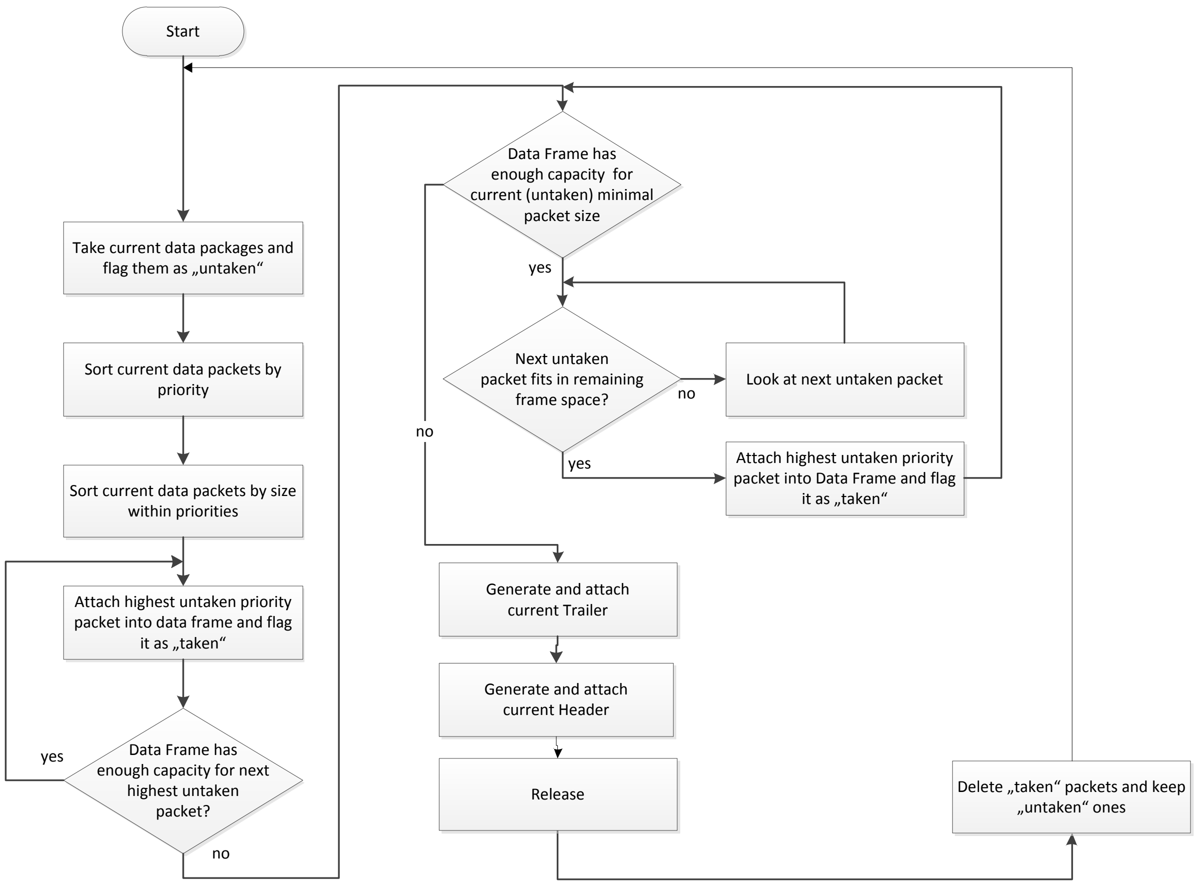


Figure 51: Telemetry Data Frame building scheme

4.8.3.8 Receiving

Data is received and decoded for use in the main-program.

4.8.4 Additional implemented Blocks

There are some Blocks which are used and implemented but not described yet.

4.8.4.1 SPI-Block

The SPI-Communication to the digital Sensors is implemented in a single cycle loop with a clock-rate of 10MHz resulting to a clock tick of 0.1µs. The block accepts an array of clusters containing all necessary information for a successful communication and delivers the received values. A detailed description will be available handbook for future teams.

4.8.4.2 Timestamper

Due the high-frequency of data acquisition it's necessary to get a timestamp of the gained values. Unfortunately a true timestamp with date and time is only available on the Real-Time Hast and there only with an accuracy of ms. Therefore an single-cycle loop with 10MHz is utilized to give an timestamp with an µs accuracy and a capacity up to six an half hour, which should cover the maximum power-up time including Countdown and flight.

The Timestamps are available to all functional block through global variables.

There are two different types of timestamps. One is the clean version which is readable as µs, ms, s, min and h. The other is a combined array of Booleans with a size of 35bit.

4.8.4.3 Timestamp clean to bin

Converts the readable timestamp to 35bit representation. For example used in the RS422 or store-block.

4.8.4.4 Timestamp clean to bin

Converts the 35bit timestamp to readable representation. For example used in the RS422 or store-block.

4.8.5 Telemetry

Several data is necessary for surveillance of the CERESS Rocket Module and CERESS Verification Module. The following section explains the packets, theirs size as well as the Telemetry Data Frame definition and the priority scheme.

4.8.5.1 Priority

Due the fact that some information is more important than other, it's a need to have a short time delay between event happening and report on ground. A Solution is to prioritize the information. There are eleven priority levels within CERESS. Level one is the highest and eleven the lowest.

It's needful to understand that priority eight to ten update their packets after each sending loop in order to downlink the latest measurement data.

Fehler! Keine gültige Verknüpfung.

4.8.5.2 Data Packets

Every Thread and Function within the OBDH has its unique SourceID. Each of them has different Data Packets which are processed, stored, downlinked etc. For identification of them the sources have packetIDs. The IDs bound together represent a Header for data packets with fixed size throughout the whole OBDH (see Table 28). This is also the reason why the GM can interpret the Data Frame with chained packets. See Appendix C for details of the data packets.

Fehler! Keine gültige Verknüpfung.

Table 28: Data Packet Header

Some representative Data packets are listed in the following Table. More packets will arise during implementation.

Fehler! Keine gültige Verknüpfung.

Table 29: Data Packets

4.8.5.3 Telemetry Data Frame definition

The usable Telemetry Data Frame consists of 24 Bytes (according to the REXUS Manual) which includes Header, Data Frame and Trailer. It is generated by the sending thread like described in Section 4.8.3.7 Sending. The whole Frame is shown in Figure 52 and explained afterwards.

Fehler! Keine gültige Verknüpfung.

Figure 52: Telemetry Data Frame

- SYNC

These Bytes are for detecting the next CERESS Telemetry Data Frame on ground.

- MSGINF – Message Info

The Message Info contains the highest included priority within the Message (four bit), a sequence control (two bit) and the sequence message count (two bit).

- MCNT – Message Count

This Counter is increased with every Message. Therefore it is easy to find out which Telemetry Data Frames were missing by detecting the absence of the MCNT number. The Counter is modulo 255 (8 bit).

- Data Frame

The data packets are stored within Byte four to nineteen.

- CRC – Cyclic Redundancy Check

The CRC is an error detecting code. It represents a check value calculated out of the transmission data. The CRC (two Bytes) will be calculated with the provided C-Code from MORABA.

- CSM – BSD Checksum

The CSM is calculated by adding all 16bit words while after each step the accumulator is rotated to the right by one bit. This prevents an overflow of the CSM (two Bytes).

4.8.5.4 Telemetry Budget

The downlink is used in different cases for different information.

Considering only the Telemetry Data Frame without Header and Trailer a usage for every mode is computable. The following Table shows the usage relating to one second and mode. Only needed telemetry for each mode is shown. All other are Priority eleven (no telemetry).

Fehler! Keine gültige Verknüpfung.

Table 30: Telemetry Budget

As it can be seen, there's no problem for too low data rate to ground. In Normal Mode all Sensor Data is updated five times per second.

4.8.6 Telecommand

No continuous uplink for data transmission is planned. Some commands are for additional BIT or configuration downlink. The Telecommand Data Frame is similar to the Telemetry.

4.8.7 Data Storage

The data storage is done with a NI-9802 SD-Card Module. It allows acces on file-level. Following Files are used:

- One for each sensor
- Telemetry
- Telecommand

The file format is *.bin to save space. Postprocessing will convert files to readable format.
Additional the onboard non-volatile storage of the sbRIO is used for:

- Timeline (including all relevant Mode-Changes, Powerups etc.)

The file format is *.txt with information organized in columns and ongoing timestamps in lines.

4.8.7.1 Budget

Table 31: Data Storage Budget shows the calculation of the data volume due to Telemetry & Measurement. The duration is defined by flight time (800s) and spare (200s) for possible test runs.

The data will be stored in two different SD Cards parallel to ensure a recovery of the data. The Data Volume is no problem due today’s storage devices.

Fehler! Keine gültige Verknüpfung.

Table 31: Data Storage Budget

4.9 Ground Support Equipment / Ground Segment

The Ground Support Equipment (GSE) of CERESS consists of three major Subsystems. For more detailed information see CHAPTER X.X.

4.9.1 CERESS Ground Module Server

The CERESS Ground Module collects all raw-data necessary to compute the data needed for the visualization. Therefore the CERESS Ground Module receives the downlink from the CERESS Rocket Module via the REXUS Downlink and decodes the stream into usable information. Furthermore it receives data from the telemetry stream of the REXUS Rocket and/or the ESRANGE Ground Segment. As a third input-stream the orientation-angle and ranging of the ESRANGE Tracking-Antenna is used.

These data-streams are merged to provide the necessary data for the ViTo. All data-streams are recorded and stored for analysis in case of failure.

Furthermore the CERESS Ground Module provides status information of the other subsystems.

Depending on the ground infrastructure (Figure 53), the software is distributed on multiple computers.

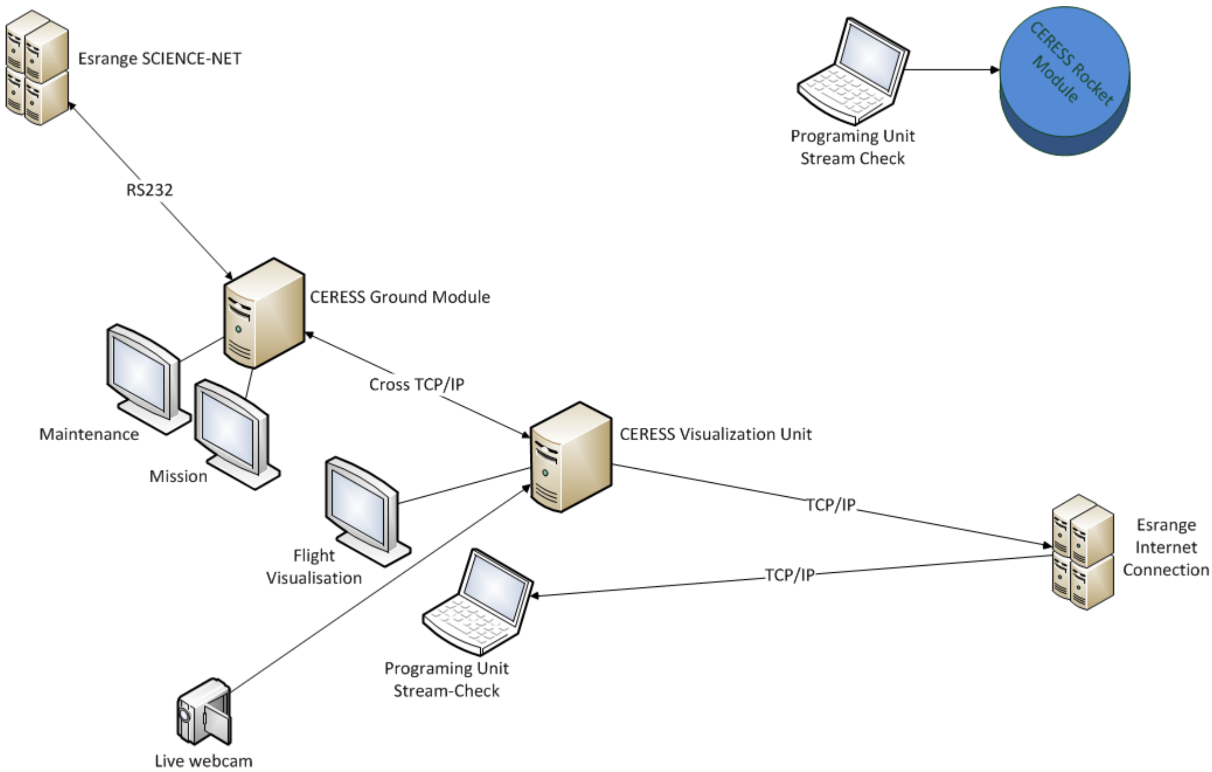


Figure 53:CERESS Ground Segment

The CERESS Ground Module has several screens. They can be categorized in Controls and Displays. The Flight Visualization Display presents connections, processing time and a preview of the Visualization as well the captured webcam stream. For insurance of proper functional behavior, both live streams are used for checking on the programing Unit.

The upper right shows the development and preflight situation for programming with the CERESS Module.

4.9.2 Trajectory determination principles

Three possibilities are considered for trajectory determination:

1) The easiest way is to use GPS signal that is sent from the RXSM and fed to the data stream that is provided at the ESRANGE Ground Station. Filtering of the received data will be necessary to fit it to the required refresh rate of the visualization tool.
2) The ESRANGE Link-Antenna provides the range between the rocket and ground station and two angles: The Azimuth- and Elevation-Angle. These together define a vector on which the REXUS rocket probably is located. The principle is also shown in Figure 54.

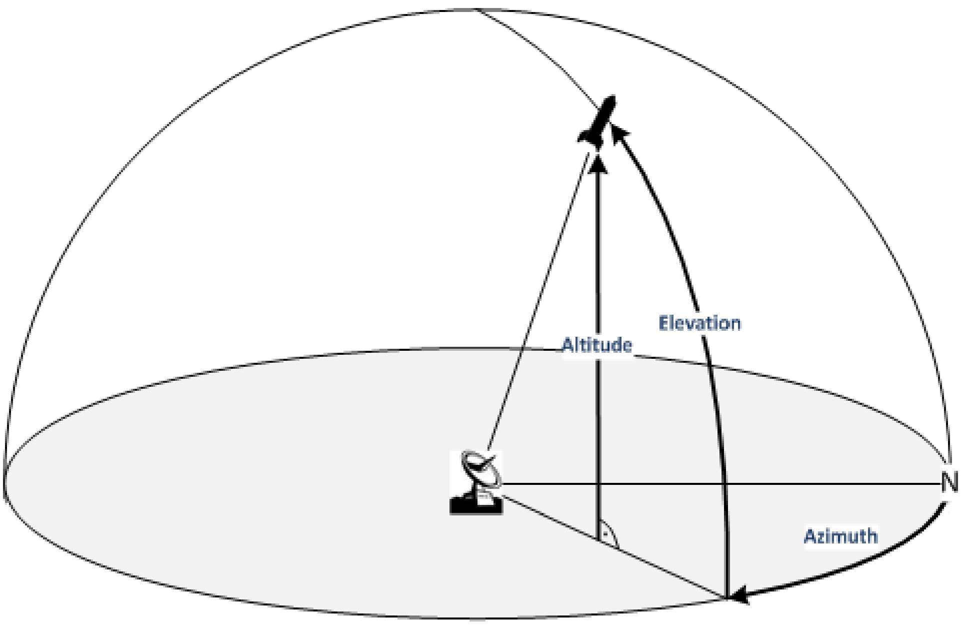


Figure 54: Trajectory determination

4.9.3 CERESS Ground Module Clients

The CERESS Ground Module provides a software interface to display all downlinked information and a possibility to communicate with the

CERESS Rocket Module. It will be implanted with LabView due the possibility to display data in real-time in graphical diagrams.

4.9.4 Visualization Tool (ViTo)

Tool is implemented as a Google-Earth plugin, which consists of two *.kml files. The Client file is run by Google-Earth. It tells the Plugin how data is visualized and the address of the required server file on the internet.

The server file contains the data that is to visualize and is updated by the GM frequently. Since there are two possibilities show the trajectory (in realtime and afterwards) there has to be different modes.

4.9.4.1 Flight-Mode

The Data is supplied via the Internet, when ViTo is in Flight-Mode. Only the position and the trajectory will be displayed.

4.9.4.2 Post-Flight-Mode

The data is supplied via a file generated by the CERESS Ground Module Visualization Server. In addition to the trajectory, the sensor-data, detected events like nose-cone ejection or engine stop are available in the post flight visualisation.

4.9.5 Service Computer

The service computer is used for configuring, programming and testing the rocket module after integration of the Processing Unit and during launch preparations. Therefore the service computer may be considered as Ground Support Equipment. It is the same through the whole project. A team-member’s laptop is used for this purpose.

4.10 Calibration and other Terminology

To prevent confusions it’s necessary to describe the terminology for each sensor.

4.10.1 Accelerometer

4.10.1.1 Zero-G offset

“Zero-g level offset (TyOff) describes the deviation of an actual output signal from the ideal output signal if no acceleration is present. A sensor in a steady state on a horizontal surface will measure 0 g in X axis and 0 g in Y axis whereas the Z axis will measure 1 g. […] A deviation from ideal value in this case is called Zero-g offset.” (LIS331HH.pdf, p.14)

This implies that all values below the explained offset have to be interpreted as no acceleration.

4.10.1.2 Factory calibration

“The IC interface is factory calibrated for sensitivity (So) and Zero-g level (TyOff).

The trimming values are stored inside the device in a non-volatile memory. Any time the device is turned on; the trimming parameters are downloaded into the registers to be used during the active operation. This allows using the device without further calibration.” (LIS331HH.pdf, p. 15)

4.10.1.3 CERESS calibration

Due the imperfect horizontal alignment of the devices within the RM the attitudes have to be defined by measurements on a horizontal reference plane (available at the lrt workshop). The devices are configured to a common acceleration vector with same direction (normal to the reference plane) and length.

The calibration values are stored on the non-volatile storage on the sbRIO due the fact they only change values if the assembly is modified or corrupted.

4.10.1.4 Data processing

1) Zero-G offset interpretation
2) Attitude correction through CERESS calibration values
3) Calculation of acceleration by linear correlation to native 16bit values
4) Filter
5) Possible Mean-Value generation from all devices
6) Possible Integration to Position

4.10.2 Gyroscope

4.10.2.1 Zero-rate level

“Zero-rate level describes the actual output signal if there is no angular rate present.” (L3G4200D.pdf, p.14)

This implies that values below the Zero-rate level has to be interpreted as no rate.

4.10.2.2 CERESS calibration

“The zero-rate level of precise MEMS sensors is, to some extent, a result of stress to the sensor and, therefore, the zero-rate level can slightly change after mounting the sensor onto a printed circuit board or after exposing it to extensive mechanical stress. This value changes very little over temperature and time.” (L3G4200D.pdf, p.14)

Furthermore the imperfect horizontal alignment of the devices within the RM the attitudes have to be defined by measurements on a horizontal reference plane with a rotatory degree of freedom.

The calibration values are stored on the non-volatile storage on the sbRIO due the fact they only change values if the assembly is modified or corrupted.

4.10.2.3 Data processing

1) Zero-rate level interpretation
2) Attitude correction through CERESS calibration values
3) Calculation of rate by linear correlation to native 16bit value
4) Filter
5) Possible Integration to Altitude

4.10.3 Thermistors

4.10.3.1 Calibration

The Calibration of Thermistors is a correlation to defined temperatures. The Thermistors will be applied to ice water, temperature 0°C and afterwards to heating water, temperature depending on day's static ambient air pressure.

4.10.4 Fine pressure sensor

4.10.4.1 Factory calibration

The device is factory calibrated and isn't supposed to be recalibrated until pollution or long-time usage distorts the measurements. (GA09222_0201_TTR91.pdf, p. 2)

4.10.4.2 Data processing

1) Calculation of pressure by linear correlation to Voltage (16bit ADC-value)
2) Calculation of height by correlation to pressure (tbd)

4.10.5 Coarse pressure sensor

4.10.5.1 Factory calibration

The device has calibration data stored in the interface IC which make typical characteristics achievable. The average of 2 to 4 subsequent pressure values is required due to noise of the ADC. (MS5534C.pdf, p.5, p.9, p.15)

4.10.5.2 Data processing

1) Pressure and temperature measurement

2) Temperature compensating
3) Possible second-order temperature compensation
4) Calculation of height by correlation to pressure (tbd)

5 EXPERIMENT VERIFICATION AND TESTING

5.1 Verification Matrix

ID	Requirement text	Verification	Status
1	Req. Rocket Module		
1.1	Req. Electrical		
1.1.1	The system shall provide regulated electrical power.	R	To be done
1.1.1.1	The Power Supply shall provide the power to melt the wires	R, T	To be done
1.1.1.5	The electrical power system shall accept unregulated power from the REXUS SM	R, T	To be done
1.1.1.6	The electrical power system shall be able to provide 30W of power.	R, T	To be done
1.1.3	The Rocket Module shall use the power provided by the RXSM	R, T	To be done
1.1.3.1	The electrical power supply shall accept input currents of 28V DC	R, T	To be done
1.1.3.2	The power supply shall accept Peak currents of 3 Amps	R, T	To be done
1.1.4.1	The experiment must make provisions to limit voltage ripple feed back to the RXSM over the power line to a maximum of 500 mV. (p. 37)	R	To be done
1.2	Req. Sensors		
1.2.1	The system shall measure acceleration in all 3 axes.	R, T	To be done
1.2.1.1	The acceleration sensor shall cover the range from 10mg (µg flight state) to 25g (launch state).	R	To be done
1.2.1.2	The acceleration sensor shall have an accuracy of 10mg (µg flight state).	R	To be done
1.2.1.3	The acceleration sensor shall take 1000 measurements every second.	R	To be done
1.2.2	All Sensors shall withstand the environment condition within a REXUS launch campaign.	T, R	To be done
1.2.2.1	The sensors shall withstand the thermal load cases	T, R	To be done
1.2.2.2	The sensors shall withstand the acceleration load cases	R	To be done
1.2.2.3	The sensor shall withstand the pressure load cases	T, R	To be done
1.2.3	The system shall measure angular rate	R, T	To be

ID	Requirement text	Verification	Status
	in all 3 axis		done
1.2.3.1	The angular rate sensor shall be able to measure up to 5Hz	R	To be done
1.2.3.2	The angular rate sensor shall have an accuracy of 10mHz.	R	To be done
1.2.3.3	The angular rate sensor shall take 1000 measurements every second.	R	To be done
1.2.4	The system shall measure the ambient pressure	R, T	To be done
1.2.4.1	The ambient pressure sensor shall cover the range from 0mbar to 1013mbar	R	To be done
1.2.4.2	The ambient pressure sensor shall be able to measure pressure with an accuracy of +/-1mbar	R	To be done
1.2.4.3	The ambient pressure sensor shall make 1 pressure measurement every second.	R	To be done
1.2.5	The system shall measure the temperature inside the inside the CSRM	R, T	To be done
1.2.5.1	The internal temperature sensor shall be able to measure temperatures between -40 and 200°C	R, T	To be done
1.2.5.2	The internal temperature sensor shall be able to measure temperatures with an accuracy of +/- 1°C	R	To be done
1.2.5.3	The internal temperature sensor shall make 1 temperature measurement every second.	R	To be done
1.3	Req. Software		
1.3.1	The rocket module shall retrieve data from internal sensors	A, R	To be done
1.3.10	The rocket module shall be capable to perform operations on the verification experiment	A, R, T	To be done
1.3.11	The rocket module shall be capable to execute received commands	A, R, T	To be done
1.3.2	The rocket module shall retrieve data from verification module sensors	A, R, T	To be done
1.3.3	The rocket module shall safe retrieved data from sensors	A, R, T	To be done
1.3.3.1	The rocket module shall safe the retrieved data from the sensors with 1000Hz	R	To be done
1.3.4	The rocket module shall be capable to interpret the received data	A, R, T	To be done

ID	Requirement text	Verification	Status
1.3.8	The rocket module shall be capable to be self-tested	R, T	To be done
1.3.8.1	The rocket module shall be capable to detect malfunctions	R, T	To be done
1.3.8.2	The rocket module shall be capable to perform counteractive measures if an malfunction is detected	R, T	To be done
1.3.9	The CSRM shall accept a request for radio silence at any time while on the launch pad	R	To be done
1.4	Req. COMS		
1.4.1	The rocket module shall be capable to receive information from the ground module through the whole flight of the rocket.	R	To be done
1.4.1.1	The rocket module shall meet the transmission specs of the Service Module for receiving data	R	To be done
1.4.2	The rocket module shall send information to the ground module through the whole flight of the rocket	T, R	To be done
1.4.2.1	The rocket module shall meet the transmission specs of the Service Module for sending data	R	To be done
1.5	Design Requirements		
1.5.1	The mechanical and electrical components shall withstand the vibration loads during nominal operation of the rocket	T, A	To be done
1.5.2	The mechanical and electrical components shall withstand the shock loads during launch of the rocket	T, A	To be done
1.5.3	The mechanical and electrical components shall withstand the acceleration loads during nominal operation of the rocket	A, R	To be done
1.5.4	The mechanical and electrical components shall withstand the pressure loads during nominal operation of the rocket	T, R	To be done
1.5.5	The mechanical and electrical components shall withstand the thermal loads during nominal operation of the rocket	T, R	To be done

ID	Requirement text	Verification	Status
1.5.7	The temperature of the experiment box shall be kept between -40°C and 30°C	A, T	To be done
1.6	Req. Topology		
1.6.2	The Rocket Module shall fit in a standard REXUS-Module (max_height = 85mm)	A, R, T	To be done
1.6.3	The hatch shall provide a plug for programming and Checking	A, R	To be done
1.6.4	[Design] Plug to RXSM	R	To be done
1.7	Req. Processing Unit		
1.7.1	deleted	-	-
1.7.2	[Design] Connection to Gyros	R	To be done
1.7.3	[Design] Connection to Verification Module	R	To be done
1.7.4	The Processing Unit shall be capable to perform the logging actions near real-time	A, R, T	To be done
1.8	Req. Structural		
1.8.1	Position of CoG: Maximum: X ± 20 mm Y ± 20 mm Z ± 20 mm	A, R	To be done
1.8.2	Moment of Inertia: Maximum: Ix ± 0.1 kg·m2 Iy ± 0.1 kg·m2 Iz ± 0.1 kg·m2	A, R	To be done
1.8.3	Total mass: Shall not deviate more than +-0.5kg	A, R	To be done
1.8.4	Mass distribution: Around 0.25kg per 100mm	A, R	To be done

Table 32: Verification Matrix

ID	Requirement text	Verification	Status
2	Requirements Verification module		
2.1	Functional Sensors		
2.1.1	The system shall measure the temperatures inside the VE	R	To be done
2.1.1.1	The temperature sensor shall be able to measure temperatures between -40 and 200°C.	R, T	To be done
2.1.1.2	The internal temperature sensor shall be able to measure temperatures with an accuracy of +/- 1°C	R, T	To be done
2.1.1.3	The internal temperature sensor shall make 1 temperature measurement every	R	To be done
2.1.2	Deleted	-	-
2.1.2.1	Deleted	-	-

ID	Requirement text	Verification	Status
2.1.2.2	Deleted	-	-
2.2	The system shall record a video of the flight (resp. of VE)	T, R	To be done
2.2.1	The video camera shall have a frame rate between 25fps and 50fps.	R	To be done
2.2.2	The video camera shall have a resolution of fullHD 1920x1080px.	R	To be done
2.3	The Verification Module shall show that an Action triggered by the rocket module is performed	T, R	To be done

Table 33: Varification Matrix

ID	Requirement text	Verification	Status
3	Req. Ground module		
3.1	Data Handling GM		
3.1.1	The Ground Module shall receive telemetry data from the ESRANGE ground networks	T, R	To be done
3.1.2	The Ground Module shall receive data from the CSRM via the REXUS downlink	T, R	To be done
3.1.2.1	The Ground Module shall store the received data stream	T, R	To be done
3.1.2.2	The Ground Module shall decode the received data streams into the usable data sets	T, R	To be done
3.1.3	The Ground Module shall send data to the CSRM via the REXUS uplink	T, R	To be done
3.1.3.1	The Ground Module shall store the received data stream	T, R	To be done
3.1.3.2	The Ground Module shall code the data, that is to be send, into the send data stream	T, R	To be done
3.1.4	The Ground Module shall be able to process down linked data from the CSRM in near-real-time	A, R	To be done
3.1.5	The Ground Module shall be able to process stored data of the CSRM in post flight	A, R	To be done
3.1.6	The Ground Module shall condition the data for visualisation	R, T	To be done
3.1.6.1	The Ground Module shall merge all conditioned data into a single file	R, T	To be done
3.1.6.2	The Ground Module shall update the data frequently	R or T	To be done

ID	Requirement text	Verification	Status
3.1.6.3	The Ground Module shall provide access to the conditioned data via the Internet during flight	R, T	To be done
3.1.7	The Ground Module shall provide access to the conditioned data post flight	R	To be done
3.1.8	The Ground Module shall provide a interface to send control data to the CSRM	A, R	To be done
3.1.9	The tool shall be capable to handle a lost contact to the data stream	T, A, R	To be done
3.2	General Req GM		
3.2.1	The Ground Module shall be operational during all flight phases of the rocket module	A, R	To be done
3.2.2	The Ground Module shall be operational during the countdown phase	A, R	To be done
3.2.3	The Ground Module shall be capable of detecting malfunctions	T, A, R	To be done
3.2.4	The Ground Module shall display the GM status	R, T	To be done
3.2.5	The Ground Module shall display the CSRM status	R, T	To be done

Table 34: Verification Matrix

ID 4	Requirement text Requirements Visualization Tool	Verification	Status
4.0	The VT shall display the flight of the REXUS Rocket	R, T	To be done
4.1	The VT shall display data during flight	R, T	To be done
4.1.2	The VT shall display the trajectory of the REXUS Rocket	R, T	To be done
4.1.3	The data shall be updated once per second	R	To be done
4.1.4	The VT shall use the data from the GM via the internet	R	To be done
4.2	The VT shall display CERESS data during post flight	R, T	To be done
4.2.1	The VT shall display the trajectory of the REXUS Rocket	R, T	To be done
4.2.3	The VT shall display the data collected by the CSRM in post flight	R, T	To be done

Table 35: Verification Matrix

5.2 Test Plan

Test Number	1
Test type	Functional test
Test facility	LRT student laboratory
Test item	Melting wires, EPS
Test level/ procedure and duration	The ability of the power supply to melt the melting wires shall be tested.
Test campaign duration	Tbd
Test Number	**2**
Test type	Functional Test
Test facility	LRT student laboratory
Test item	DC/DC Converters
Test level/ procedure and duration	The DC/DC converters shall be tested on correct output voltages and ability to handle peak currents
Test campaign duration	Tbd
Test Number	**2.1**
Test type	Functional Test
Test facility	LRT student laboratory
Test item	Sensors
Test level/ procedure and duration	The sensors shall be tested on correct functionality
Test campaign duration	Tbd
Test Number	**4**
Test type	Vibration Test
Test facility	DLR Bremen
Test item	Mechanical components
Test level/ procedure and duration	The mechanical components of the experiment shall be tested under vibrations that occur during nominal launcher operations.
Test campaign duration	Tbd

Test Number	5
Test type	Vibration Test
Test facility	DLR Bremen
Test item	Entire system
Test level/ procedure and duration	The entire experiment shall be tested under vibrations that occur during nominal launcher operations.
Test campaign duration	Tbd
Test Number	**6**
Test type	Electromechanical interferences
Test facility	LRT Laboratory
Test item	Electrical components
Test level/ procedure and duration	The influence of electrical components on each other shall be tested
Test campaign duration	Tbd
Test Number	**7**
Test type	Functional Test
Test facility	LRT Laboratory
Test item	Whole RM
Test level/ procedure and duration	RM shall recover to the last state in every phase of countdown and flight when a power drop occurs
Test campaign duration	2 days
Test Number	**8**
Test type	Functional Test
Test facility	LRT Laboratory
Test item	Whole RM
Test level/ procedure and duration	Data on SD-Cards has to be readable after a power drop and no data is overwritten.
Test campaign duration	2 days

Test Number	9
Test type	Functional Test
Test facility	LRT Laboratory
Test item	Whole RM
Test level/ procedure and duration	Full test in full length including countdown and “flight”
Test campaign duration	2 days
Test Number	**10**
Test type	Thermal/Vacuum Test
Test facility	LRT laboratory
Test item	sbRIO
Test level/ procedure and duration	The sbRIOs performance in an environment resembling the flight environment shall be tested
Test campaign duration	Tbd
Test Number	**11**
Test type	Thermal/Vacuum Test
Test facility	LRT laboratory
Test item	All electrical components
Test level/ procedure and duration	All electrical components shall be tested for survivability under vacuum conditions
Test campaign duration	Tbd
Test Number	**12**
Test type	Thermal/Vacuum Test
Test facility	LRT laboratory
Test item	Fine Pressure sensor heating cycle
Test level/ procedure and duration	All components of the heating cycle shall be tested under flight conditions (temperature and vacuum)
Test campaign duration	Tbd

Test Number	13
Test type	Functional Test
Test facility	LRT student laboratory
Test item	sbRIO/Software
Test level/ procedure and duration	The software shall be tested for correct state recovery after reboot of the sbRIO
Test campaign duration	Tbd

Table 36: Test Plan

5.3 Test Results

Physical testing starts after the delivery of the hardware.

6 LAUNCH CAMPAIGN PREPARATION

6.1 Input for the Campaign / Flight Requirement Plans

6.1.1 Dimensions and mass

Experiment mass (in kg):	2.98 (+4.5)
Experiment dimensions (in m):	Ø0.356 x 0.12
Experiment footprint area (in m2):	0.3982
Experiment volume (in m3):	0.04778
Experiment expected COG (centre of gravity) position:	G_x: 2.8mm G_y: -0.9mm G_z: 47.9mm (from lowest surface of the hull)

Table 37: Experiment dimensions and mass summary

6.1.2 Safety risks

6.1.3 Electrical interfaces

Table 9 Electrical interfaces applicable to REXUS

REXUS Electrical Interfaces		
Service module interface required? Yes/No (usually yes)		
	Number of service module interfaces:	1
	TV channel required? If yes, when is it required:	Yes (you asked for it)
Up-/Downlink (RS-422) required? Yes/No		
	Data rate - downlink:	2594 bytes/s
	Data rate – uplink	800 bit/s
Power system: Service module power required? Yes/No (usually yes)		
	Peak power consumption:	31 W
	Average power consumption:	31 W
	Total power consumption after lift-off (until T+1000s)	8.6 Wh
	Power ON	1200 s before lift-off
	Power OFF	1000 s after lift-off
	Battery recharging through service module:	no
Experiment signals: Signals from service module required? Yes/No		
	LO:	Yes
	SOE:	Yes
	SODS:	Yes

Table 38: Electrical Interfaces

6.1.4 Launch Site Requirements

6.1.4.1 Infrastructure

ESR-POSNET Access

Access is needed to the ESR-POSNET via the RS232 interface for near-realtime GPS position data of the REXUS rocket as well as the tracking angles and ranging information of the ESRANGE ground station tracking antenna.

SCIENCE-NET Access

Access is needed to the SCIENCE-NET via the RS232 interface for access to the REXUS TM/TC stream.

Internet Access

Access to an „one-way“ outgoing internet connection is needed via Ethernet TCP/IP interface.

6.1.4.2 Data

Launcher Angles

The final launcher angles/orientation are needed.

Timed Flight Events

A schedule with timed flight events is needed.

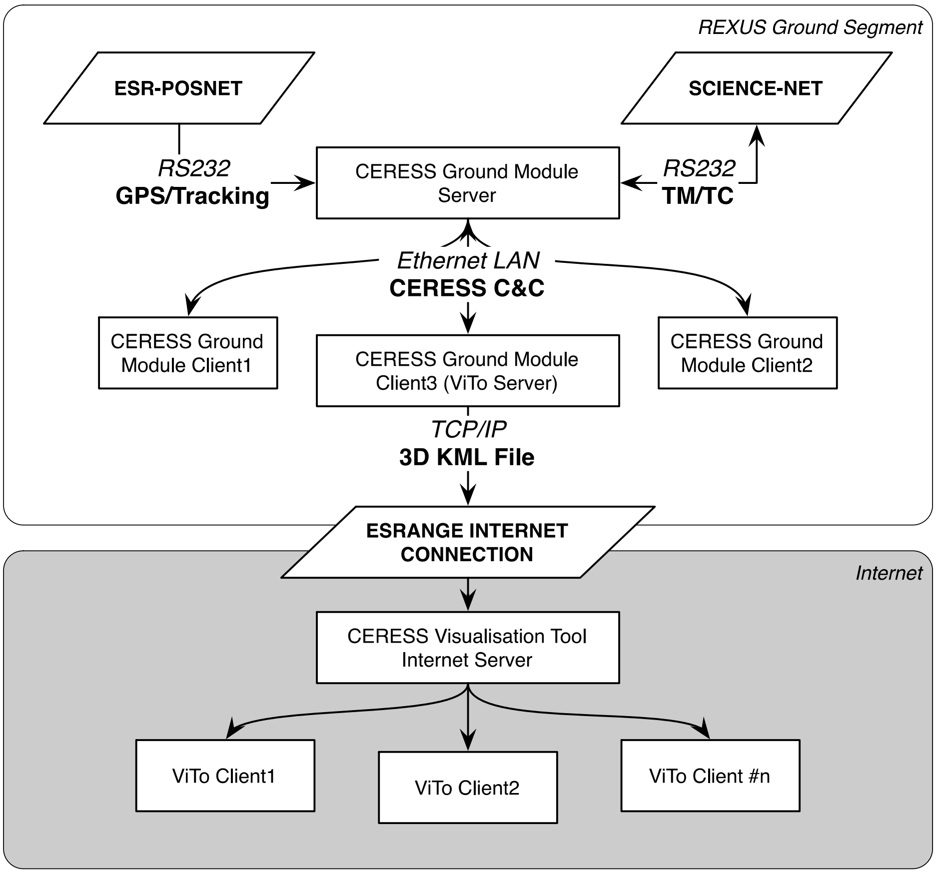


Figure 55: Connections at ground segment

6.2 Preparation and test activities at ESRANGE

Since the CERESS Experiment does not contain any hazardous, decomposing or overly fragile objects, it arrives at ESRANGE fully assembled, meaning all components are already mounted in flight configuration. Flight software is preinstalled and only changed, if necessary.

To ensure launch readiness, the experiment is inspected on arrival by the team, including visual inspections and functional tests.

1. Visual inspections:
    - Check for damage inflicted during transport
    - Check for any loose screws, bolts or connectors
    - Check solder joints
2. Functional tests
    - Turn on ground support equipment and run software
    - Connect experiment to power source

- Experiment Status Checkout
- Turn on power supply and check correct output voltages of DC/DC convertors
- Turn on sbRIO and check for nominal sensor data of all sensors
- Run experiment timeline according to flight plan (wire melting simulated). Check data storage of experiment and camera for correctly stored data and GSE for downlinked data.
- Test debriefing of the Team
- Plan further steps if necessary

After completion of the test run, the experiment module is submitted to integration on the REXUS rocket.

6.3 Launch Campaign Timeline

CERESS - Launch Campaign Timeline

(based on Presentation at Student Training Week)

When?	What?
Day 1:	Welcome Meeting
	Safety briefing
	Mission Control installation
	Visualization installation
	Check Communication GM <-> Visualization
	Check Communication GM <-> Sience Net
	CERESS BIT
Day 2:	Data availability check (Launch angles, GPS etc.)
	Time-Sync Check with Esrange
	Check Communication GM <-> Rocket Module
	Check Communication Visualization <-> Internet
	Check Communication Laptop <-> Internet
	Check Communication WebCam <-> Internet
Day 3:	CERESS assembly
	Visualization Check (data GM -> Visualisation)
	Visualization Check (data RM hard saved -> Visualisation)
	Visualization Check (data RM sensors -> Visualisation)
Day 4:	CERESS flight simulation
	Flight Readiness Review preparation
Day 5:	Flight Readiness Review
Day 6:	"Day off for operational crew"
Day 7:	Rocket 1 roll out to launcher and test countdown
Day 8:	Pre-flight meeting
	Drink & Food Equipment preparation
	Rocket 1 Hot countdown
	Launch readiness review
Day 9:	Rocket 2 roll out to launcher and test countdown
Day 10:	Pre-flight meeting
	Rocket 2 Hot countdown
Day 11-12:	Reserve Days
Day Awesome	Beer
	Fun

Table 39: Launch Campaign Timeline

6.4 Timeline for countdown and flight

CERESS Ground Module	**CERESS** Rocket Module	**TIME [s]**	**ESRANGE**
Initialize		-3600	Plug-In-before-Flight insertion
	STATE to POST->STARTUP ->IDLE	-1000	Power On
Check Communication	Check Communication		
	STATE to BIT (and back)	-660	
Display BIT		-600	
Acq. VALUES		-480	Provide VALUES
Switch to Flight Visualization		-120	
	STATE to NORMAL w/o PIRANI	-60	SODS act.
Internal Timer Reset	Internal Timer Reset	~0	LO act.
	STATE to NORMAL with PIRANI	+80 (to be checked)	SOE act
	Burn Meltingwire I (time triggered)	+100	
Send Meltingwire II signal		+300	
	Burn Meltingwire II (from ground triggered)	+300+offset	
	Burn Meltingwire III (event triggered)	Possible time range tbd.	
Switch Visualisation to Interpolation	STATE to Shutdown	+1000	SODS deact.
		+1010 (estimated by CDR Gremium)	Power Off

Note: Like in the CDR discussed, the meltingwires will get time-slots in which they can be activated. The timeslots have to defined in agreement with the other teams to prevent peak-currents.

6.5 Post Flight Activities

- Recover storage device from CERESS Rocket Module, if CERESS is recovered
- Transfer storage device to GM
- Check Meltingwires, document status.
- Backup the data
- Process the data for post flight visualization
- Thank Sponsors

7 DATA ANALYSIS PLAN

7.1 Data analysis plan

Verification of the CERESS System is one primary objective of the CERESS Project. Therefore the collected data is mainly used to evaluate different verification aspects:

7.1.1 Verification, Triggered Events

- Command and Control of Experiment, time triggered event
- Command and Control of Experiment, event triggered event
- Command and Control of Experiment, TC triggered event

CERESS is designed to provide the data needed to generate the information needed for the verification, even if the REXUS Rocket is not recovered. See Chapter “Experiment Setup, Meltingwires”.

The CERESS Rocket Module provides the following data:

- Feedback of each Meltingwire, if current is flowing through the coils.
- Feedback of each Meltingwire device by a switch.

Each of the feedback signals is stored with a timestamp on-board and also via TM on the CERESS Ground Segment.

By this, the order of events can be correlated and judged for plausibility.

7.1.2 Verification, Data handling

Although each single part of the data handling chain is verified before flight, the complete interaction of every component involved in data handling can only be verified in flight.

The complete process of data acquisition to data storing, data protection and data readout can be verified by inspection of the data stored on the SD-Cards. Therefore two procedures are planed:

1) Correlate expected and actual data format on both SD-Cards
2) Bitwise comparison of the two different SD-Cards

Furthermore CERESS stores data at the CERESS Rocket Module and at the CERESS Ground Module via TM. These two elements are not part of the same signal chain. Therefore a correlation of the on-board- and the on-ground stored data is used to judge the quality of the data redundancy.

The amount of downlinked data is expected to be only a fractional part of the on-board stored.

7.1.3 Verification, Signal Chain TC

The complete control chain from a CERESS Ground Module Control Console Client to the trigger of an event at the CERESS Rocket Module is verified by test in flight. Therefore the timestamps of the send command and the event report from the CERESS Rocket Module need to be compared.

7.1.4 Verification, Signal Chain TM

The complete signal chain from the CERESS Rocket Module to a ViTo running on the Internet is verified by test. Comparison of the data stored from a ViTo running as a CERESS Ground Module Client and a ViTo running as Internet Client is used for this purpose.

7.1.5 Verification, COTS Sensors

The CERESS Rocket Module uses lower cost COTS Sensors. In order to qualify / disqualify them for future REXUS Missions the determination of characteristic values is planned:

- Mean Value
- Standard Deviation
- Min & Max Values

In Case of the Gyroscope and the Accelerometer the values will be compared to the ones measured from the REXUS Service-Module.

7.1.5.1 Error calculations, Position

CERESS gathers position data from two different sources:

- GPS from the REXUS Telemetry stream
- Antenna tracking angles and range from ESRANGE Ground Station

Furthermore the Trajectory will be determined by integration of Acceleration and rotation rates provided by the CERESS Rocket Module. Due the high-frequency measurement (1000Hz) it’s expected to achieve good results.

This way, three Trajectories can be determined and compared.

7.1.5.2 Correlations between Accelerometers and Gyroscopes

The CERESS Rocket Module is equipped with 4 acceleration sensors in a tetrahedron configuration. By using kinematics a correlation between acceleration and rotational rates can be defined. A comparison of the calculated data with the measured data of the gyroscope would be interesting to judge the drift and accuracy of both measuring methods.

7.1.5.3 Error calculation, Altitude

The CERESS Verification Module measures the static atmospheric pressure inside a vented REXUS Module. This data is used to calculate the altitude of the CERESS Rocket Module. This is correlated to the GPS and tracking data to evaluate the measurement error of the height calculated from the static pressure.

The occurring error will describe the quality of the implemented module venting.

7.1.6 Flight Environment

Characterisation of a REXUS Experiments flight environment is secondary objective of the CERESS Project. Following measurements are taken to accomplish this task:

7.1.6.1 Vacuum

The fine pressure sensor of the CERESS Verification Module is used to measure the static pressure inside a vented REXUS Module during free flight, thus the “quality” of vacuum is measured.

7.1.6.2 Micro-Gravity

The CERESS Rocket Module is equipped with 4 acceleration sensors and 1 gyroscope (Each number times two for coarse and fine measurement). These are used to judge the “quality” of micro-gravity during free flight.

7.2 Launch Campaign

7.3 Results

7.4 Discussion and Conclusions

7.5 Lessons Learned

7.5.1 Project Planning

Working in a small Team without a clear work distribution may work, when the Team has not keep up with deadlines and no external standards are applied.

As soon as deadlines and external standards (e.g. REXUS SED) apply, the work distribution is critical for keeping up with the deadlines.

7.5.2 System Definition

The system definition needs to be done in an iterative process. All systems on a specific system level need to be defined before going deeper in the system hierarchy in the next iteration.

A system level hierarchy deeper than 4 levels is not applicable due to complexity.

8 CERESS USER MANUAL

This section aims to provide future Teams the information needed to use CERESS on their mission. It is continuously updated after CDR.

8.1 Services provided by CERESS

CERESS is a Compatible and Extendable REXUS Experiment Support Bus aiming to simplify the REXUS interfaces and experiment development.

Therefore CERESS offers several services for future Missions.

1) The Software is fully reusable and designed with expandability in mind.
2) The CERESS Rocket Module may need to be modified, but is also intended to be reused.
3) The used components and electric circuits can be adopted in the new mission.

If you can wrap the services up in this few words, we have done our job right:
“It’s a plug’n play for REXUS experiments.”

8.1.1 Regulated Power Supply

The CERESS Rocket Module supplies switchable 3.3V, 5V and 24V regulated and fused power lines as well as the not switchable but fused 28V unregulated REXUS Power.

8.1.2 Command & Control

The CERESS Rocket module offers more than 100 DIO channels and 20 Analogue I/Os which can be used for 10 differential measurements.

Command and Control actions can be:

- time triggered by the on-board sequencer
- event triggered by an on-board event
- Telecommand triggered by the CERESS Ground Module

8.1.3 On Board Data Storage

The CERESS Rocket Module is able to store experiment data on two redundant SD-Cards.

8.1.4 TM/TC

The CERESS System offers a complete TM/TC interface derived from the ECSS – Telemetry and Telecomand packet utilization.

8.1.5 LabView integration

A LabView SubVI is provided by the CERESS Ground Module which ports provide the values at the sbRIO I/O Pins in near-realtime during flight and during replay of the data in post-flight.

8.1.6 CERESS Ground Module Server

The CERESS Ground Module Server handles the TC/TM streams, provides TM data and receives TC data from multiple clients. Theoretically a infinite number of Clients for mission specific needs can be connected to the CERESS Ground Module Server.

Furthermore the CERESS Ground Module Server can be set up to back up the experiment data via TM on ground, in case the REXUS Rocket is not recovered.

8.1.7 3D flight Visualization

The Visualization Tool can be used to display REXUS flight data and CERESS Rocket Module data.

The *.kml files used for the 3D flight data visualization are an open source standard and can be easily modified.

8.2 Requirements for future Teams

To be able to use the CERESS System successfully the following Requirements need to be obtained

8.2.1 Floating Ground

The CERESS Rocket Module has a floating ground different to the REXUS Ground. CERESS is completely galvanic isolated. Future Experiments need to maintain the galvanic isolation.

8.2.2 CGP

To not build ground loops, the CERESS Provides a common Ground Point, located at the sbRIO. Future teams shall use the provided ground connection to the CERESS Rocket Module Common Ground Point.

8.2.3 sbRIO I/Os

The CERESS Bus I/Os are directly forwarded from the sbRIO. Therefore the maximal current loads on the CERESS Bus shall be the same than in the sbRIO specifications.

8.2.4 Maximal Power Consumption

The maximal provided by the CERESS Rocket module needs to be determined.

9 ABBREVIATIONS AND REFERENCES

9.1 Abbreviations

AIT	Assembly, Integration and Test
asap	as soon as possible
bdd	block definition diagram (SysML)
BO	Bonn, DLR, German Space Agency
BR	Bremen, DLR Institute of Space Systems
CDR	Critical Design Review
CERESS	Compatible and Extendable REXUS Experiment Support buS
COG	Centre of gravity
CRP	Campaign Requirement Plan
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EAR	Experiment Acceptance Review
EAT	Experiment Acceptance Test
ECTS	European Credit Transfer System
EIT	Electrical Interface Test
EPM	Esrange Project Manager
EPS	Electric power system
ESA	European Space Agency
Esrange	Esrange Space Center
ESTEC	European Space Research and Technology Centre, ESA (NL)
ESW	Experiment Selection Workshop
FAR	Flight Acceptance Review
FPGA	Field Programmable Gate Array
FRP	Flight Requirement Plan
FRR	Flight Readiness Review
FST	Flight Simulation Test
GM	Ground Module
GSE	Ground Support Equipment
H/W	Hardware
HK	House Keeping
HSCS	High side current sense
I/F	Interface
ibd	internal block diagram (SysML)
ICD	Interface Control Document
IPR	Interim Progress Review
LO	Lift Off
LOS	Line of sight
LRT	Lehrstuhl für Raumfahrttechnik (Institute of Astronautics)
LT	Local Time
Mbps	Mega Bits per second

MCU	Main Computation Unit
MFH	Mission Flight Handbook
MORABA	Mobile Raketen Basis (DLR, EuroLaunch)
OBDH	On-Board Data Handling
OP	Oberpfaffenhofen, DLR Center
PCB	Printed Circuit Board (electronic card)
PDR	Preliminary Design Review
PST	Payload System Test
RGM	REXUS ground module
RM	Rocket Module
RXSM	REXUS Service Module
S/W	Software
SED	Student Experiment Documentation
SNSB	Swedish National Space Board
SODS	Start Of Data Storage
SOE	Start Of Experiment
SSC	Swedish Space Corporation
STW	Student Training Week
SysML	Systems Modeling Language
T	Time before and after launch noted with + or -
TBC	To be confirmed
TBD	To be determined
TUM	Technische Universität München
ViTo	Visualization Tool
VM	Verification Module
WBS	Work Breakdown Structure

9.2 References

[1] EuroLaunch: **BEXUS User Manual** (2010), **REXUS User Manual** (2010)

[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 Cooperation for Space Standardization ECSS: Space Engineering, **Ground systems and operations – Monitoring and control data definition**, ECSS-E-ST-70-31C, 31 July 2008

[9] European Cooperation for Space Standardization ECSS: Space Engineering, **Ground systems and operations**, ECSS-E-ST-70C, 31 July 2008

[10] European Cooperation for Space Standardization ECSS: Space Engineering, **Ground systems and operations – Telemetry and Telecommand packet utilization**, ECSS-E-70-41A, 30 January 2003

[11] European Cooperation for Space Standardization ECSS: Space Engineering, **SpaceWire – Links, nodes, routers and networks**, ECSS-E-50-12C, 31 July 2008

[12] Wilfried Ley, Klaus Wittmann, Willi Hallmann: **Handbook of Space technology**. John Wiley & Sons, Ltd, 2009

APPENDIX A – EXPERIMENT REVIEWS

Experiment PDR, ESRANGE, Kiruna, 28. Feb. 2012

Presentation:

- Was 41 seconds too long
- Presented well and confidently
- Writing on slides often too small

General SED Comments

- Many missing sections followed up in presentation
- References need to be updated for literature and component references
- Front page very good
- Chapter 7 for Data Analysis needs to be considered so that it is reflected in the design

Requirements and constraints

- Although not by the standard format appears to be effective
- Can be difficult for system level verification
- Considering this experiment, requirements become so much more important
- What's missing is a market survey of what could be accommodated
- Sensors that could be connected to this should be included that CERESS would still function if these were connected

Mechanical

- Camera viewport can be made to fit to the camera to reduce its size
- Piranis can actually survive
- Cable feedthrough extended to wall and positioned at 180o
- Consider ports on top on top rather than on the side for accessibility
- Mass budget nice and clear

Electrical

- melting wire electronics – students: will be same as focus used
- power schematic for sbRIO should be included in SED
- Interface lines to RXSM should also be included
- Must be careful with reliability with using modules and other software with using LabView
- Who will manufacture PCBs? Students: to be done outside
- Sensitivity analysis would be a good thing to do
- Need to careful of behaviour of sensors when packaged together for a flight
- Careful of I/O connectors and sensitivity to EMI
- Sub-Ds normally used, consider lockable mil-c connectors or

Experiment PDR, ESRANGE, Kiruna, 28. Feb. 2012

other, consider expensive sub-Ds

- Thermocouples can be connected through the connectors but will require the pins of connectors and sockets to be the same materials
- Need to be careful of ground loops as they could affect your readings
- Need to also be careful of where the sbRIO is grounded to
- Grounding concept needs to be investigated especially considering the experiments
- Thermocouples may well need to be isolated

Thermal

- Graph was a very neat way to show component ranges
- Consider a heatsink on the processor
- Test processor on ground first and then in a thermo-vac chamber

Software

- Software has been covered very well
- Can see that the team realises that software is a major component of their experiment
- It’s not clear what the signals from RXSM are used for within the exp software
- Themal cutter would be activated by a command from ground? – desired
- Calibration of sensors when the rocket is lifted ready for launch

Testing

- Some verification methodologies were missed
- e.g. REQ 151 – test and review currently, should be analysis and test
- Make sure to be careful with tests not inspection when something is being set up for a test
- Other issues to be discussed with Mr. DeBeule
- Look at high accelerated live testing

Safety and risks

- Take the risk description out of the SED
- Risks such as team losing members covered
- Covered well after revisions

Operations

- Slantrange is also provided by Esrange and DLR TM
- Problem with being connected to Esranges system and internet and so must be connected with Esranges support
- Power ON should be at T-600 sec
- Is Ethernet to be used in a nominal case or emergency?

Experiment PDR, ESRANGE, Kiruna, 28. Feb. 2012

Students: only emergency

- Are you thinking about being able to determine attitude?

Students: will attempt but not hopeful

- Team must elaborate on calibration of sensors as it is a very important
- Be careful with use of the word calibration, it can be misleading
- p.67 please include the module in experiment mass (in brackets)
- p.68 please include timings for SOE and SODS in the electrical interfaces

---

- Planning Org and Outreach
- Good to see GANTT chart in current level of development
- Considering to add more team members? Students: not yet, please look at that again
- Please look at manpower required to fulfil the project
- Look at backing each other up within the experiment (team already planning for this)

Final Board Call

- Glass window recommended for the experiment to protect the camera

---

Student questions

- Do components that were flown before need the logbook? No… not for such a case

Experiment Critical Design Review

Flight: REXUS 14
Payload Manager: Mikael Inga
Experiment: CERESS
Location: DLR, Oberpfaffenhofen, Germany **Date:** 3 July 2012

1. Review Board members Martin Siegl (chair, editor)	DLR Bremen
Mark Fittock (minutes)	DLR Bremen
Marcus Hörschgen	DLR MORABA
Tobias Ruhe	DLR MORABA
Nils Höger	DLR MORABA
Frank Hassenflug	DLR MORABA
Markus Pinzer	DLR MORABA
Natacha Callens	ESA Education
Alex Kinnaird	ESA Education
Mikael Inga	SSC Solna
Jianning Li	SSC Solna

2. Experiment Team members	
Daniel Bugger	Technische Universität München
Alexander Schmitt	Technische Universität München
Sebastian Althapp	Technische Universität München
Christoph Friedl	Technische Universität München

3. General Comments

- Presentation

  - It was 19 min. long – make sure to keep the time!
  - It was delivered confidently and answered many open questions.
  - The system overview was very good but might have had too many details in the slides.

- SED

  - The document is very good from a formal perspective.
  - The correct EuroLaunch logos are used throughout the document.
  - All presented information is very clear.
  - The graphics used to present the system overview in the presentation should also be part of the SED.
  - In some sections, relevant information is missing.
  - The extensive use of abbreviations/three-letter acronyms makes the document hard to read.

4. Panel Comments and Recommendations

- Requirements and constraints (SED chapter 2)

  - Clarify currents between Req. 1.1.3.1 and 1.1.3.2.
  - Req. 1.3.: The term “pulsing” should be clarified to mean frequency.
  - Req. 1.7.4.: The term “logging actions within real-time” is imprecise.
  - Req. 1.8.3.: Remove the term “exact about”.
  - Req. 3.1.1 is not phrased clearly.
  - Since SysML is used for requirement definition, tracing of requirements could be considered.

- Mechanics (SED chapter 4.2.1 & 4.4)

  - The mechanical design is generally very clear.

- Add overall dimensions and basic dimensions in the text.
- Include manufacturing drawings in the appendices as the construction appears to be sufficiently advanced.
- Perform structural analysis to verify structural integrity (consider static and dynamic load cases, give boundary conditions).
- Note that the 0°-line (launcher rail) is along the hatch.
- Venting hole sheets may be provided by SSC.
- **Rework the camera mounting to make it stiffer and stronger.**
- Include further detail on the camera window as the mounting was not clear.
- Also clarify the mounting of the sbRIO (11 screws) in the document.
- Please cover the accelerometers both on top and at the bottom of the module to prevent accidental damage.
- Add the experiment footprint to the document, including the angles of module modifications (hatches, venting holes).
- **Add arm plug design.**

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

- **The electronics schematics must be improved significantly.**
- Urgently resolve all errors in the schematics.
- The interface to the REXUS service module is incorrect. Connect the correct pins.
- Include filters in the schematics. Information is included in the STW presentation and can be found on the teamsite.
- Do not leave any floating lines.
- Please send the corrected schematics to Martin Siegl (deadlines see below) – they will be forwarded to Markus Pinzer.
- The PTC fuses are unlikely to trip before failure of the DC/DC converters.
- Lock the sbRIO connectors (glue, strap).
- “power is filtered through a fuse”: Clarify what is meant with this statement.
- **Provide a PCB design.**
- Include a grounding concept.
- Beware of noise behaviour / sensitivity issues of the sensor lines.

▪ Thermal (SED chapter 4.2.4 & 4.6)

- The approach to thermal design is fine.
- A thermal vacuum test should be performed to verify the thermal design.
- **“Detailed calculations / simulations need to be done.” Specify what calculations you will perform and carry them out.**
- Test or analyse the vacuum thermal conditions of the sbRIO.

▪ Software (SED chapter 4.8)

- **Software development needs to proceed urgently.**
- Do not rely too heavily on software engineers who are not part of the team.
- Carefully plan the prioritization of tasks and perform load tests.
- Consider a stop-byte on telemetry packets.

▪ Verification and testing (SED chapter 5)

○ The test plan is well developed and could be expanded with tests for subsystem testing and different failure modes (dropout of data, power, etc).

5. Internal Panel Discussion

- Summary of main actions for the experiment team

○ Rework the camera mounting to make it stiffer and stronger.
○ Add arm plug design.
○ The electronics schematics must be improved significantly.
○ Provide a PCB design.
○ "Detailed calculations / simulations need to be done." Specify what calculations you will perform and carry them out.
○ Software development needs to proceed urgently.

- CDR Result: Pass under the following conditions:

○ Complete electronics schematics and PCB design are submitted no later than 25 July 2012.
○ An iteration of the SED is submitted as specified below.

- Next SED version due

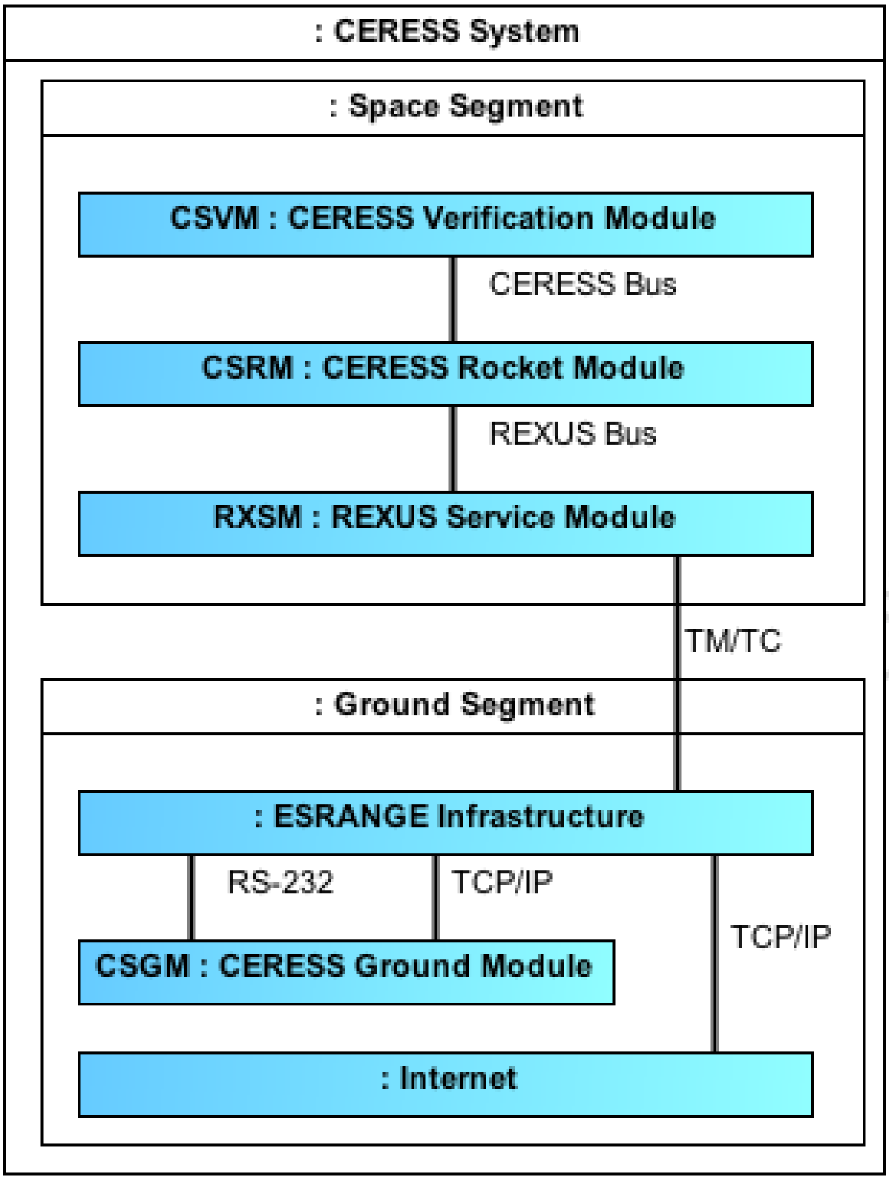
○ **Version 2-1** is due on 31 July (three weeks after receipt of this document) and shall address all open items.
○ Provided that Version 2-1 addresses all open items, Version 3-0 will only need an update of the project management part.

APPENDIX B – OUTREACH AND MEDIA COVERAGE

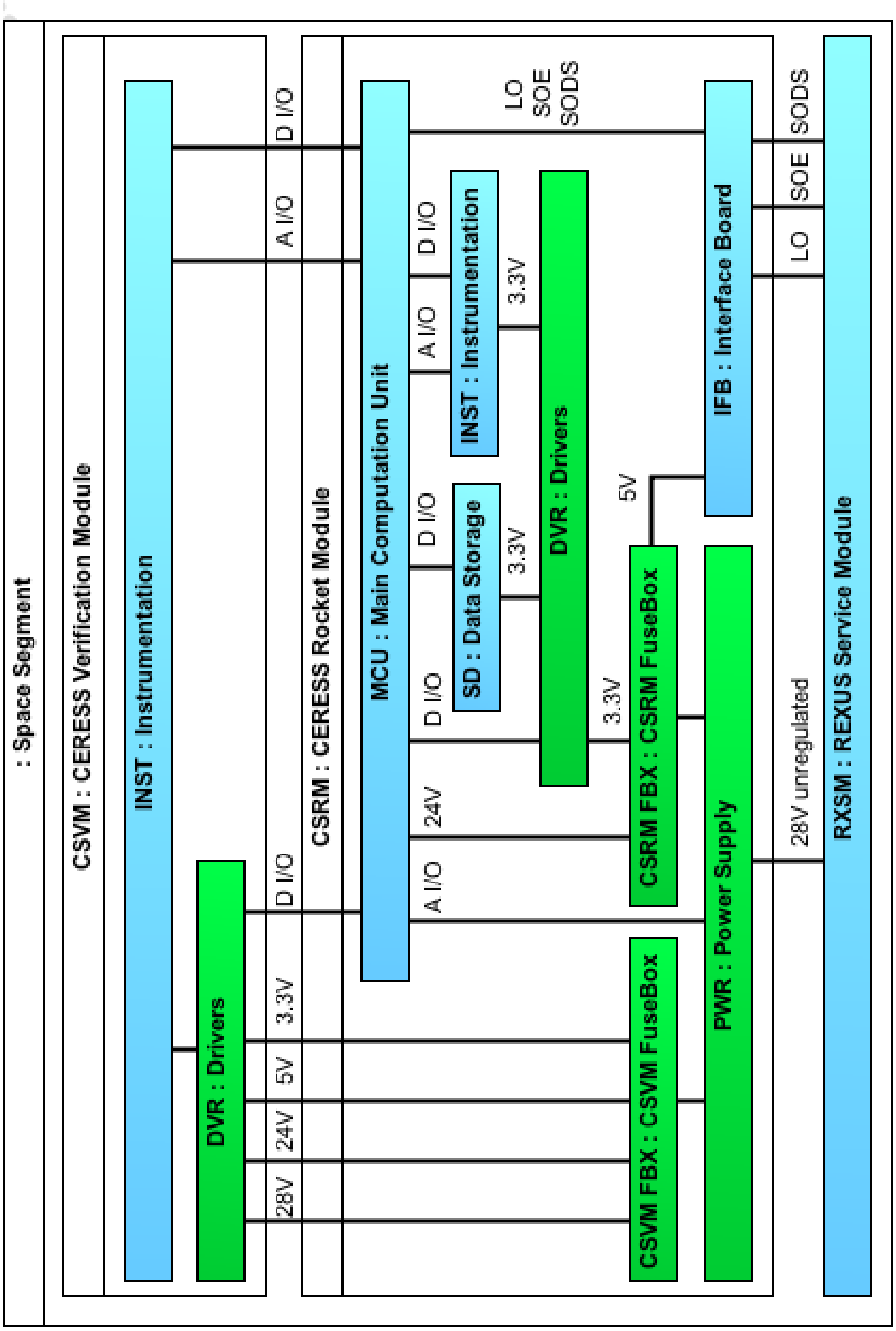
Print & Online Releases			
Date	Media	Publisher	Content
-	Homepage	CERESS	Detailed project information http://ceress.de/
-	Facebook	CERESS	Status updates and photographs http://facebook.de/Team.Ceress
-	Twitter	CERESS	Status updates http://twitter.ceress.de/
-	YouTube	CERESS	Videos http://www.youtube.com/user/CeressRexus
To be released	Press release	CERESS	General project information
Feb. 2012	Press release	FSMB	Article about CERESS and the usage of university funding.

APPENDIX C – ADDITIONAL TECHNICAL INFORMATION

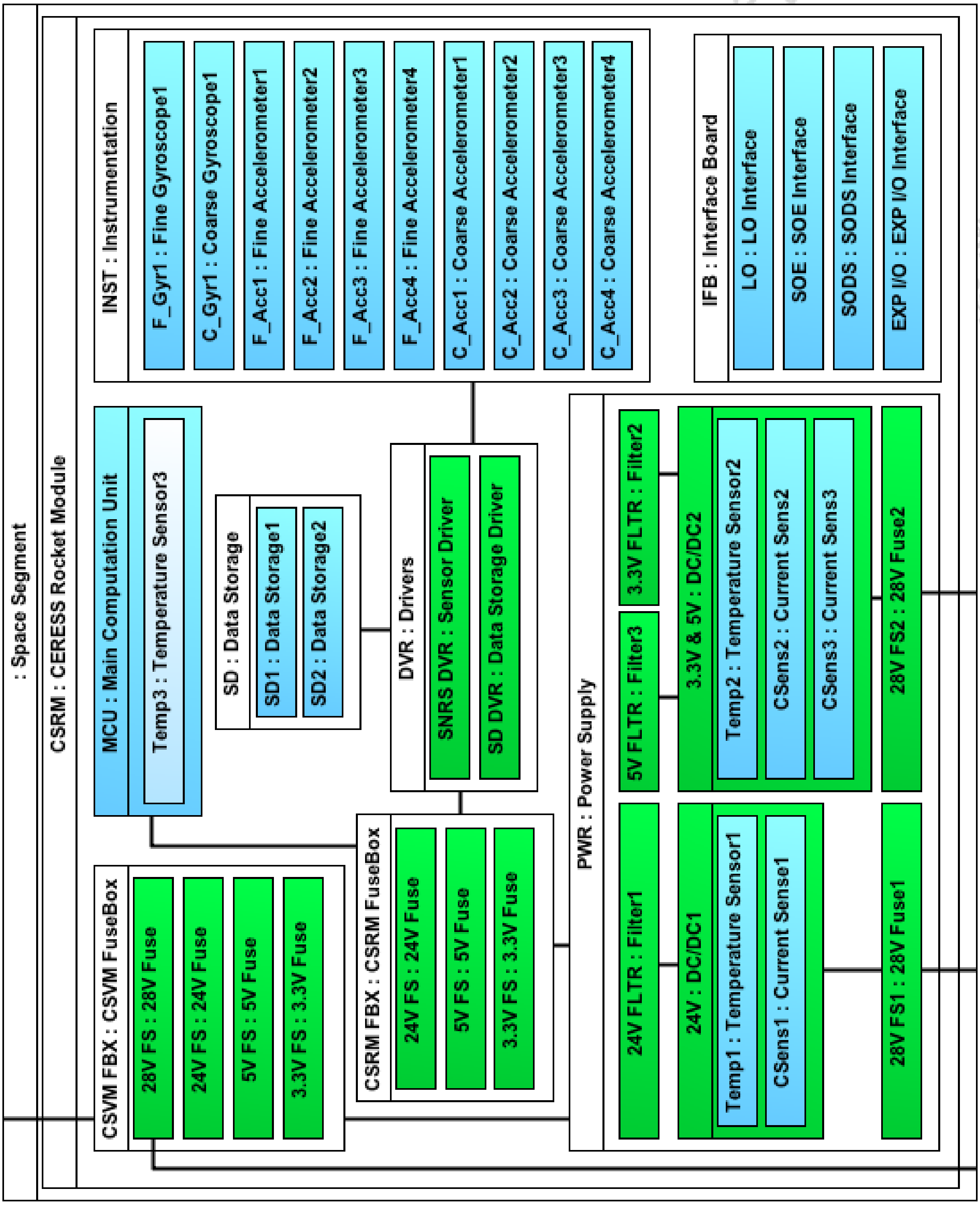
1. CERESS System Overview



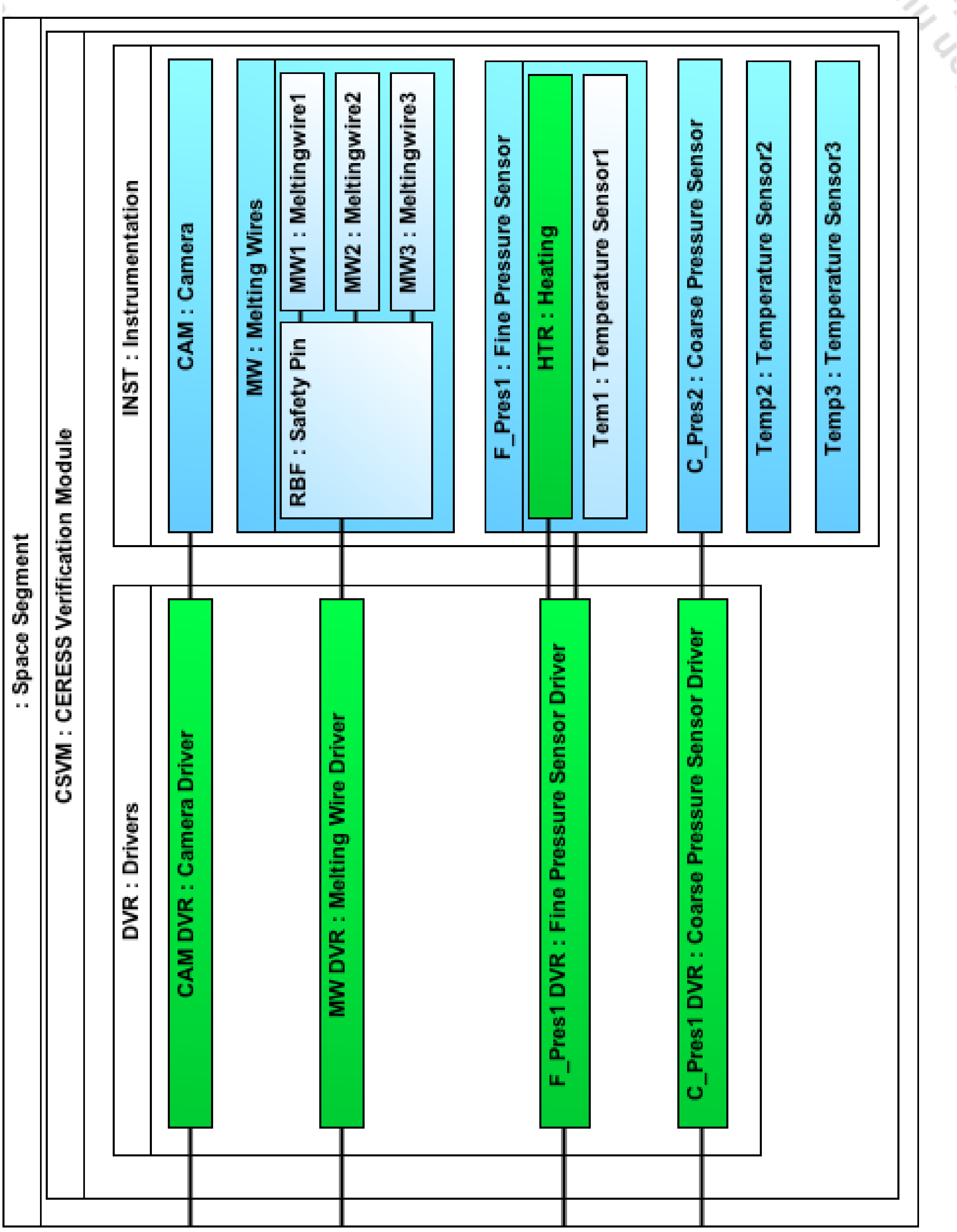
1.1 CERESS Space Segment



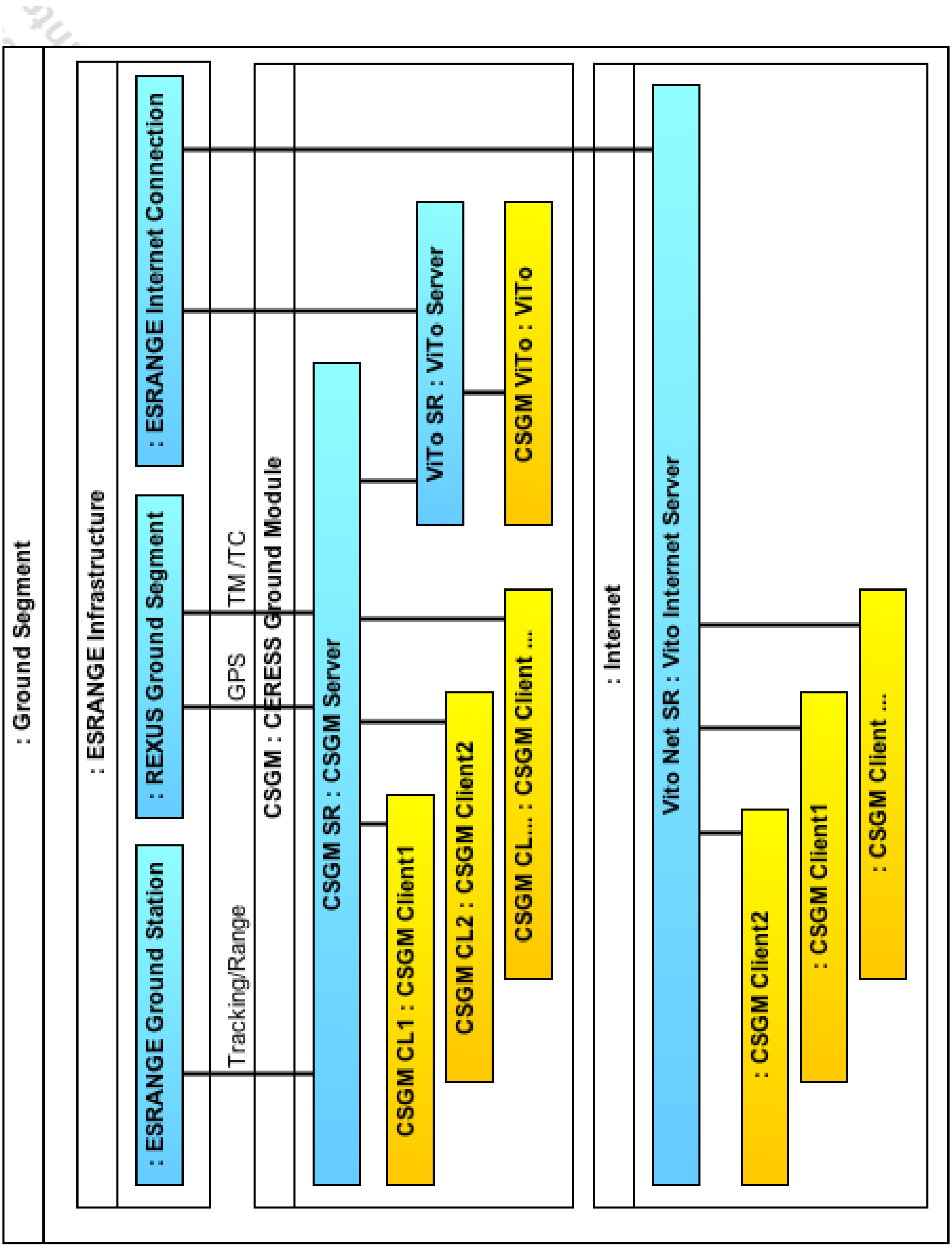
1.1.1CERESS Rocket Module



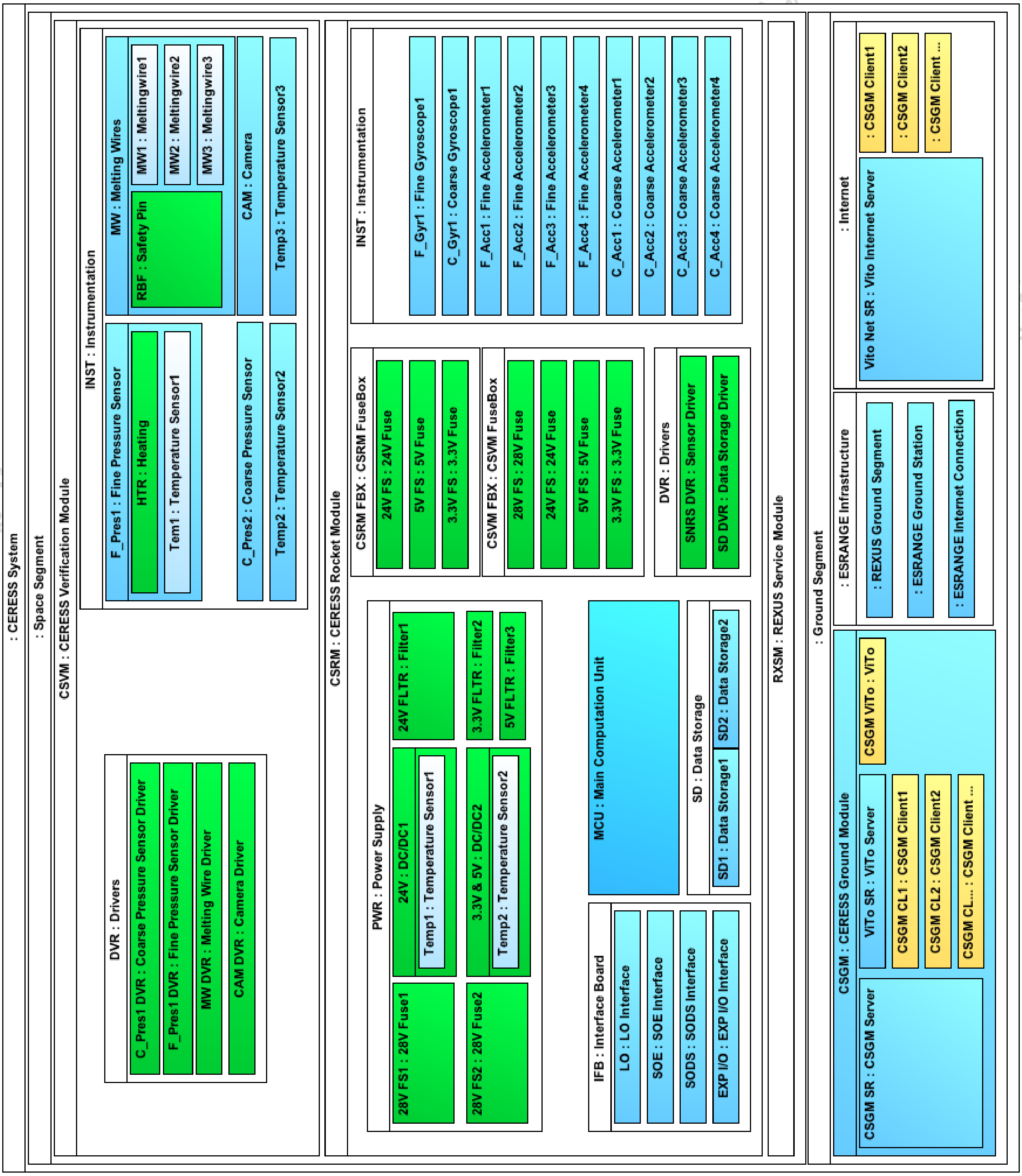
1.1.2CERESS Verification Module



1.2 CERESS Ground Segment



2. CERESS Components Overview



Additional information can be found in the files attached to this SED.

APPENDIX D - EXPLANATION OF RISK REGISTER

Risk ID
TC – technical/implementation
MS – mission (operational performance)
SF – safety
VE – vehicle
PE – personnel

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

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)

Risk index (P x S)	Risk magnitude	Proposed action
E4, E5, D5	Very high risk	Unacceptable risk: implement new process or change baseline – seek attention at appropriate high level
E3, D4, C5	High risk	Unacceptable risk: see above
E2, D3, C4, B5	Medium risk	Unacceaptable risk: must be managed. Consider alternative process or baseline. Seek attention at appropriate level.
E1, D1, D2, C2, C3, B3, B4, A5	Low risk	Acceptable risk: control, monitor, consider options.
C1, B1, A1, B2 A2, A3, A4	Very low risk	Acceptable risk: control, monitor.