# SED

**Student Experiment Documentation**

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**Mission: REXUS16**

## Team Name: MOXA

Experiment Title: Measurement of Ozone and Oxygen in the Atmosphere



| **Team** | **Name** | **University** |
|---|---|---|
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## Change Record

| Version | Date | Changed chapters | Remarks |
|---|---|---|---|
| 0 | 2008-12-18 | New Version | Blank Book 2010 |
| 1 | 2013-02-28 | All | PDR |
| 2.0 | 2013-06-06 | 2.2. Perform. Req.<br>1.4.2, 3.1, 3.3,<br>4.2-8, 5.1, 5.2, 6.1.1, 6.3, 6.4<br>Appendix A,B,C | New pressure accuracy<br>New temperature range<br>CDR |
| 2.1 | 2013-06-17 | 3.3, 3.5, 4.1, 4.8, 4.9, 10 | |
| 2.2 | 2013-08-08 | 1.5, 2.2, 2.4, 3, 4, 5, 6.1, 8 | Version to pass CDR<br>Changes resulting of CDR |
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| 4.1 | 2014-03-28 | | |
| 5 | 2014-10-29 | All chapters | Final report |

**Abstract:**

**Keywords:** REXUS or BEXUS, SED - Student Experiment Documentation, MOXA – Measurement of Oxygen and Ozone in the Atmosphere, Atomic Oxygen, TU Dresden

## CONTENTS

**PREFACE**

This Documentation describes the experiment and configuration of the MOXA experiment for the Rexus 15/16 sound rocket. The idea followed the development of new sensors at the Institute for Aerospace Engineering, Dresden University of Technology, lead by Dr. Tino Schmiel. We want to thank the institute for all the support given to us and the DLR/Esrange for this unique opportunity.

# File Naming

The naming convention for the SED is as follows:

- BX for BEXUS or RX for REXUS, plus number of flight
- MOXA for Measurement of Ozone and Oxygen in the Atmosphere
- FIPEX “Flux-(*Φ-Phi*)-Probe-Experiments”
- SED, plus version (e.g. 3 for CDR) and issue number (beginning with 0 and increasing number when a new issue is sent)
- Date of issue in format ddmmyy

## ABSTRACT

The models of the distribution of residual gases varies widely. For instance the atomic oxygen models results differ up to 400%. To predict climate it is important to know the distribution of Oxygen in its various forms. For instance, atomic oxygen is a major influence on space borne objects, resulting in degradation of exposed materials.

Therefore the MOXA experiment will measure ozone, atomic and molecular oxygen, temperature and pressure during the flight. The Institute for Aerospace Engineering at Dresden University of Technology has developed innovative sensors for oxygen and ozone with a very low response time and high measurement accuracy. The atomic oxygen sensors of the experiment FIPEX have already performed successful measurements onboard the International Space Station and will be integrated in the experiment in a new miniaturized form.

The newly developed ozone sensor will be tested by comparing the measured data during the flight, in dependence of the pressure with existing data.

In addition the data of the oxygen measurements give a hint on the ozone values and will help to verify functionality of the ozone sensor.

The development of accurate sensors for residual gases contributes to the survey of the atmosphere to correlate existing atmospheric models. So it is possible to make precise prediction of residual gases.

This will support atmospheric science and improve the preparation of planned long term missions in the LEO.

The sensors are also applied in many other sections, for example breathing gas analysis.

# 1 INTRODUCTION

## 1.1 Scientific/Technical Background

### Scientific background:

Earth is “breathing”.
The Atmosphere of earth is a dynamic and complex system which changes permanent and depend on different influences.
The most important one is the electromagnetic radiation of the sun which leads to photo dissociation, temperature variations and many other effects.
Other Influences are atmospheric tide effects, geomagnetism and up to now not cleared up variations.

Depending on wavelength (320 nm < λ < 1180 nm) ozone reacts to molecular and atomic. Because of the temperature variation and the gravitational field atomic oxygen diffuse to a higher altitude and recombine again when the radiation relieving Then the oxygen fall down again.

Due to the reduction of molecular oxygen and the diffusion of the atomic oxygen, in the altitude of 450 km atomic oxygen comes about 90 percent.

So the daily and annual variation of the sun radiation on a certain place on earth leads to significant changes of chemical composition in the atmosphere.

Atmospheric models were developed to predict densities, temperature and pressure in different altitudes for different longitudes and latitudes.
These models differ on the theoretical assumption, used data sources and needed input parameter.

Atmospheric models

NRLMSISE-00:

MSIS (Mass Spectrometer and Incoherent Scatter) is an empiric model that is based on mass spectrometer data and pressure measurements of rockets, satellites and airplanes as well as on temperature measurements of incoherent scatter radars.
By addition of new data and combination with physical models the MSIS model has been developed to the NRLMSISE-00 (Naval Research Laboratory Mass Spectrometer and Incoherent Scatter) model. It predicts from sea level to the exosphere.

DTM:

The DTM model (Drag Temperature model) uses optical temperature measurements and data of atmospheric drag from satellites. It works with the assumption that helium, nitrogen and oxygen are the essential elements of the atmosphere from 120 km to higher altitude and connect them with diffusion equations.

MET-2.0:

The MET model (Marshall Engineering Thermosphere Model) has edge condition of temperature and gas composition of 90km and based on diffusion equations and temperature assumptions to the altitude where data from satellite retardation exist.

Prediction of atomic and molecular oxygen

We calculated a prediction of atomic and molecular oxygen to an altitude of 340 km for longitude and latitude of 0 degree for the year 2012, based on these three models. We used SPENVIS (ESA, European Space Agency, Space Environment Information System) for the calculation and the input parameters from the NOAA database.

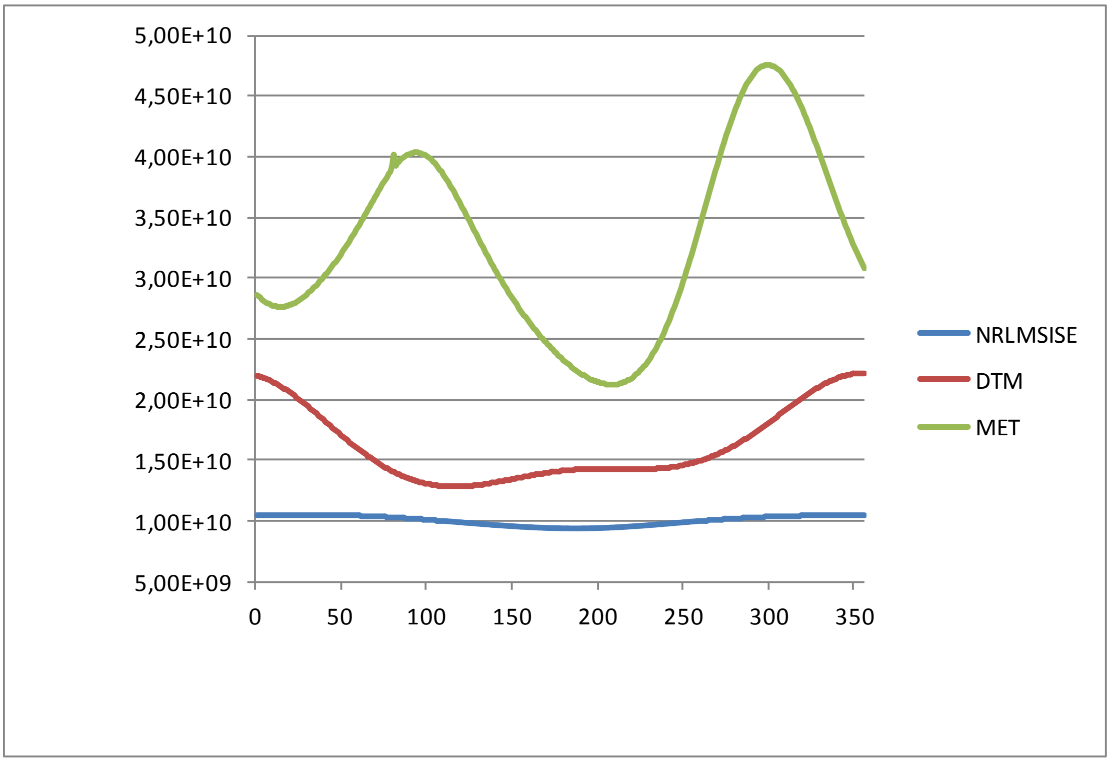



**fig. 1: Prediction of molecular oxygen**

In the prediction of molecular Oxygen the MET model shows a strong influence of the seasons.
The DTM model predicts a higher density for the beginning and end of the year and the in NRLMSISE model are no significant variations visible.
The values differ a lot from day to day.

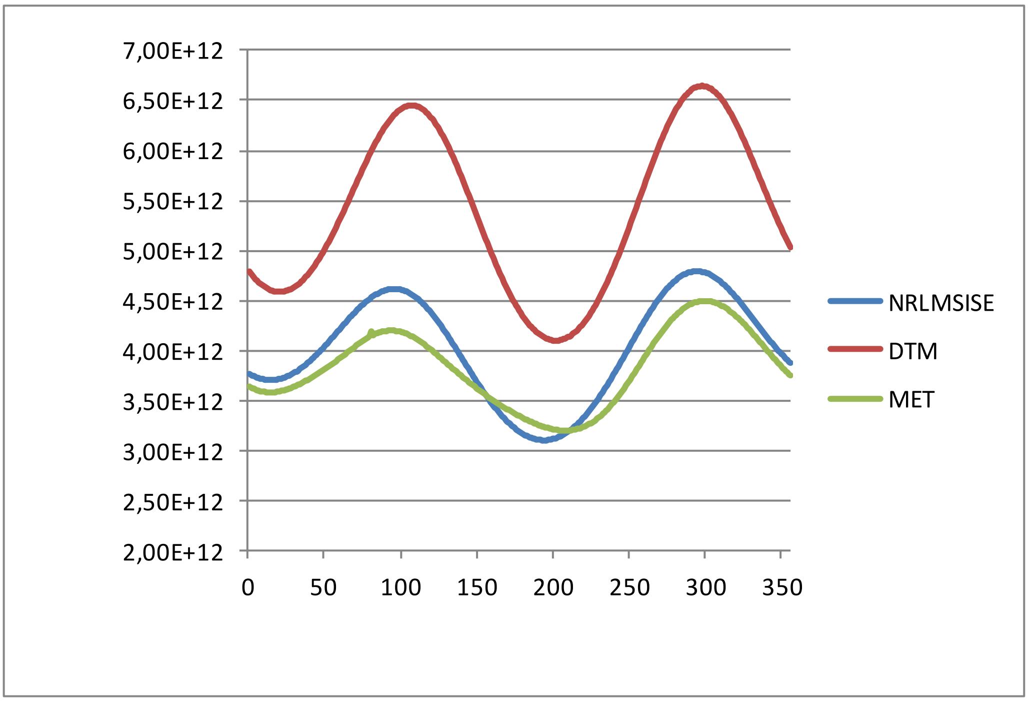



**fig. 2: Prediction of atomic oxygen**

In the prediction of atomic oxygen every model shows a clear influence of the seasons.

This comparison shows that these models are insufficient for a clear prediction. It is necessary to take time-resolved measurements of the densities of the gases in the atmosphere. That is a reason why these sensors have been developed.
The aim is to correlate one model or prospect up to now unknown influences and create a new model for calculating a precise prediction.

The sensors

First time resolved measurements of atomic and molecular oxygen were taken by the Flux-(*Φ-Phi*)-Probe-Experiments (FIPEX). It operated 572 days on European Technology Exposure Facility (EUTEF) on the International Space Station (ISS), fulfilled its primary objectives and collected complete reasonable data.

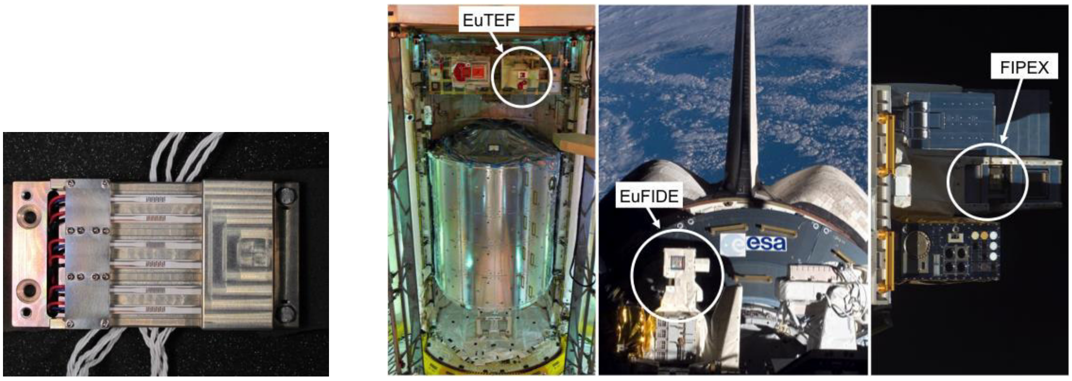



**fig. 3: FIPEX**

These AO and O2 sensors and in addition the new ozone sensor will operate in our experiment in a miniaturized form.

They are solid electrolyte sensors based on amperometric combined with the potentiometric-Nernst-principle for polarization control.

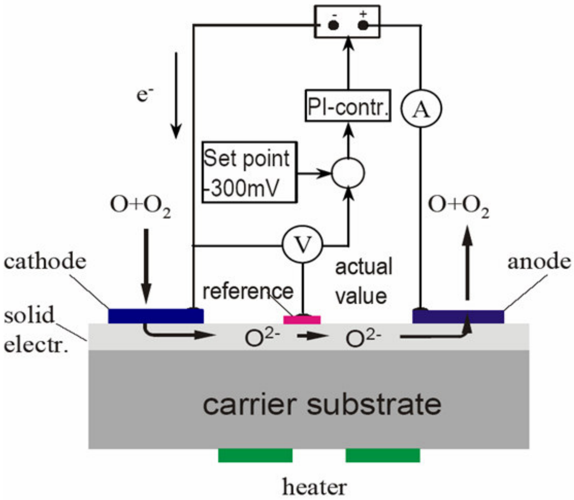



**fig. 4: Amperometric principle for the AO sensor**

Simplified cathode reaction:

$$(O_2) + O + 2e^- \rightarrow O^{2-} + (O_2)$$

In case of contact of the gaugeable species with the cathode the impressed voltage between cathode and anode leads to a current. This is because the molecule or atom take electrons from the cathode and transport them to the anode.

The current can be measured and compared with diagrams, which were created for different partial pressures of the gaugeable species and different static pressures of the gas composition.

Difference between the oxygen sensors

The difference between the atomic and molecular oxygen sensor are the electrodes.

Atomic oxygen prefers reaction with gold electrodes however atomic and molecular oxygen prefers reaction with platinum electrodes.

So cermet electrodes on base of gold or platinum can allow a distinction between atomic and molecular oxygen.

The feedback control of the reduced potential with a reference electrode is very important because of the higher electrode polarisation in the gold electrode. The Sensor for O2 and O3 does not need this reference.

Ozone sensor

The ozone sensor works on another principle. But we must not tell more about it, because it is in a patent process.

Summary

The development of these precise sensors is an important step for better understanding of the complex and dynamic character of our atmosphere.
By means of this you can make precise prediction of specific gas densities, for example corrosive atomic oxygen.
That leads to a better assessment of necessary safeguards for long-term missions in the low earth orbit.
In addition we can better understand climatie effects which will lead to a better prediction of climatic changes and the weather.

## 1.2 Mission Statement

We will test a new developed ozone sensor. In a review we will compare the measured data, in dependence on pressure (will be measured), with known data to estimate the sensors operation quality under conditions of the rocket flight.

Our secondary payloads are the sensors for atomic and molecular oxygen and a temperature sensor.

## 1.3 Experiment Objectives

Primary:

Obj. 1 : Test of the ozone sensor during the flight.

Obj. 2 : Measurement of atomic and molecular oxygen during the flight.

Obj. 3 : Measurement of pressure (necessary for data analysis) during the flight.

Secondary:

Obj. 4 : Measurement of temperature during the flight.

## 1.4 Experiment Concept

Ozone, atomic and molecular oxygen, pressure and the temperature will be measured on the outer shape of our experiment module. So the module has to be modified in a way that the sensors (AO, O2, O3) look outside but are not directly in the airstream because the high velocity and pressure variations would disturb the measurements of the sensitive sensors. The sensor system is a balance between a good gas exchange in front of the sensors and the realization of an operation environment in which the sensors are able to work.

Two sensor boxes will be arranged in an angle of 180 degree and designed that the sensors are easy to exchange. Each sensor box will be controlled by a single electronic circuit. Each box is separated from the other to obtain two independent systems.

The sensor control provides a specific operating temperature for the sensors (AO about 600 °C ,O2 about 550 °C ,O3 about 120 °C ).

The data will be collected and saved on a SD-card.

Some data will be send down to the ground station. That we have live measurement data of the flight.

All electronic circuits, the SD-card and rechargeable batteries will be stored and stabilized in boxes, which will be mounted on the bulkhead.

## 1.5 Team Details

### 1.5.1 Contact Point

Email: contact@rexus-moxa.de
Tel. Team leader: 015228981521
Website: www.rexus-moxa.de

### 1.5.2 Team Members

| | |
|---|---|
| Alexander Mager<br>Aerospace engineer<br>6. Academic year | Team leader/ Payload |
| Bastian Klose<br>Mechatronics engineer<br>6. Academic year | Electronic & Software Design |
| Patrick Geigengack<br>Aerospace engineer<br>4. Academic year | Mechanics |
| Alexander Schultz<br>Mechatronics engineer<br>6. Academic year | Electronic & Software Design, Web |
| Jonas Uhlman<br>Mechanical engineer<br>6. Academic year | Mechanics |
| Daniel Becker<br>Aerospace engineer<br>4. Academic year | Fluid mechanics |
| Fabienne Kinzelmann<br>Philosophies and Catholic Theology<br>3. Academic year | Outreach |
| Susann Knapik<br>Chemical engineer<br>4. Academic year | Gas sensors |
| Nathanael Warth<br>Mechanical engineer<br>3. Academic year | Mechanics & Tests |

| | |
|---|---|
| Max Oswald<br>Aerospace engineer<br>5. Academic year | Mechanics & Tests |
| Sebastian Weixler<br>Mechanical engineer<br>3. Academic year | Mechanics |

# 2 EXPERIMENT REQUIREMENTS AND CONSTRAINTS

## 2.1 Functional Requirements

F.1.: The experiment shall measure ozone on the outer shape of the RX rocket during the flight with two different electronic circuits.

F.2.: The experiment shall measure atomic oxygen on the outer shape of the RX rocket during the flight with two different electronic circuits.

F.3.: The experiment shall measure molecular oxygen on the outer shape of the RX during rocket the flight with two different electronic circuits.

F.4.: The experiment shall measure pressure on the outer shape of the RX during rocket the flight with two different electronic circuits.

F.5.: The experiment shall measure temperature on the outer shape of the RX during rocket the flight with two different electronic circuits.

## 2.2 Performance requirements

P.1.: The ozone measurement (partial pressure) shall be made between $10^{-6}$ bar and 1 bar.

P.2.: The ozone measurement(partial pressure) shall be made with an accuracy of 2 % ( between an attitude of 30 to 90 km).

P.3.: The ozone measurement(partial pressure) shall be made with an rate of 100 measurements per second.

P.4.: The atomic oxygen measurement(partial pressure) shall be made Between $10^{-6}$ bar and 1 bar.

P.5.: The atomic oxygen measurement(partial pressure) shall be made with an accuracy of 1 % (between an attitude of 30 to 90 km)

P.6.: The atomic oxygen measurement(partial pressure) shall be made with an rate of 100 measurements per second.

P.7.: The molecular oxygen measurement (partial pressure) shall be made between $10^{-6}$ bar and 1 bar.

P.8.: The molecular oxygen measurement(partial pressure) shall be made with an accuracy of 1% (between an attitude of 30 to 90 km)

P.9.: The molecular oxygen measurement(partial pressure) shall be made with an rate of 100 measurements per second.

P.10.: The pressure measurement shall be made between $10^{-4}$ bar and 1.5 bar.

P.11.: The pressure measurement shall be made with an accuracy of 8%.

P.11: The pressure measurement from 20 mbar to 3 bar shall be made with an accuracy of 1.5 %.

P.12.: The pressure measurement shall be made with an rate of 100 measurement per second.

P.13.: The temperature measurement shall be made between -100 °C and 100 °C.

P.13.: The temperature measurement shall be possible between -100 °C and 200 °C.

P.14.: The temperature measurement shall be made with an accuracy of +/- 1°C.

P.15.: The temperature measurement shall be made with an rate of 100 measurement every second.

P.16: The pressure measurement from 0.001 to 20 mbar shall be made with an accuracy of 10 %.

P.17: The experiment shall save and process the data at a rate of 10 Hz.

P.18: The experiment control loop shall process at 50 Hz.

## 2.3 Design Requirements

D.1.: The experiment shall be designed to operate in the vibration profile of the RX rocket.

D.2.: The experiment shall be designed in such a way that it shall not disturb and harm the RX rocket or other experiments.

D.3.: The experiment batteries shall be qualified the rocket flights.

D.4.: The experiment batteries shall be rechargeable to run the experiment during pre-flight test, flight preparation and flight.

D.5.: The experiment batteries interface shall be accessible for recharging.

D.6.: The experiment sensors shall be accessible for a late exchange.

D.7.: The experiment sensors shall be put on the outer shape of the rocket for a convenient approaching flow.

D.8.: The electronic boards has to be fixed and hedged against humidity and electromagnetic influences.

D.9.: The hatch shall work (opening time, mechanism) under operating conditions.

D.10.: The heat, produced by the electric, shall be dissipated.

## 2.4 Operational Requirements

O.1.: The experiment shall operate automatically.

O.2.: The experiment shall be release the hatch for the sensor protection automatically.

O.2.: The hatch shall be released automatically.

O.3.: The experiment shall accept a request for radio silence at any time while on the launch pad.

O.4.: The experiment shall store the measured data on a SD-card.

O.5.: The experiment shall send a part of the measured data down to the ground station.

O.6.: The experiment shall be able to turn off all electrical parts for landing.

O.7.: The experiment electrics shall control the sensors all the time.

O.8.: The sensors must not be touched when they are hot.

O.9.: The automatic events shall automatically triggered by Timeline after liftoff.

0.10.: The manual events shall be transmitted over the REXUS Interface

## 2.5 Constraints

C.1.: The experiment shall fit in the module.

C.2.: The experiment shall be able to handle the vibration spectrum.

C.2.: The electric produces heat.

C.4.: The flow vector on the experiment sensors change during the flight.

# 3 PROJECT PLANNING

## 3.1 Work Breakdown Structure (WBS)

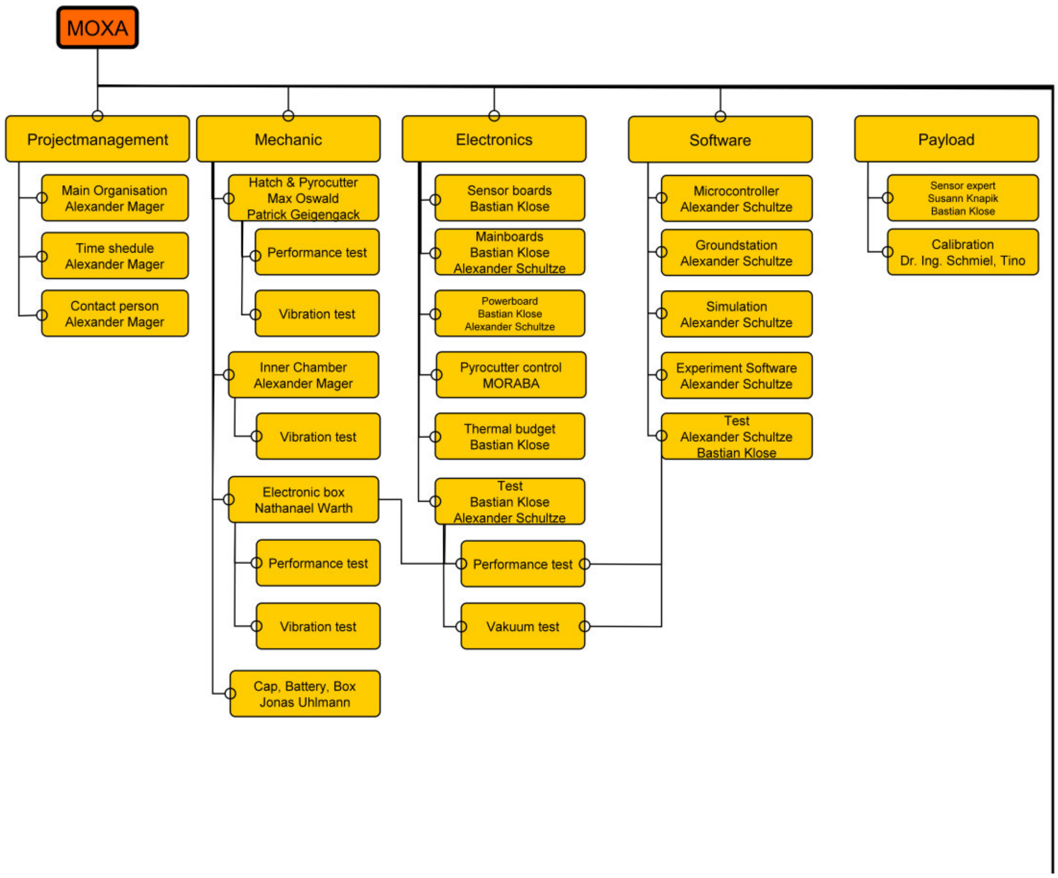



**fig. 5: WBS (1)MOXA**

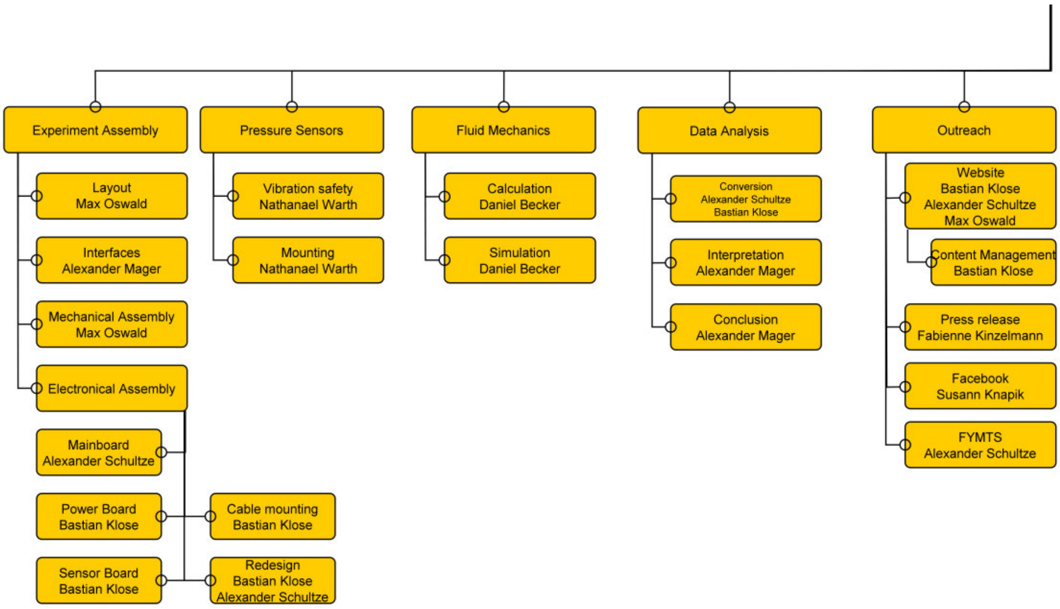



**Fig. 6: WBS (2) MOXA**

## 3.2 Schedule

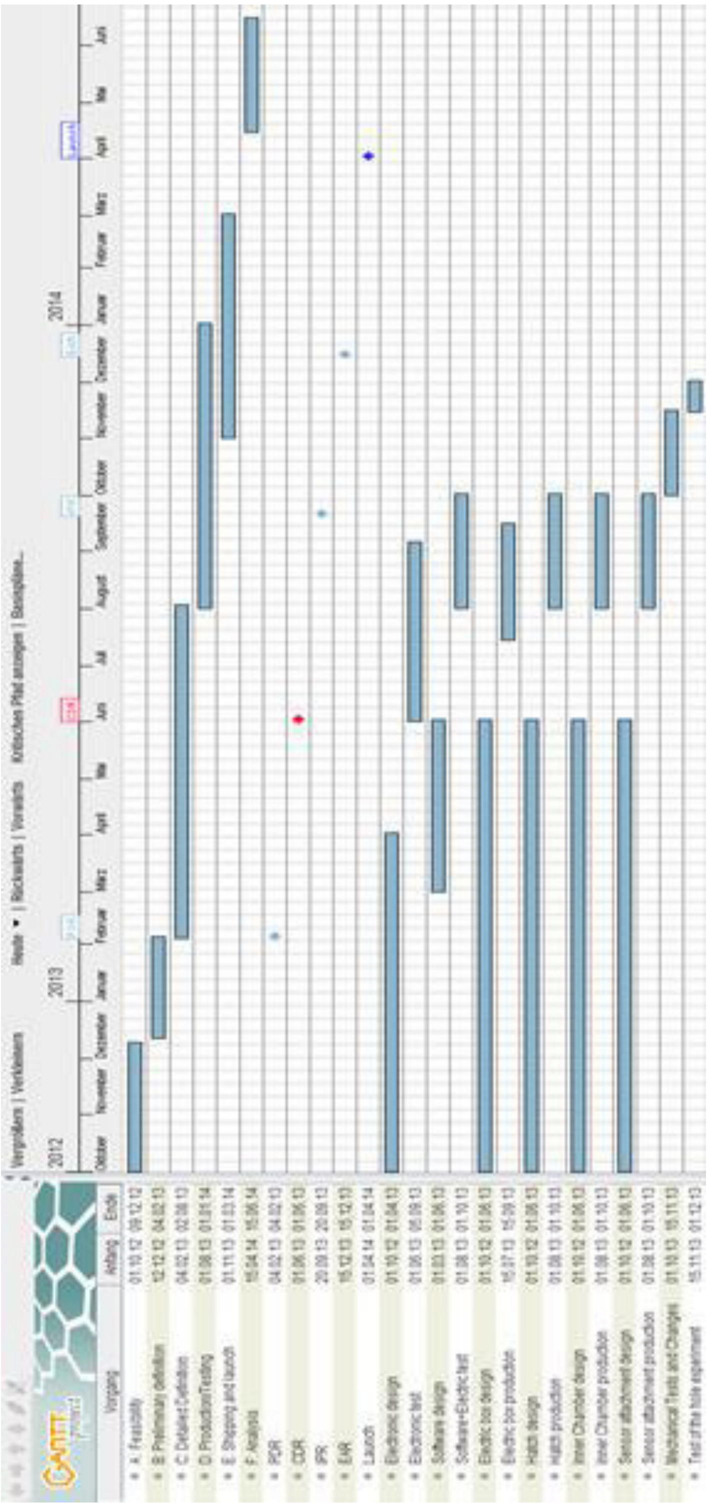


**fig. 7: Timetable of MOXA experiment**

## 3.3 Resources

### 3.3.1 Manpower

Alexander Mager

- Aerospace engineer student
- Lectures of system engineering
- SOLID WORKS

Bastian Klose

- Mechatronics engineering student
- Specialization power electronics
- Practical training in micro controller programming

Alexander Schultze

- Mechatronics engineering student
- Specialization power electronics
- Board development in a student research project

Patrick Geigengack

- Aerospace engineer student
- CATIA V5
- Dual studies of construction engineering (bachelor of science)

Jonas Uhlmann

- Mechanical engineering student
- Designed a test stand in a student research project
- Traineeship in the area of designing mobile processing machine
- Student staff at Institute for Fluid Mechanics at TU Dresden
- SOLID WORKS, CATIA

Daniel Becker

- Aerospace engineer student
- Bachelor of engineering
- CATIA

Fabienne Kinzelmann

- Philosophies and catholic Theology
- Trained as a journalist

Susann Knapik

- Chemical engineer student
- SOILD WORKS

Max Oswald

- Aerospace engineer student
- Internship at Astrium Satellites Friedrichshafen
- Student staff at Institute of Aerospace Engineering
- involved in the software development for the next student picosat of the TU Dresden (SOMP2)
- CATIA, SOLID WORKS

Nathanael Warth

- Aerospace engineer student
- SOLID WORKS

Sebastian Weixler

- Mechanical engineering student
- SOLID WORKS

Students Experiment Document. MOXA Experiment RX16. TU Dresden.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exams | | Internship | | Other (Vacation etc.) | | | | | | |

| Datum | Bastian | Patrick | AlexS | AlexM | Daniel | Susann | Nathanael | Jonas | Fabienne | Sebastian | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.7 | 5 | 2 | 1 | 7 | 0 | 3 | 1 | 0 | 0 | 2 | |
| 6.7 | 5 | 2 | 0 | 7 | 0 | 3 | 1 | 0 | 0 | 2 | 0 |
| 7.7 | 5 | 2 | 0 | 7 | 0 | 3 | 1 | 0 | 0 | 2 | 0 |
| 8.7 | 5 | 8 | 0 | 5 | | 3 | 1 | 2 | 0 | 2 | 0 |
| 9.7 | 5 | 2 | 1 | 5 | 2 | 0 | 1 | 0 | 0 | 2 | 0 |
| 10.7 | 5 | 2 | 1 | 5 | 2 | 3 | 1 | 0 | 0 | 2 | 0 |
| 11.7 | 5 | 2 | 1 | 5 | 2 | 3 | 1 | 0 | 0 | 2 | 0 |
| 12.7 | 5 | 3 | 1 | 5 | 2 | 3 | 1 | 0 | 0 | 2 | 0 |
| 13.7 | 5 | 2 | 8 | 5 | 2 | 3 | 1 | 0 | 0 | 2 | 0 |
| 14.7 | 5 | 2 | 8 | 5 | 2 | 0 | 1 | 0 | 0 | 2 | 0 |
| 15.7 | 5 | 8 | 1 | 5 | 2 | 3 | 1 | 2 | 0 | 2 | 0 |
| 16.7 | 5 | 2 | 1 | 5 | 2 | 3 | 1 | 0 | 0 | 2 | 0 |
| 17.7 | 5 | 2 | 1 | 5 | 2 | 3 | 1 | 0 | 0 | 2 | 0 |
| 18.7 | 5 | 2 | 1 | 5 | 2 | 0 | 1 | 0 | 0 | 2 | 0 |
| 19.7 | 5 | 3 | 1 | 5 | 0 | 3 | 1 | 0 | 0 | 2 | 0 |
| 20.7 | 5 | 2 | 8 | 5 | 0 | 7 | 1 | 0 | 1 | 2 | 0 |
| 21.7 | 5 | 2 | 8 | 5 | 0 | 7 | 1 | 0 | 1 | 2 | 0 |
| 22.7 | 5 | 8 | 1 | 5 | 0 | 7 | 0 | 2 | 1 | 2 | 2 |
| 23.7 | 5 | 2 | 1 | 5 | 0 | 7 | 0 | 0 | 1 | 2 | 0 |
| 24.7 | 5 | 2 | 1 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 0 |
| 25.7 | 5 | 2 | 1 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 0 |
| 26.7 | 5 | 3 | 1 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 0 |
| 27.7 | 5 | 2 | 8 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 2 |
| 28.7 | 5 | 2 | 8 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 2 |
| 29.7 | 5 | 1 | 1 | 5 | 0 | 7 | 0 | 2 | 1 | 2 | 4 |
| 30.7 | 5 | 2 | 1 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 4 |
| 31.7 | 5 | 2 | 1 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 1 |
| 1.8 | 5 | 2 | 0 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 0 |
| 2.8 | 5 | 3 | 0 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 0 |
| 3.8 | 5 | 2 | 0 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 0 |
| 4.8 | 5 | 2 | 0 | 5 | 2 | 7 | 0 | 0 | 1 | 2 | 0 |
| 5.8 | 5 | | 0 | 5 | 0 | 7 | 0 | 2 | 1 | 2 | 2 |
| 6.8 | 5 | 3 | 0 | 5 | 0 | 7 | 0 | 0 | 1 | 2 | 1 |
| 7.8 | 5 | 3 | 0 | 5 | 0 | 7 | 0 | 0 | 1 | 2 | 1 |
| 8.8 | 5 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 2 | 1 |
| 9.8 | 5 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| 10.8 | 5 | 0 | 0 | 5 | 4-8 | 0 | 0 | 0 | 1 | 2 | 2 |
| 11.8 | 5 | 1 | 0 | 5 | 4-8 | 0 | 0 | 0 | 1 | 2 | 2 |
| 12.8 | 5 | 1 | 0 | 5 | 4-8 | 0 | 0 | 2 | 1 | 2 | 2 |
| 13.8 | 5 | 1 | 0 | 5 | 4-8 | 0 | 0 | 0 | 1 | 2 | 0 |
| 14.8 | 5 | 1 | 1 | 5 | 4-8 | 0 | 0 | 0 | 1 | 2 | 0 |
| 15.8 | 5 | 1 | 1 | 5 | 4-8 | 0 | 0 | 0 | 1 | 2 | 0 |
| 16.8 | 2 | 1 | 1 | 5 | 4-8 | 0 | 0 | 0 | 1 | 2 | 0 |
| 17.8 | 2 | 1 | 1 | 7 | 4-8 | 0 | 0 | 0 | 1 | 2 | 0 |
| 18.8 | 2 | 1 | 1 | 7 | 4-8 | 0 | 0 | 0 | 1 | 2 | 0 |
| 19.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 2 | 2 | 1 | 4 | 0 |
| 20.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 4 | 0 |
| 21.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 4 | 0 |
| 22.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 4 | 0 |
| 23.8 | 2 | 1 | 1 | 7 | 4-8 | 0 | 12 | 0 | 1 | 1 | 0 |
| 24.8 | 2 | 1 | 1 | 7 | 4-8 | 0 | 12 | 0 | 1 | 1 | 0 |
| 25.8 | 2 | 1 | 1 | 7 | 4-8 | 0 | 12 | 0 | 1 | 1 | 0 |
| 26.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 2 | 1 | 1 | 0 |
| 27.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 1 | 0 |
| 28.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 1 | 0 |
| 29.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 1 | 0 |
| 30.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 1 | 0 |
| 31.8 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 1 | 0 |

**fig. 8: Manpower (1)**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 0 | 1 | 1 | 0 |
| 2.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 12 | 2 | 1 | 1 | 0 |
| 3.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 2 | 1 | 1 | 1 | 0 |
| 4.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 7 | 1 | 1 | 1 | 0 |
| 5.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 7 | 1 | 1 | 1 | 0 |
| 6.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 7 | 1 | 1 | 1 | 0 |
| 7.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 7 | 1 | 1 | 1 | 0 |
| 8.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 7 | 1 | 1 | 1 | 0 |
| 9.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 2 | 2 | 1 | 1 | 4-10 |
| 10.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 2 | 1 | 1 | 1 | 4-10 |
| 11.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 2 | 1 | 1 | 1 | 4-10 |
| 12.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 2 | 1 | 1 | 1 | 4-10 |
| 13.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 2 | 1 | 1 | 1 | 4-10 |
| 14.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 7 | 1 | 1 | 1 | 4-10 |
| 15.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 7 | 1 | | 1 | 4-10 |
| 16.9 | 2 | 1 | 1 | 7 | 4-8 | 7 | 7 | 2 | | 1 | 4-10 |
| 17.9 | 2 | 1 | 1 | 7 | 0 | 7 | 7 | 1 | | 1 | 4-10 |
| 18.9 | 2 | 1 | 1 | 7 | 0 | 7 | 7 | 1 | | 1 | 4-10 |
| 19.9 | 2 | 1 | 1 | 7 | 0 | 7 | 7 | 1 | | 1 | 4-10 |
| 20.9 | 2 | 1 | 1 | 7 | 0 | 7 | 7 | 1 | | 1 | 4-10 |
| 21.9 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | | 1 | 4-10 |
| 22.9 | 2 | 1 | 1 | 7 | 0 | 7 | 12 | 1 | | 1 | 4-10 |
| 23.9 | 2 | 1 | 1 | 7 | 0 | 7 | 12 | 1 | | 1 | 4-10 |
| 24.9 | 2 | 1 | 1 | 7 | 0 | 7 | 12 | 1 | | 1 | 4-10 |
| 25.9 | 2 | 1 | 1 | 7 | 0 | 7 | 12 | 1 | | 1 | 4-10 |
| 26.9 | 2 | 1 | 1 | 7 | 0 | 7 | 12 | 1 | | 1 | 4-10 |
| 27.9 | 2 | 1 | 1 | 7 | 0 | 7 | 12 | 1 | | 1 | 4-10 |
| 28.9 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 1 | 4-10 |
| 29.9 | 2 | 1 | 1 | 7 | 0 | 7 | 7 | 1 | 1 | 1 | 4-10 |
| 30.9 | 2 | 1 | 1 | 7 | 0 | 7 | 7 | 1 | 1 | 4 | 4-10 |
| 1.10 | 2 | 1 | 1 | 7 | 0 | 7 | 7 | 1 | 1 | 4 | 4-10 |
| 2.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 3.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 4.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 5.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 6.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 7.10 | 2 | 1 | 8 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 8.10 | 2 | 1 | 8 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 9.10 | 2 | 1 | 8 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 10.10 | 2 | 1 | 8 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 11.10 | 2 | 1 | 8 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 12.10 | 2 | 1 | 8 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 13.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 14.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 15.10 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 16.10 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 17.10 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 18.10 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 19.10 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 20.10 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 21.10 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 22.10 | 2 | 1 | 1 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 23.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 24.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 25.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 26.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 27.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 28.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 29.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 30.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |
| 31.10 | 2 | 1 | 0 | 7 | 0 | 7 | 2 | 1 | 1 | 4 | 4-10 |

**fig. 9: Manpower (2)**

| Week | Bastian | Patrick | AlexS | AlexM | Daniel | Susann | Nathanael | Jonas | Fabienne | Sebastian | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| 44 | 10 | 1 | 10 | 10 | 1 | 2 | 5 | 2 | 0,5 | 10 | 15 |
| 45 | 10 | 1 | 10 | 10 | 1 | 2 | 5 | 2 | 0,5 | 10 | 15 |
| 46 | 10 | 1 | 10 | 10 | 1 | 2 | 5 | 2 | 0,5 | 10 | 15 |
| 47 | 10 | 1 | 10 | 10 | 1 | 2 | 5 | 2 | 0,5 | 10 | 15 |
| 48 | 10 | 1 | 10 | 10 | 1 | 2 | 5 | 2 | 0,5 | 10 | 15 |
| 49 | 10 | 1 | 10 | 10 | 1 | 2 | 5 | 2 | 0,5 | 10 | 15 |
| 50 | 10 | 1 | 10 | 10 | 1 | 2 | 5 | 2 | 0,5 | 10 | 15 |
| 51 | 10 | 1 | 0 | 10 | 1 | 2 | 5 | 2 | 0,5 | 10 | 10 |
| 52 | 10 | 1 | 0 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 10 |
| 2014 1 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 15 |
| 2 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 15 |
| 3 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 15 |
| 4 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 15 |
| 5 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 10 |
| 6 | 0 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 5 |
| 7 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 5 |
| 8 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 5 |
| 9 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 5 |
| 10 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 2 | 0,5 | 10 | 5 |
| 11 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 5 |
| 12 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 5 |
| 13 | 40 | 1 | 41 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 14 | 40 | 1 | 41 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 15 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 16 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 17 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 18 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 19 | 5 | 1 | 5 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 20 | 0 | 1 | 0 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 21 | 0 | 1 | 0 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |
| 22 | 0 | 1 | 0 | 10 | 1 | 3 | 5 | 0 | 0,5 | 10 | 20 |

**fig. 10: Manpower (3)**

### 3.3.2 Budget

The fabrication of the mechanic will be taken by our university.

**Table 3-1: Mechanical and Electric Parts Cost Estimate**

| Number | Section | Subsection | Ordered | Total Amount | Sponsor | Cost for DLR | other sp. C. |
|---|---|---|---|---|---|---|---|
| 1 | Electronic | Mainboard PCB | 2 | 3 | DLR | 148,02 € | |
| 2 | Electronic | Protoboards | 2 | 2 | Bastian K | 0 € | 50 € |
| 3 | Electronic | Mainboard Parts | | | DLR | 306 € | |
| 4 | Electronic | Sensorboard PCB | 2 | 3 | DLR | 148,02 € | |
| 5 | Electronic | Sensorboard Parts | | | DLR | 257 € | |
| 6 | Electronic | Powerboard | 0 | 1 | DLR | 71,40 € | |
| 7 | Electronic | Temperature PCB | 0 | 8 | Other | 0 € | |
| 8 | Electronic | Generic | | | TUD | 0 € | |
| 9 | Electronic | Sensors | 9 | 9 | TUD | 0 € | |
| 10 | Electronic | Magnetic Switch PCB | 2 | 2 | DLR | 49,00 € | |
| 11 | Electronic | Generic Parts | | | DLR | 481 € | |
| 12 | Electronic | PCB for Sensors | 0 | 2 | DLR | 320 € | |
| 13 | Electronic | Magnetic Switch Parts | | | DLR | 43,37 € | |
| 14 | Electronic | RXIF SIM | | | DLR | 16,85 € | |
| 15 | Mechanic | Screws | 1 | | DLR | 139,70 € | |
| 16 | Mechanic | Chemicals | 1 | | DLR | 140,62 € | |
| 17 | Mechanic | Hatch in-house production | 1 | | TUD | 0 € | |
| 18 | Mechanic | Hatch purchase parts | 1 | | DLR | 109,02 € | |
| 19 | Mechanic | Inner Chamber in-house production | 1 | | TUD | 0 € | |
| 20 | Mechanic | Electronic Box in-house production | 1 | | TUD | 0 € | |
| 21 | Mechanic | Electronic Box purchase parts | 1 | | DLR | 86,31 € | |
| 22 | Mechanic | Modul in-house production | 1 | | TUD | 0 € | |
| 23 | Mechanic | Modul purchase parts | 1 | | DLR | 73,93 € | |
| 24 | Mechanic | Pirani Sensor | 1 | | DLR | 675,92 € | |
| 25 | Mechanic | Piezo Sensor | 1 | | DLR | 170,37 € | |
| | | | | | Total | 3.236,66 € | |

### 3.3.3 External Support

**Dresden University of Technology**

Institute of Aerospace Engineering

Space Systems

Prof. Dr. Martin Tajmar

- Dr. Tino Schmiel (Head of research group of the sensor development (AO,O2,O3))
- Dr. Christian Meyer (responsible for the ozone sensor)

Chair of Fluid Dynamics

- Dr. Frank Rüdiger (Shallow water analogy)

## 3.4 Outreach Approach

### 3.4.1 Social Media


**fig. 11: Facebook, site**

In January 2013, we launched a *Facebook page* to inform industry insiders, journalists, classmates and friends about our project's progress and other news. www.facebook.com/REXUS.MOXA

### 3.4.2 Website

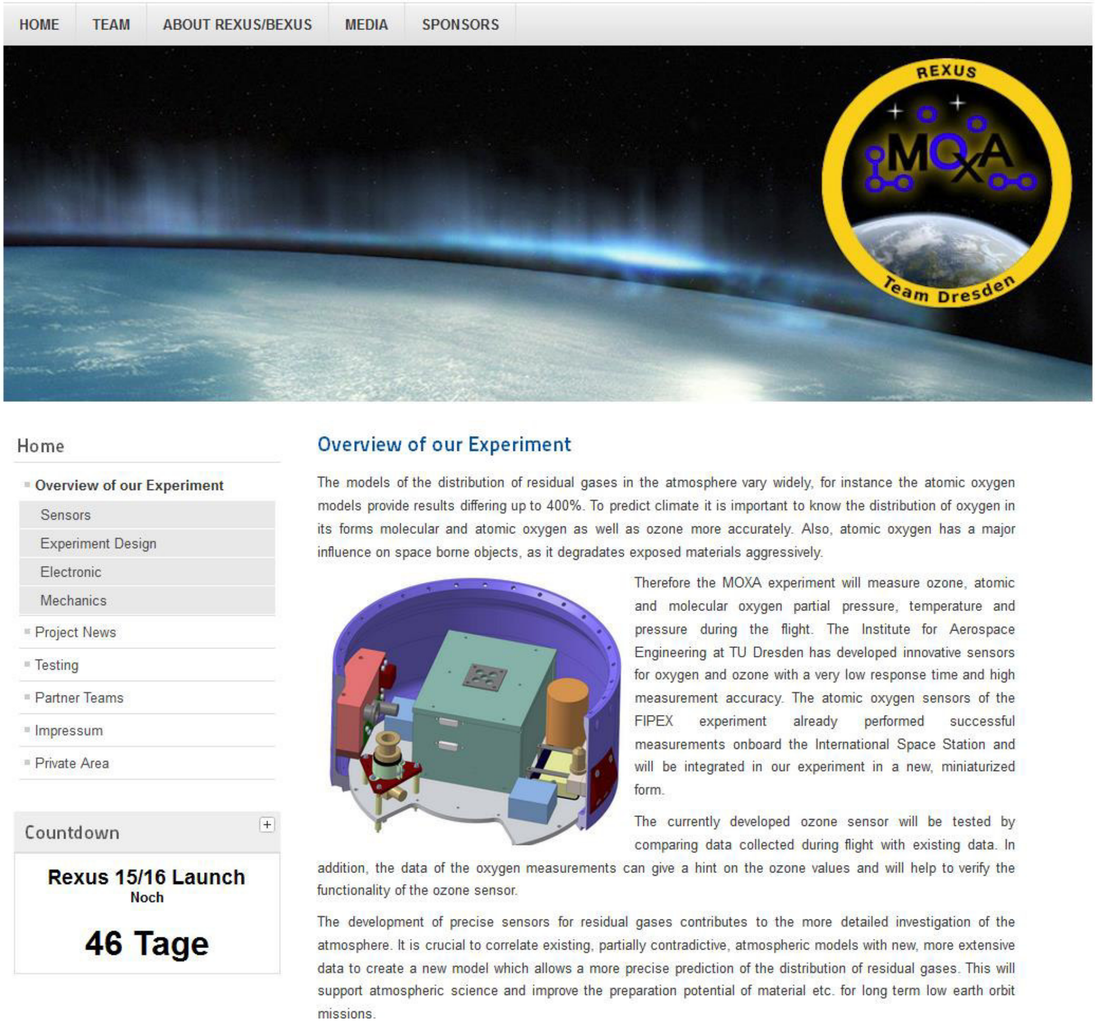



**fig. 12: Website**

Our website can currently be visited via www.REXUS-MOXA.de. The website generally informs about the REXUS program, our MOXA team and of course about our experiment. Furthermore, we there collect and present all published articles and posts about MOXA. In future, every visitor of the website will have access to press material (press releases, photos, etc.).

### 3.4.3 Classic PR-work


**fig. 13: MOXA on TU Dresden**

On the 8th of January, the TU Dresden's press office sent out our first *press release under the heading* "Studenten der TU Dresden starten ein weiteres Weltraumprojekt" (http://tu-dresden.de/aktuelles/newsarchiv/2013/1/REXUS). About ten magazines and papers took it out in either print or online. Moreover, we published a detailed article in our University's Journal. This article appeared on the front page on the 14th of January (PDF: http://bit.ly/Y1A8Bv). Throughout the very first press release and the article, we gained a lot of attention. Several media wanted to report about us and our project. We were already interviewed by different media, for example by the Campusradio Dresden and the MDR (Mitteldeutscher Rundfunk).

### 3.4.4 Flyers, Posters, Buttons

So far, we have already designed flyers, posters and buttons which present our work in courses or on special events on university.

### 3.4.5 Fly Your Message To Space (FYMTS)

Our campaign "Fly Your Message To Space" (FYMTS) will give people the chance to send a small message to outer space. These messages will be collected and printed out, being included inside the MOXA experiment box, each on a further sheet of paper. We would like to use the campaign to get more attention for the rocket start about two months in advance. We are quite sure that the press would love the idea to report about FYMTS and will also spread the call out for messages.

## 3.5 Risk Register

**Table 3-2: Risk Register**

| ID | Risk(& consequence if not obvious) | P | S | PxS | Action |
|---|---|---|---|---|---|
| **M-X-01** | Parts get unconnected due to vibration | B | 3 | Low | Vibration test |
| **M-X-02** | Hatch is not opening | C | 3 | Low | Function test |
| **M-X-03** | Hatch is closing uncontrolled because of malfunction of the springs | C | 3 | Low | Function test |
| **M-X-04** | Hatch is opening to early | A | 2 | Very low | Test |
| **M-X-05** | Hatch tilts on the guide | A | 3 | Very low | Test and good design of tolerances |
| **M-X-06** | Pyrocutter doesn't fire | A | 3 | Very Low | Calculation and test |
| **M-X-07** | Springs crack | A | 2 | Very low | Test and consultation with manufacture for probability |
| **M-X-08** | Sensor breaks | B | 3 | Low | Sensors are intermountable |
| **M-X-09** | Hatch or inner chamber not tight (hot air gets in the module) | A | 3 | Very low | Good design |
| **M-X-10** | Anything gets damages during late access | A | 2 | Very low | Plan of procedure |
| **M-X-11** | Air inlet or outlet gets unconnected during flight | A | 5 | Low | Redundancy of screws |
| **M-X-12** | Cables break/get unconnected | A | 3 | Very low | Design large bend radii |
| **M-X-13** | Flexible tubes breaks / get unconnected | A | 3 | Very low | Design large bend radii |
| **M-X-13** | Pyrocutter fires to early | A | 2 | Very low | Controlled by MORABA |
| **E-X-01** | Mosfet gets overheated during the flight | B | 4 | Low | Vacuum chamber test |
| **E-X-02** | DC/DC Converter gets overheated during the flight | B | 4 | Low | Thermal design and Vacuum chamber test |

| | | | | | |
|---|---|---|---|---|---|
| **E-X-03** | Battery gets overheated | C | 3 | Low | Calculate and test before CDR |
| **E-X-04** | Short circuit | A | 4 | Very low | Function Test |
| **E-X-05** | Connectors do not complete the circuit while flight | A | 3 | Very low | Select connectors that are resistant to vibration |
| **P-X-01** | Team member leaves the project | A | 4 | Very low | Allocate responsibilities |
| **P-X-02** | Team member is temporary not available for personal reason | B | 3 | Low | Use flow chart and time schedule |
| **P-X-03** | Conflicts in the team slow the work flow. | B | 2 | Very low | Communication,<br>Share tasks in work packages |
| **P-X-04** | Team member underestimates the amount of work | C | 2 | Low | Time schedule |
| **P-X-05** | Have not as much people as required working on the project | B | 3 | Low | Time schedule |
| **L-X-01** | Material on Order arrives too late | C | 2 | Low | Schedule buffer time |
| **L-X-02** | Parts ordered too late | A | 3 | Very low | Adhere strictly to the time schedule |
| **L-X-03** | Material on order are broken or don't fit | B | 3 | Low | Schedule buffer time |
| **F-X-01** | Delayed Fabrication of the university workshop | B | 3 | Low | Schedule buffer time |
| **F-X-02** | Detect design failure during the fabrication | B | 4 | Low | Schedule buffer time |
| **F-X-03** | Bad communication and misunderstandings between the team and the workshop | A | 2 | Very low | Appoint a contact person |
| **S-X-01** | Experiment Software Synchronization Loss (LO) | A | 2 | Very low | Synchronize Data after Landing |
| **S-X-02** | SD Card Failure | A | 1 | Very low | Redundancy: RX I/F |
| **S-X-03** | RX I/F Failure | A | 1 | Very low | Redundancy: SD Card |

| | | | | | |
|---|---|---|---|---|---|
| **S-X-04** | Experiment Restart during Flight (Power Line Cut, Experiment Stuck) | A | 2 | Very low | Instantly start collecting data |
| **S-X-05** | Critical Module Failure (DAC, ADC, Quartz) | A | 3 | Very low | Extensive Preflight Tests |
| **S-XXX** | Software is not Ready at Launch | A | 3 | Very low | Time schedule |

E…..Electronics

M….Mechanics

P……Personal

L……Logistic

F……Fabrication

S……Software

# 4 EXPERIMENT DESCRIPTION

Due to the interesting higher concentrations of atomic oxygen above 70 km and for Ozone between about 10-50 km, we need to provide adequate measuring during the complete REXUS flight. To provide best measurements during high and low atmospheric pressure two different kinds of measurement chambers will be used. One set of sensors will be placed within an inner chamber. The chamber is designed for high velocity and high pressures. The outside chamber is protected by a hatch. After the hatch opens the sensors will be directly exposed and will therefore perform measurements of low pressure slows down airspeed.

The hatch will be triggered by MORABA after the burnout of the rocket engine at around 30 km (28 seconds) and expose the outside sensors during the apogee of the flight. Additional pressure and temperature sensors are included to each module.

**Table 4-1: Experiment Timeline**

| ToF [s] | -1000 | -900 | -100 | 0 | 28 | 50 | 100 | 150 | 200 | 250 | 300 | 350 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Height[km]** | 0 | 0 | 0 | 0 | 30 | 40 | 70 | 90 | 70 | 30 | 12 | 5 |
| **Heating** | | | | | | | | | | | | |
| **Measurement** | | | | | | | | | | | | |
| **Valid Range (AO)** | | | | | | | | | | | | |
| **Valid Range (O2)** | | | | | | | | | | | | |
| **Valid Range (O3)** | | | | | | | | | | | | |
| **Hatch** | | | | | x | | | | | | | |
| **Shutdown** | | | | | | | | | | | | X |

The sensors will be exchanged at the beginning of the campaign in Kiruna to ensure their functionality. At launchpad the Sensors will be preheated to their operating temperature. Measurements will be performed after liftoff and the hatch will be opened at about 30 km height by timeline. At shutdown, all the sensors will be disabled and the experiment will be switched off.

## 4.1 Experiment Setup

The system design will be described using SART (acc. Hatley87). The experiment system design implements two similar independent designs.

### 4.1.1 System Model

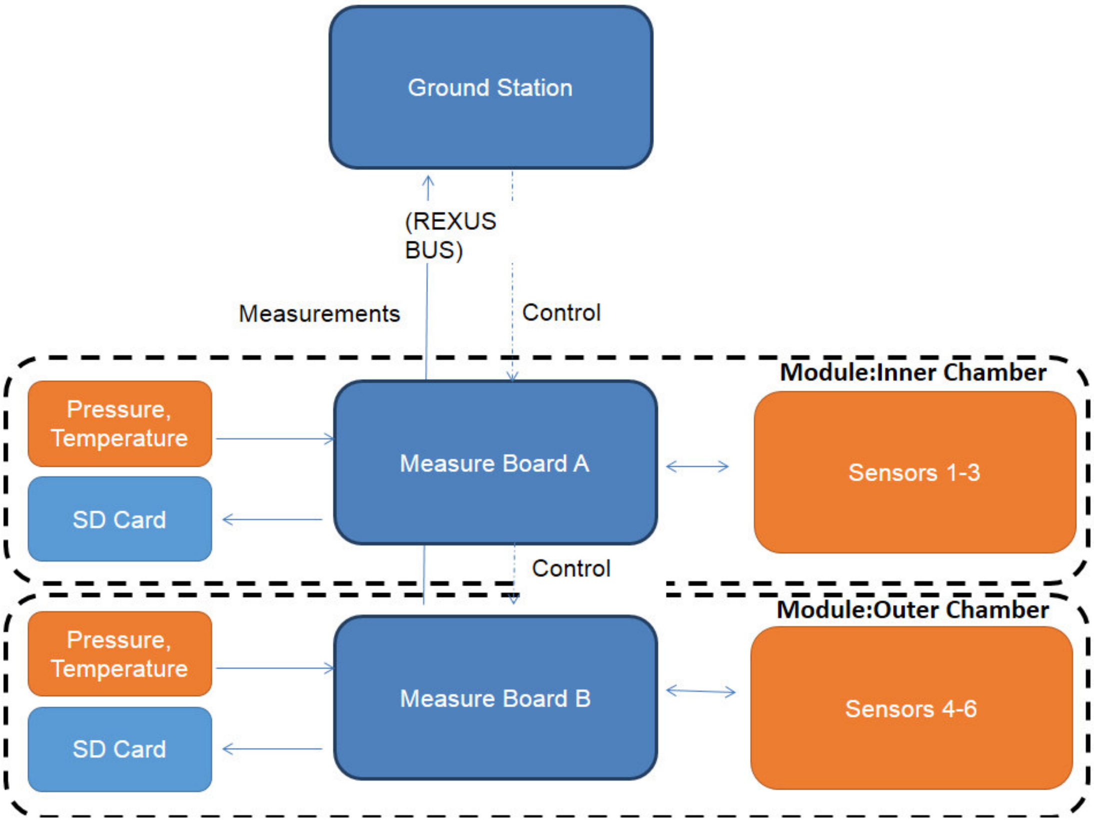



**fig. 14: System Model**

**Table 4-2: Module Specifications**

| Device | Hardware | Software | Function |
|---|---|---|---|
| **Measurement Board A** | STM32F1 ARM7 | | Measurement, Saving, Transmission |
| **Measurement Board B** | STM32F1 ARM7 | | Measurement, Saving |
| **REXUS BUS** | RS422 | | Data Transmission |
| **Ground Station** | x86 PC | Java, Windows or Linux | Data Receiving and Saving |

#### 4.1.2 Modules

The MOXA experiment electronics will be designed modular. The two modules (similar structure) will be stand-alone. They will be developed on standardized 4-layer Euro-size circuit boards.

An additional circuit board will be designed for the power system. All systems will be housed in (Electro Magnetic Capability (EMC) shielded segments of the box to avoid EMC troubles.

**Table 4-3: Data lexicon**

| Data Flow | Description |
|---|---|
| **Control** | Bit LO, Bit SOE |
| **Temperature** | 0-600°C |
| **Temperature (analog)** | 3-11 Ohms |
| **Reference Measurement Value** | 300 mVolt |
| **Reference Heating Value** | 0-3.3 Volt |
| **Measurement I** | 0-3.3 Volt |
| **Measurement U** | 0-3.3 Volt |
| **Heating I** | 0-3.3 Volt |
| **Heating U** | 0-3.3 Volt |

## 4.2 Experiment Interfaces

### 4.2.1 Mechanical

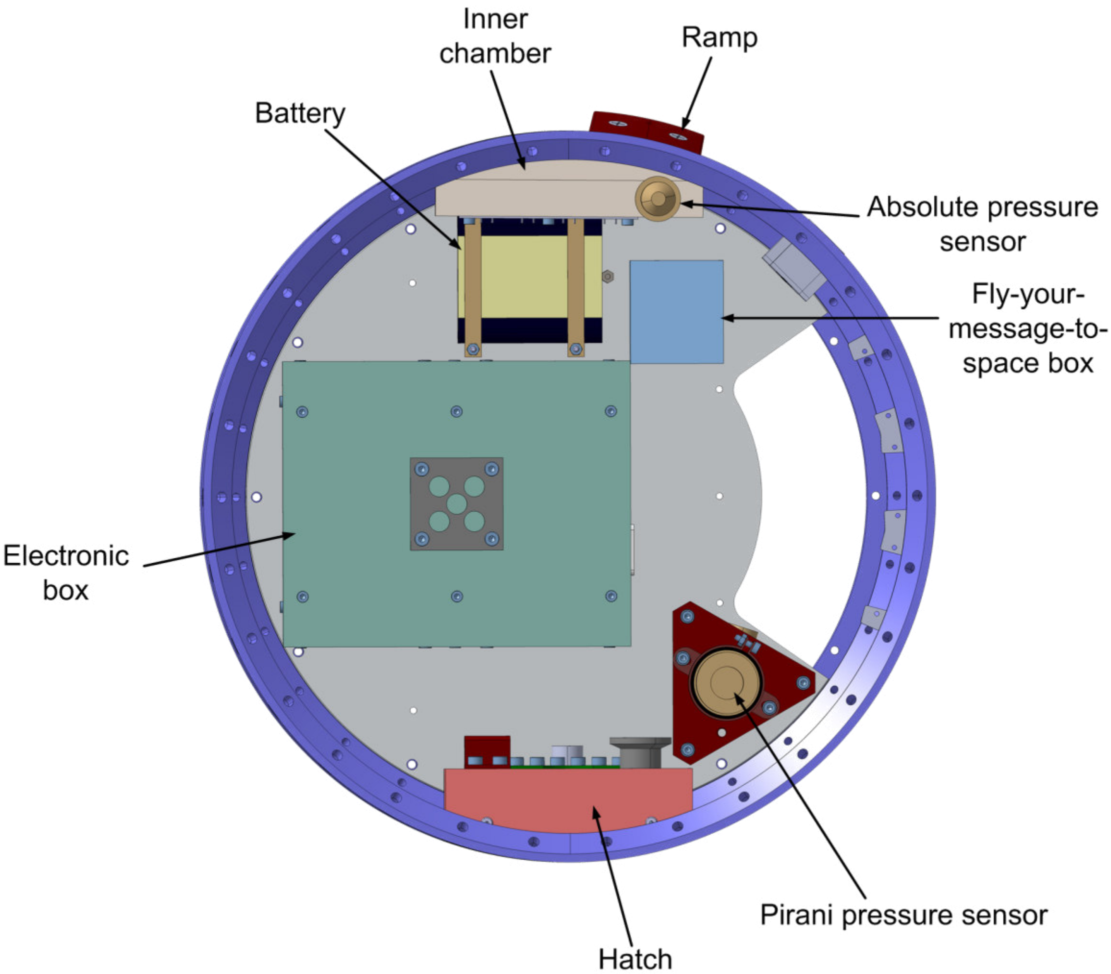



**fig. 15: Top view of experimental module**

The bulkhead is mounted with 11x EN ISO 4762 M5x12.

- The hatch will be mounted with 4x EN ISO 7046-1 M5 screws, from outside.
- The inner chamber is split into parts inside and the ramp outside. The ramp will be mounted on the outer shape of the module with 4xDIN965 M4 counter-sunk screws. The inside parts, mounted together with screws, will be attached with the adhesive OMEGA Bond 300 which provides an safety of 272. Additional it will be mounted with one M4 counter-sunk screw.
- There will be a thread in a drill hole at the inner chamber to mount the piezo pressure sensor.
- The Pirani sensor will be mounted with a screwed clip on top of an aluminium plate which is connected to the bulkhead via tree screws, three vibration

dampers and tree spacers. There are several configurations for the rubber dampers. A final setting was chosen after the vibration tests.

- The electronic box will be mounted with 6xDIN 912 M4 screws on the bulkhead.
- The fly-your-message-to-space box will be mounted with 2x DIN 912 M3 screws on the bulkhead.
- The battery will be pinched with two plates that will be fixed with two M3 nuts on threaded rods.

There is no modification concerning the mounting of the D-Sub-bracket or the attachment of the module with the experiments below and above.

All screws will be locked with Loctite at the final assembly. Where we have enough space there will be serrated lock washers or rather screws with tooth head.

## 4.3 Experiment Components

Mechanical parts and connectors are listed in this section. All electronic components that have to be soldered on one of the PCB Boards are listed in appendix C.

### 4.3.1 Mechanical Parts

**Table 4-4: Mechanical Parts summary table**

| component | supplier | current status | weight in Kg |
|---|---|---|---|
| | | | |
| **Srews and little fixation parts** | several | ordered | 0,50 |
| | | | |
| **Hatch** | | | |
| parts of in-house production (material:AlMgSi1) | TUD | ordered | 0,90 |
| springs | GUTEKUNST | ordered | 0,01 |
| photosensor | CONRAD | ordered | 0,03 |
| slide bushes | IGUS | ordered | 0,01 |
| shafts | MISUMI | ordered | 0,01 |
| pyrocutter | TRW | ordered | 0,02 |
| | | | |
| **Inner Chamber** | | | |
| Ramp (material: X5CrNi18-10) | TUD | ordered | 0,25 |
| inside parts (material:AlMgSi1) | TUD | ordered | 0,60 |
| high temperature adhesive | OMEGA | ordered | 0,01 |
| | | | |
| **Electronic box** | | | |
| parts of in-house production (material:AlMgSi1) | TUD | ordered | 1,10 |
| other | several | ordered | 0,20 |
| | | | |
| | | | |
| **Module** | | | |
| pirani sensor | PCE | ordered | 0,12 |
| pirani flexible tube | LANDEFELD | ordered | 0,01 |
| pirani vibration dumper | Schwingungsdämpfer DD | ordered | 0,01 |
| piezo sensor | sensor technics | ordered | 0,10 |
| battery | FEYELECTRONIK | ordered | 0,14 |
| box (Fly your message to space) | CONRAD | ordered | 0,02 |
| | | | |
| | | **Total mass mechanic** | **4,04** |

**Table 4-5: Experiment summary table**

| Attribute | Dimension |
|---|---|
| Experiment mass (in kg): | 8.973kg including module and bulkhead |
| Experiment dimensions (in m): | Ø 0.348 x 0.130 |
| Experiment footprint area (in $m^2$): | 0.0657 |
| Experiment volume (in $m^3$): | 0.012 |
| Experiment expected CoG (centre of gravity) position: | (x=137, y=106, z=0.191) |

## 4.4 Mechanical Design

### 4.4.1 Outer structure

We use a 170 mm module that is provided by the DLR together with the bottom mounted bulkhead. The bulkhead will be modified with holes for screws to mount the board box and all parts that are located at the bottom of the module.

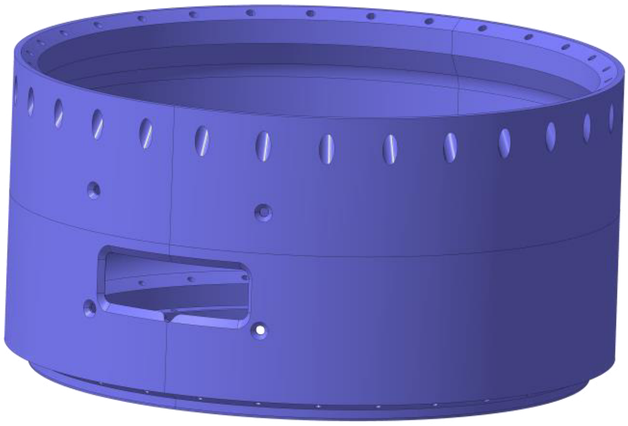


**fig. 16: Outer casing**

There are some modifications concerning the module. To allow the sensors access to the environmental air, 3 recesses will be made. One is situated at 270° from the 0° line with the dimensions 95mm (length) and 30mm (height). This one gives the sensors in the hatch (see 4.4.3) access to the ambient air. As shown in the description of the hatch this hole will be closed at the launch and opened during flight.

The other two recesses are situated opposite of the one at circa 90°. They will give the other sensors that are situated in an inner chamber access to the ambient air. These are just small drill holes with a diameter of 2.54mm. Below the D-Sub bracket at 180° will be a pass in the bulkhead for any cables between the modules. The dimensions are shown in the picture below.

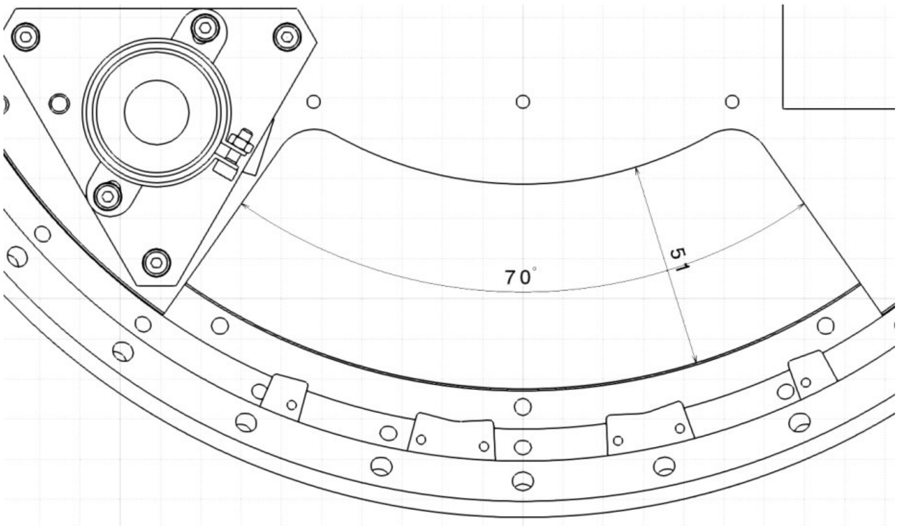



**fig. 17: pass for cables**

#### 4.4.2 Board box

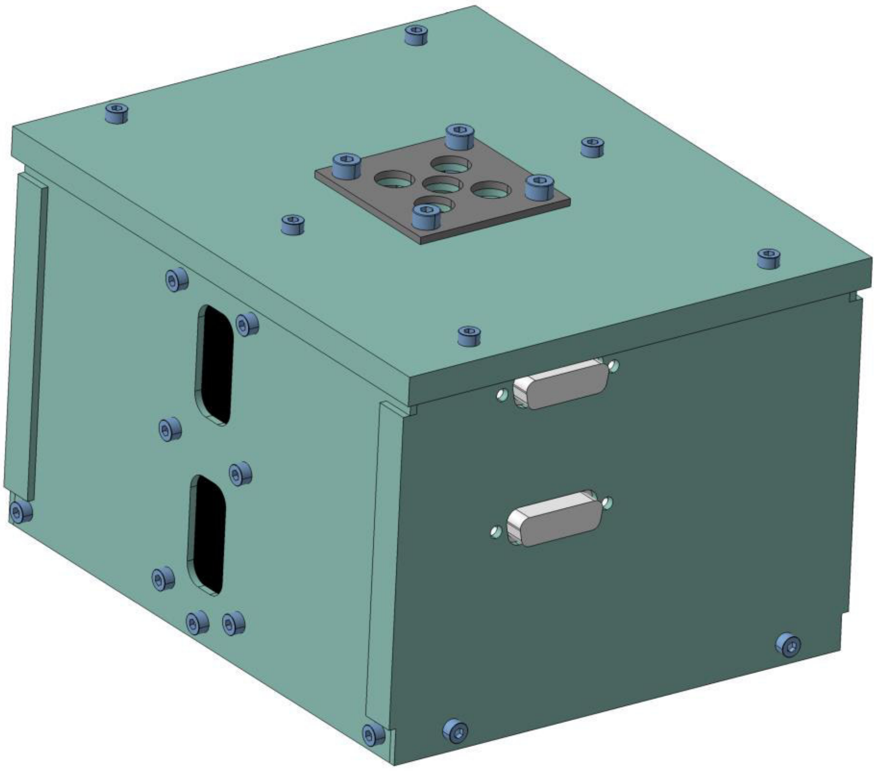


**fig. 18: board box**

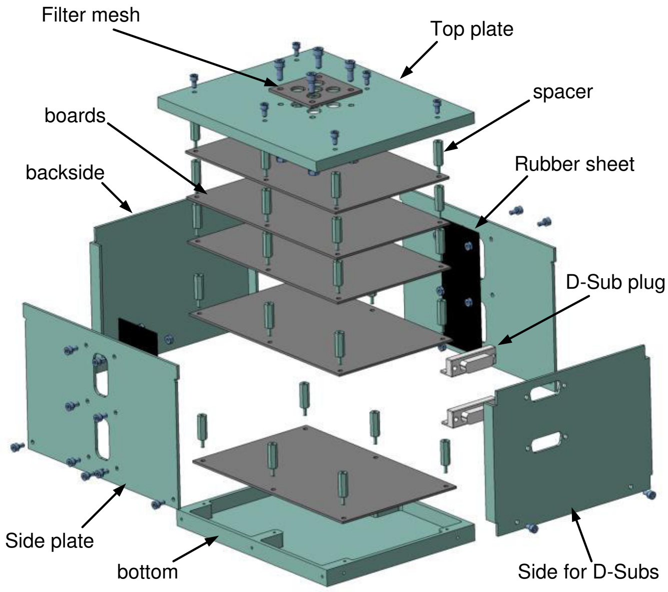



**fig. 19: board box (exploded view)**

The board box is the centre of the module. It includes two mainboards, two sensorboards and the powerboard.

Array of the boards from top to bottom:
mainboard – senorboard – mainboard – sensorboard – powerboard

The board box consists of one bottom plate, one front plate, one backside plate, two identical side plates and one top plate. The powerboard is directly mounted onto the bottom plate, the following boards are mounted and fixed on each top of another with 17mm spacers. The front plate has two cut-outs for the two D-sub-interfaces. In the middle of the two side plates are two cut-outs for the wires to the sensorboards and the powerboard. The front and backside plates are fixed on the bottom plate with self-sealing 2x EN ISO 10642 - M3x8, the two side plates are fixed with self-sealing 3x EN ISO 10642 - M3x8. The top plate is fixed with 6x EN ISO 10642 – M3x8 directly with the spacers from the upper mainboard. Front-, backside and side plates are form-closed by the top plate, and in addition the side plates get stabilization by flaps of the front- and backside plate.

The board box is not designed to be gastight. It is just designed to cover the boards and to prevent the income of small aluminium chips. Air flow will be enabled through five holes (diameter 10mm). These holes are covered with a 45x45mm filter net to prevent the boards from aluminium chips and thereby eventually caused short circuit. The net is fixed between a small 45x45mm plate (also with 5x 10mm holes to enable air flow), the plate is fixed on the top plate with 4xM4 screws and nuts. The whole board box is affixed on the module with 6x EN ISO 10642 – M4x12. All plates will be manufactured of aluminium (EN AW-6082 T6).

### 4.4.3 Sensors box with hatch

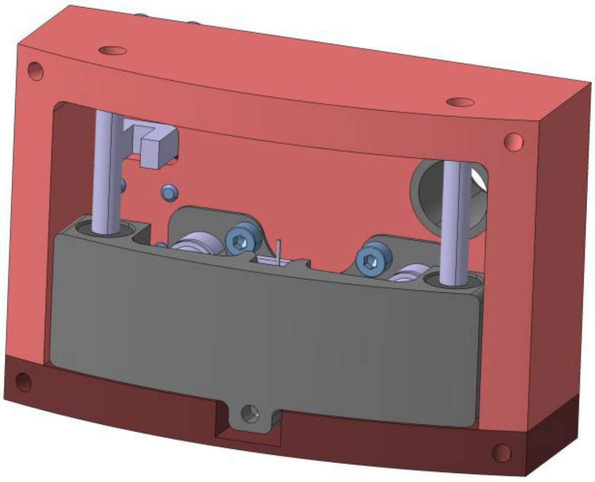


**fig. 20: hatch assembly**

This is one of two assemblies which include sensors, the other one is the inner chamber in chapter 4.4.4. The included sensors will measure atomic oxygen, molecular oxygen, ozone and temperature, so there are 4 sensors inside.

The main task of the hatch is to mount the sensors in the module and give them access to the ambient air by demand. The sensors will be protected from exhaust gases at the launch. That will be realized by a hatch plate that is closed and fixed by thin steel wire in the initial position. This wire is clamped with a plate and 4 screws on the movable hatch and again with a clamping plate and 4 screws on the underneath bottom plate of the hatch housing. By cutting the thin wire with a pyrotechnical cutting cylinder we open the hatch with springs that push the hatch up. In the pictures below you see schematics of this mechanism.

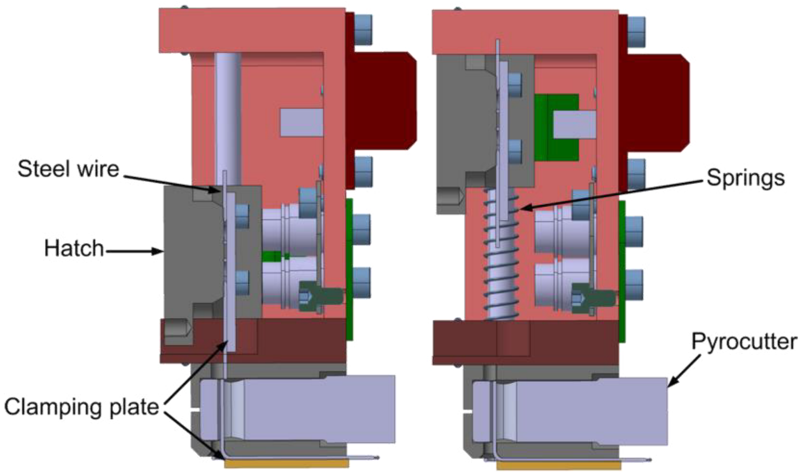



**fig. 21: hatch function**

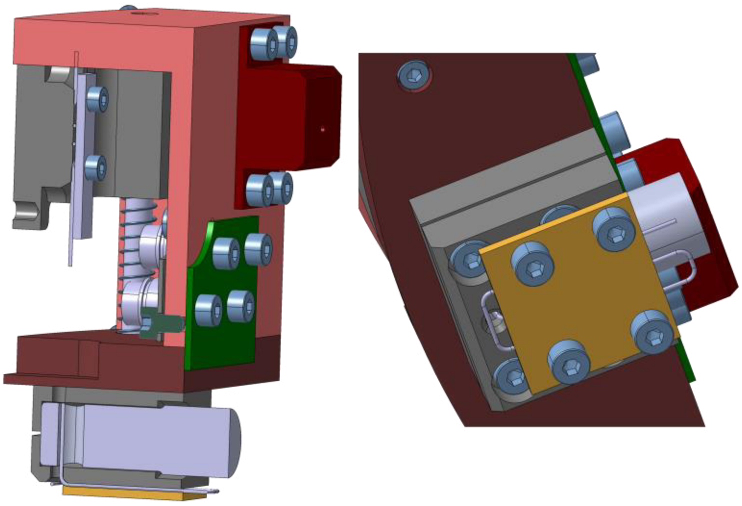


**fig. 22: Detail view clamping mechanism**

Part overview of the hatch mechanism

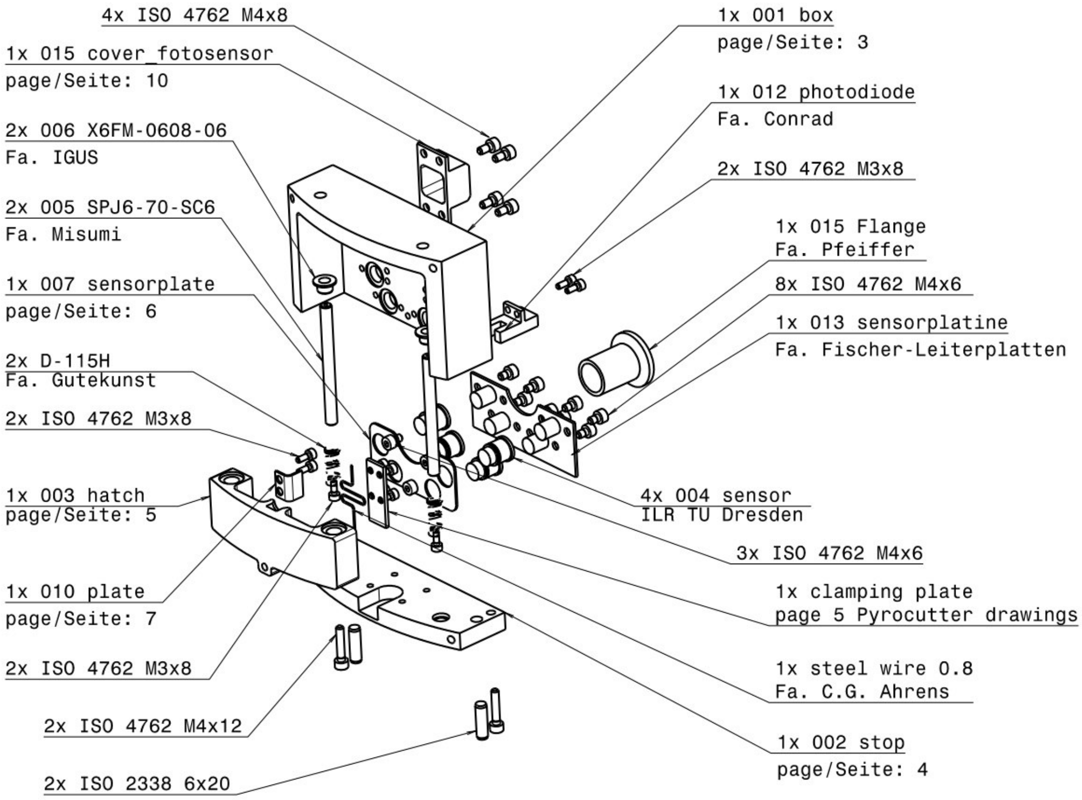



**fig. 23: hatch (exploded view)**

Materials for each component are shown in the attached drawings.

box and sensor mounting

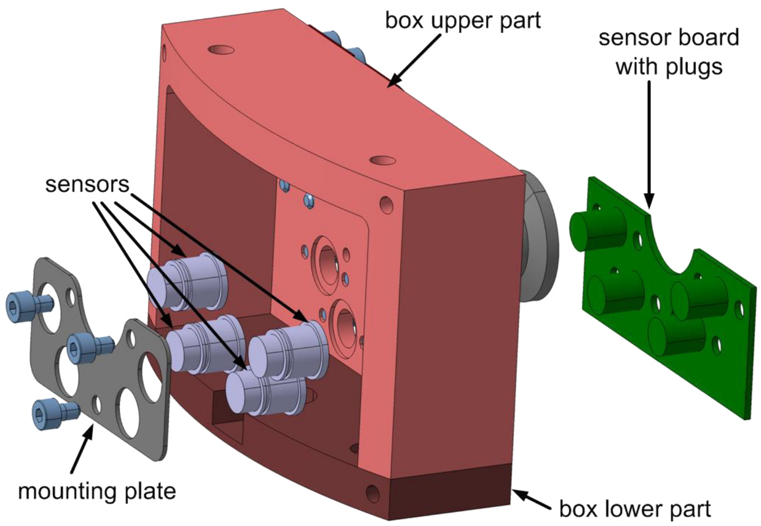



**fig. 24: sensor mounting hatch**

The outer box is made of two parts that are assembled with screws 2 x EN ISO 4762 M5x15 and positioned with bolts 2 x EN ISO 8734 6x15 to realize an accurate mounting on the module wall.

The four sensors are positioned in four cuts in the upper part. On the backside of the box there is a sensor board with four plugs mounted (8 x EN ISO 2010 2x6). The sensors are attached to these plugs. To prevent an unplugging of the sensors we mounted them with a plate from the other side that pushes them with its 3 x EN ISO 2010 M3x6 screws against the box so that a form fit is realized (the holes in the plate are smaller than the smallest sensors diameter).

hatch mechanism

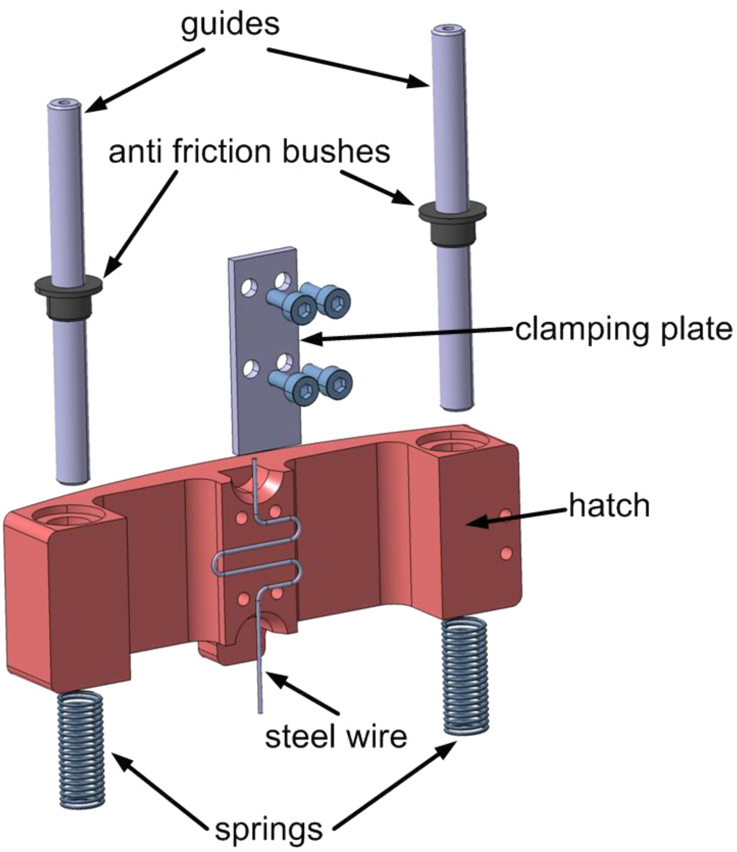



**fig. 25: Hatch mechanism**

To move the hatch there are four antifriction bushes integrated in the aluminium plate. They touch the guides which will support a fluent movement of the hatch. The springs push the hatch up when the wire is cut.

While beeing stressed the springs each have one a force of 16.38 N. So a force of 32.76 N pushes the hatch to open the recess in the module completely so that air can get to the sensors.

The steel wire which keeps the hatch in its inital position is cut at an altitude of around 30 km by a pyrocutter. It is fired by an electric current of at least more than 0.4 A. To fire it in any case there have to be a current of 1.2 A. The triggerring of the explosive inside the pyrocutter lies by MORABA(Mobile Raketen Basis, DLR).

The replacement of the pyrocutter and the wire due to tests requires an unscrewing of the hatch box out of the module and a disintegration of the clamping plates and the pyrocutter mounting.

Owing to the fact that the pyrocutter contains explosives there have to be some security constraints. To prevent early ignition and damage to men or material the electric circuit have to be capsuled and seperated from other cords.

**Positioning photo sensors**

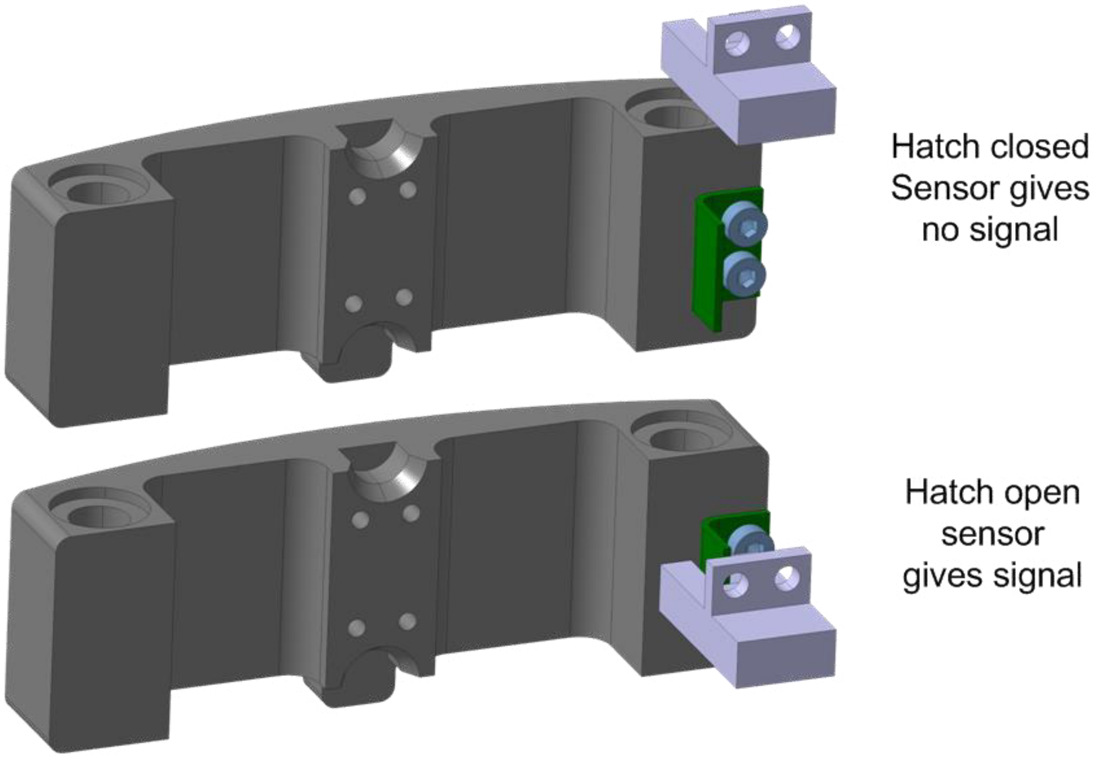
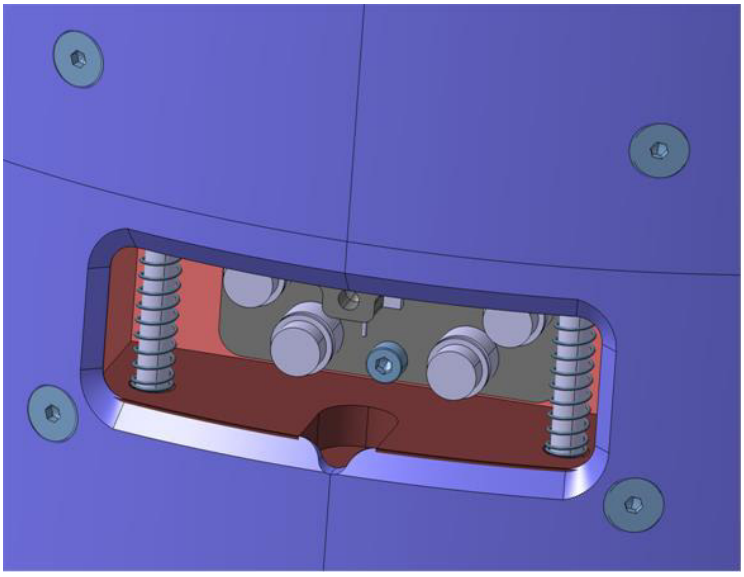
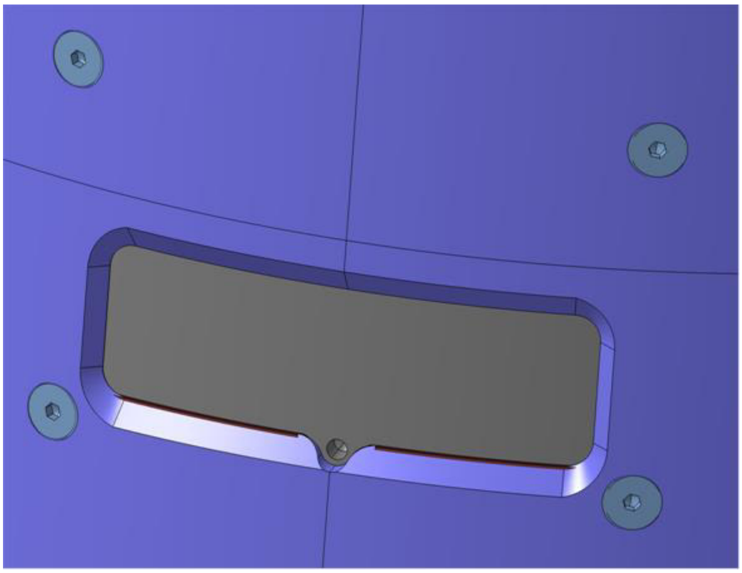



**fig. 26 photo sensors**

To know whether the hatch is closed or open we use a photo sensor (mounted with 2 x EN ISO 4762 M3 x 6) and a cover mounted on the hatch with 2 x EN ISO 2010 2x6. The cover will move between the light beam of the sensor when it is opened so we get a feedback of the position of the hatch.



open state



closed state

**fig. 27 open and closed hatch**

### 4.4.4 Inner chamber

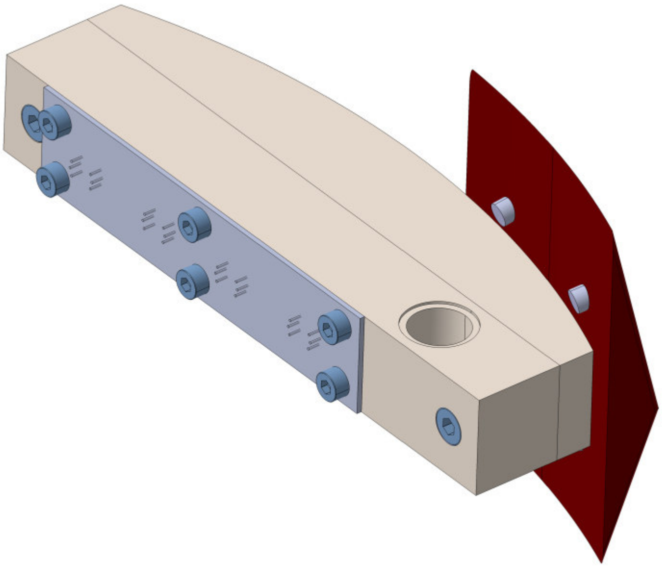


**fig. 28 inner chamber**

The principal task of the inner chamber is to offset air of the fluid flow streaming on the rocket. This requires that the inlet geometry wont heat up too much, the inlet should not disturb the aerodynamic of the rocket and the gas exchange should be very fast without stressing the gas sensors to much.

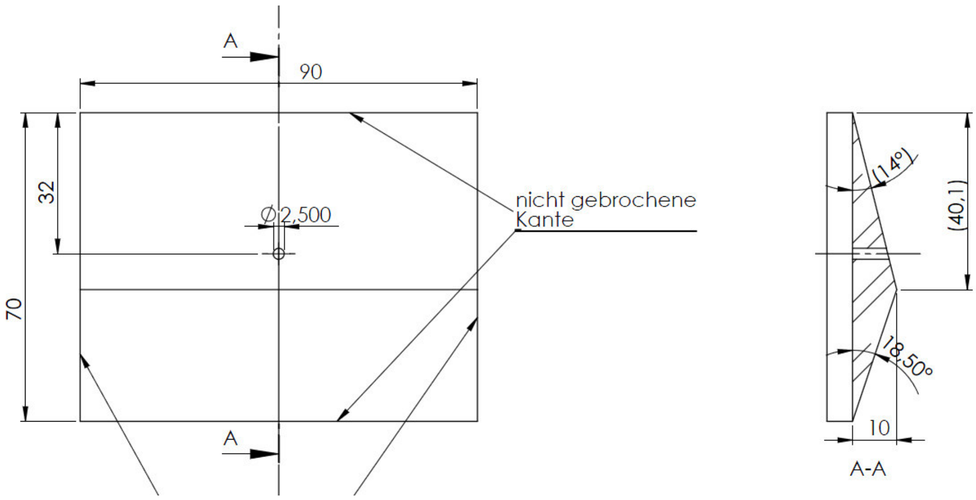



**fig. 29 ramp**

Because the ramp is very flat the fluid flow has little contact points for friction, so the ramp wont heat up so much. Also because the ramp is so flat, it has little contact area for the fluid flow to disturb it.

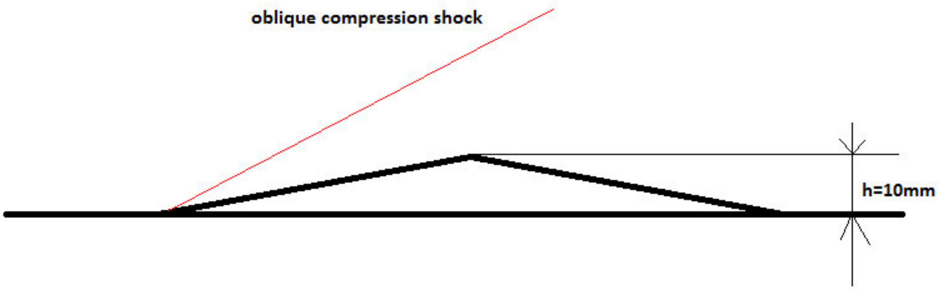



**fig. 30 compression shock**

The break for the fluid flow, caused by the ramp, leads to an oblique compression shock. Across this shock the pressure, temperature and airflow velocity change. The velocity will go down and the temperature rises, but the most important fact is that the pressure rises too. So the pressure at the ramp is higher than the pressure next to the ramp.

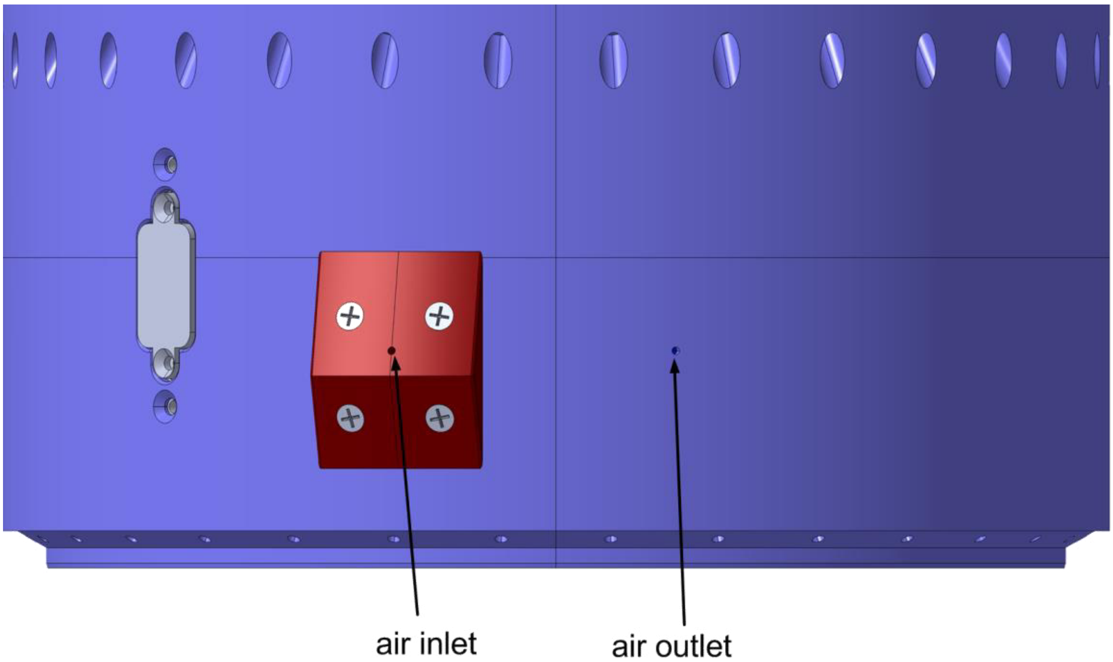



**fig. 31 Ramp on module with air in- and outlet**

Between the drill holes of the in- and outlet the air flow generates a pressure differential which leads to an air flow through a chamber with sensors for pressure, temperature, ozone, atomic and molecular oxygen.

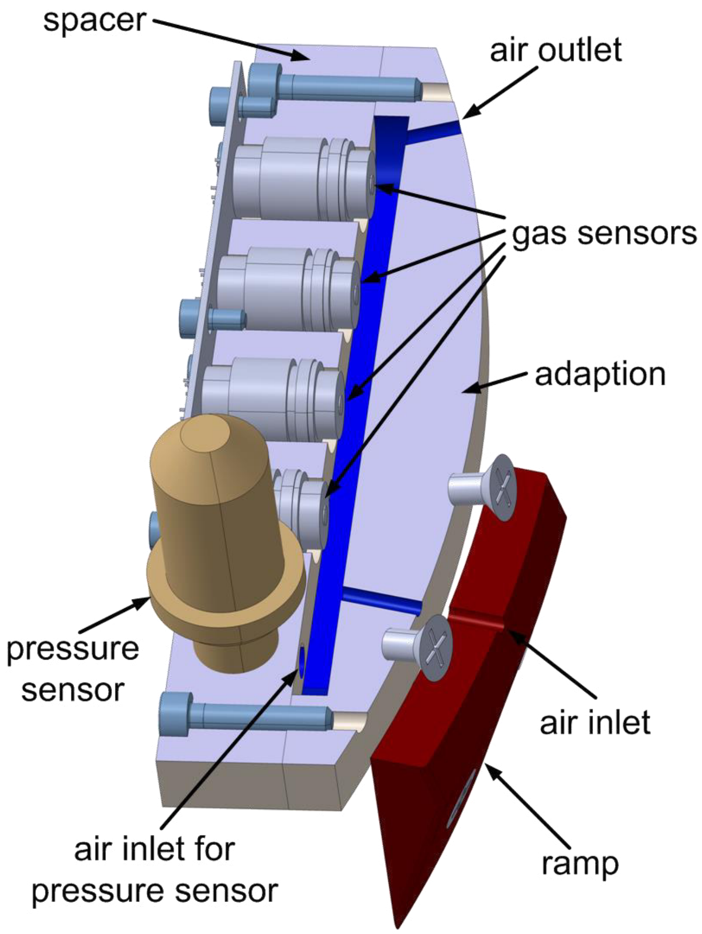



**fig. 32 air stream through inner chamber**

After the air flows through the inlet in the chamber it hits the spacer, scatters there and expands because of the profile extension. Because of the pressure differential the air flows over the sensors to the outlet and leaves the inner chamber.

The ramp, made of X5CrNi18-10 will be mounted with 4 x DIN965 M4 counter-sunk screws. The adaption which is made of AlMgSi1 will be glued from the inside on the shape with a safety of 272 and positioned with one DIN 7991 M4 counter-sunk screw. Then the spacer is fixed with two M4 screws on the adaption. The sensor board, with the soldered sensor clips, is fixed with six M3 screws. The sensor board is easy to disintegrate for an easy exchange of the sensors.

### 4.4.5 Pressure sensors

To measure the pressure we use the following sensors in the named subassemblies (more information in the datasheets):

Hatch sensor box : VSP63

Internal sensor box : Keller-21Y

The VSP63 sensor will not be mounted directly where the measurement is taken because of space problems. We use a flexible tube to connect the sensor with the position of measurement. To mount the flexible tube at the hatch and at the sensor we will be using hose band clips over a screwable adapter. The flexible tube will have an inner diameter of 9 mm. The sensors themselves have suitable connectors.

The VSP63 pressure sensor will be fixed as shown below.

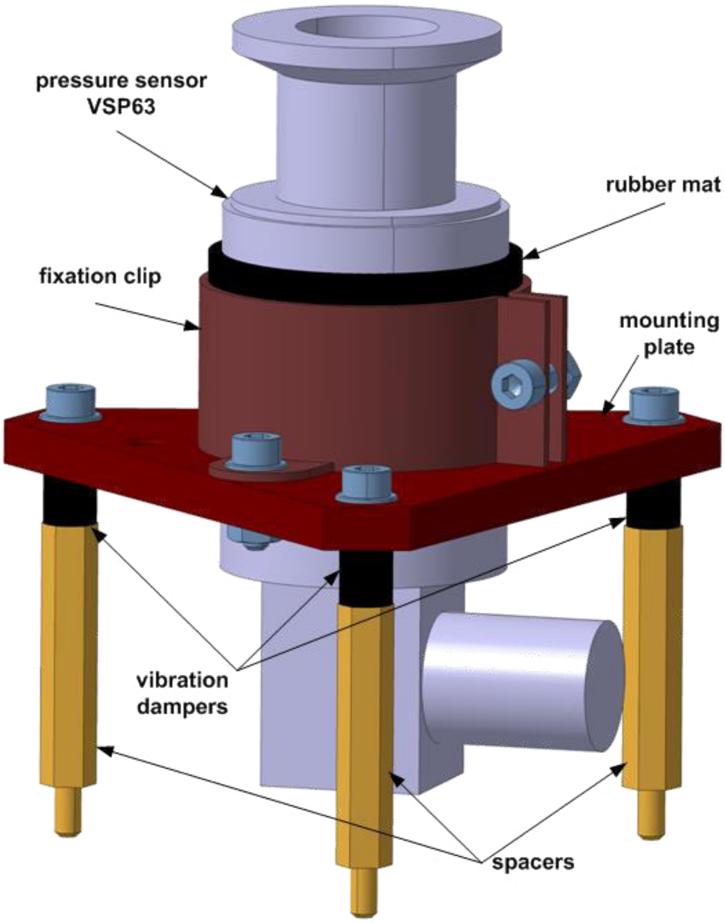



**fig. 33 sensor fixation**

The sensor will be fixed by a clip which will be screwed down. A rubber mat will be placed between the sensor and the clip to prevent damage to the sensor. The clip will be held by two screws which connect the clip with the mounting plate. The plate will be mounted on three vibration dampers. These will decouple the sensor from vibrations. The dampers will be installed on top of the spacers to create enough place for the electric connector. The spacers will be screwed directly on the bulkhead. Detailed information about the dimensions will be found in the drawings.

### 4.4.6 Position and fixation of the Battery

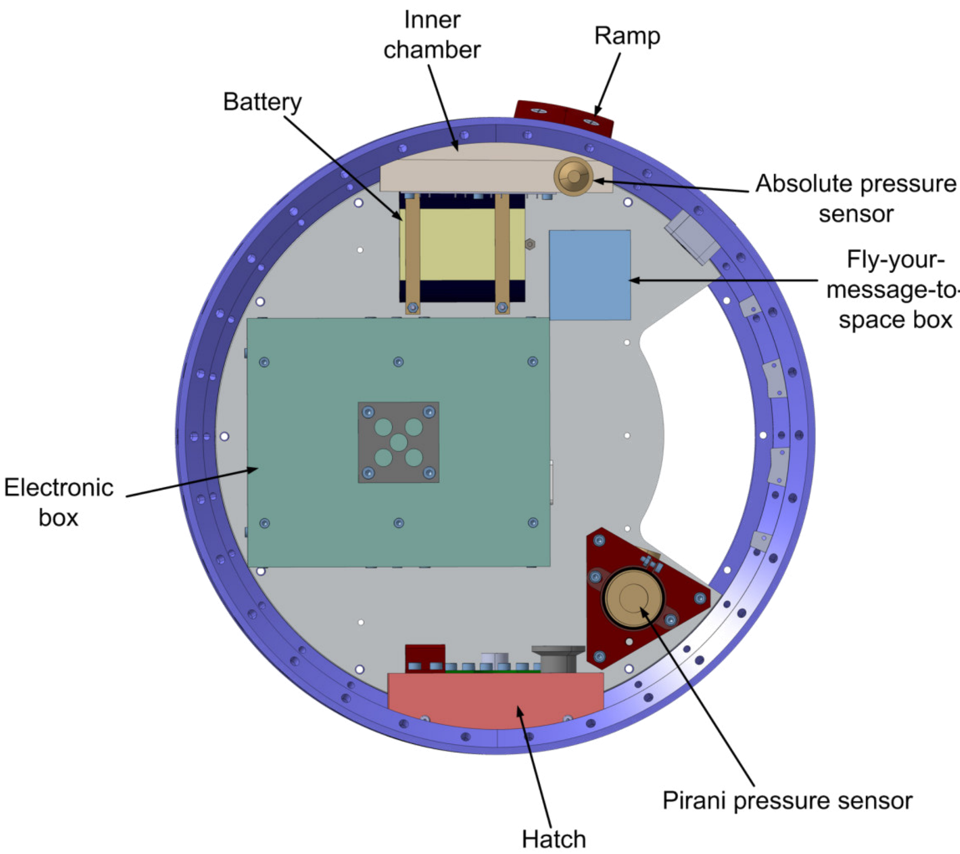



**fig. 34 top view of the experiment**

The picture above shows the position of the battery. It will be fixed by two screwed metal strips at the bulkhead.

### 4.4.7 "fly your message to space"- part

The messages that will fly to space will be printed on two or three sheets of paper. These sheets will be inside a closed box with an venting hole, so its not air tight. To ensure that the paper will not block the hole, we will push it down with a screw and clip them together. The box will be mounted by two screws in the bulkhead.

## 4.5 Fluid Mechanic

For the implementation of measuring ozone, atomic oxygen and molecular oxygen we choose two experiments for different height ranges. For ranges higher than 30 km, we use a cavity which opens its hatch a few seconds after lift-off and reveals the sensors. Because of decreasing density and the high velocity of the rocket we use an inner chamber for representative measurements up to an altitude of 30 km.

To analyze the flow over the cavity of our module, we build a simple 2d-model (fig. 35) with the assistance of simulation software to work with it. Problems in this experiment might be the turbulent flow around the sensors, placed at the bottom of the cavity, and the conditions of the air properties in the higher altitude, e.g. low density. On the basis of these facts we agree to a supplementary configuration for ozone-measurement in lower altitude, up to. 30 km.

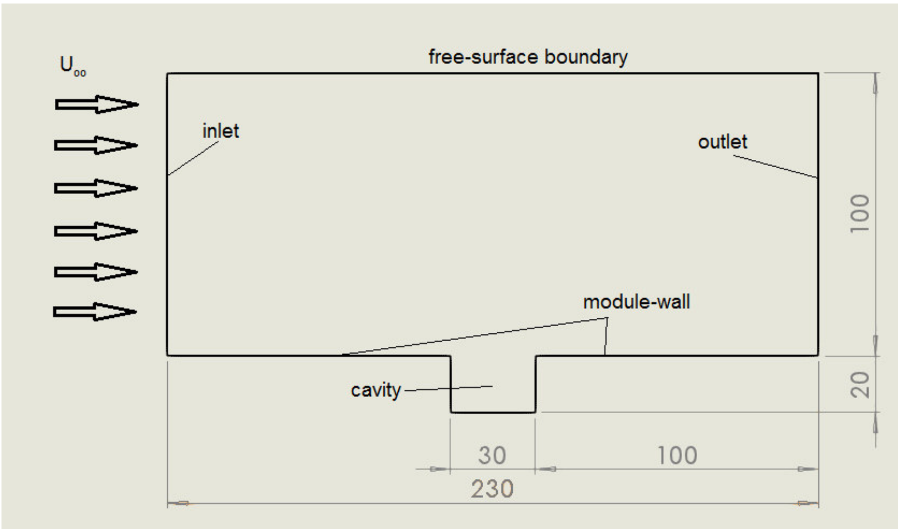



**fig. 35: 2d-Scheme of the 2d-model of the MOXA-module**

For first simulations of the fluid models we use simple dates for incompressible fluids to show the functionality of our experiment in a simple ambience. We want to consider the flow dynamics with different settings in stationary vicinity at determined altitudes. The series of tests will start with constant density and low speed. In additional tests the speed approach up to the flight speed of the rocket, the density is still constant. After the test with increasing speed of the incident flow, we want to realize additional tests with changing density. The velocity profile (fig. 36) is adopted by the experiments of Spalart “Direct simulation of a turbulent boundary layer up to Rθ = 1410” from 1998.

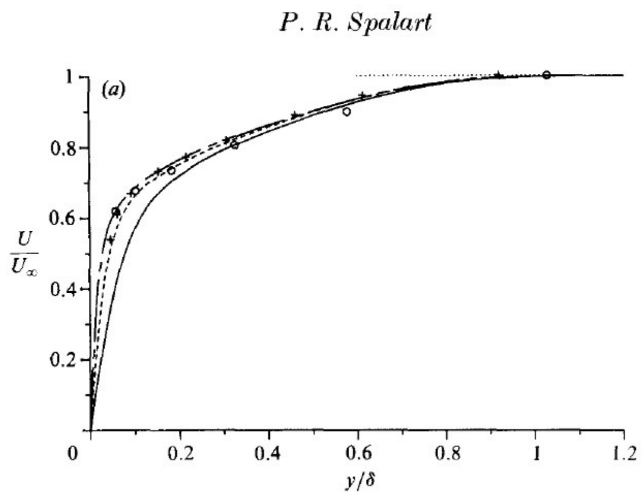



**fig. 36: Velocity profile at different Reynolds numbers by the Experiment of Spalart "Direct simulation of a turbulent boundary layer up to Rθ = 1410" from 1998**

The calculations of the issues occur with the Shear Stress Transport Modell (SST) and most likely with the Reynolds Stress model (RSM). Here, the SST-Model requires much less computation time as the RSM and combines the advantage of the k-ω-model near the module boundary with the advantage of the k-ω-model for the free-surface boundary. The RSM owns higher model accuracy but with the disadvantage of higher effort and no guarantee of more precise results. The outcome of the SST-Model is acceptable, so the RSM is not really necessary.

## 4.6 Electronics Design

### 4.6.1 Microcontroller Design (Mainboard PCB)

To handle measuring and data handling, for each sensor control board one ARM7 microcontroller of the type STM32F103RB will be used. A customized PCB with supplementary ADC, DAC, SD-Card and USART level converters with be used.

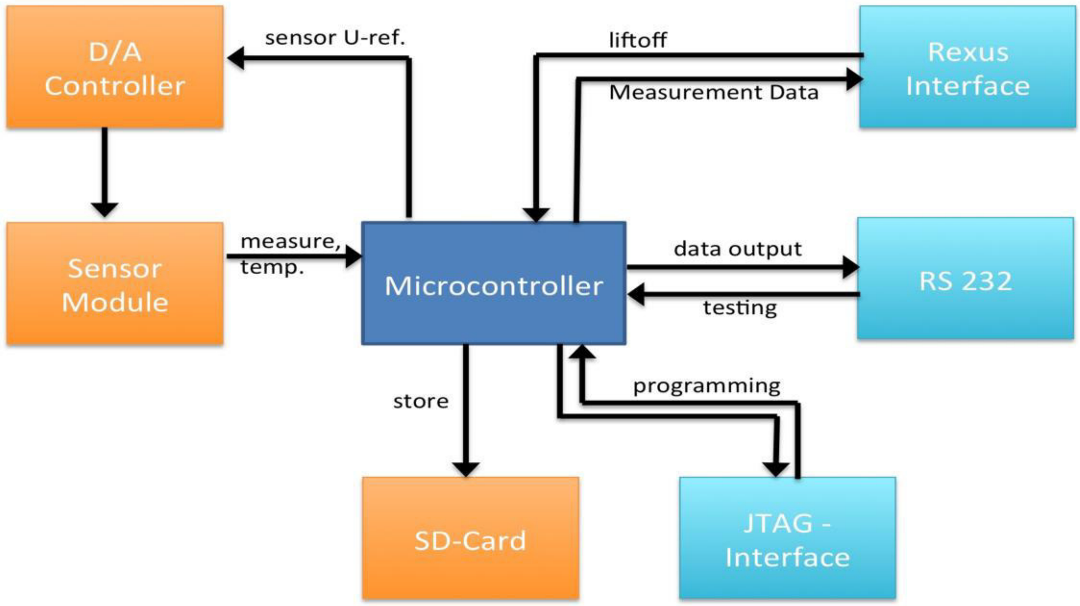



**fig. 37: Simple schema of our microcontroller architecture**

For better understanding all modules are explained in this chapter. Very important modules are listed with a connection-table for detailed information. All other modules are connected as recommended in the data sheet. You can find the pdf document for circuits and board layout as well as the part lists with a hyperlink to the distributor in Annex C.

**<u>Microcontroller:</u>**

Our main unit. Pin connections are described here:

**Table 4-6: Connections**

| PIN | Function MOXA | Signal | Type |
|---|---|---|---|
| PA0 | ADC | ADC1$1 | A/D sensor 1 |
| PA1 | ADC | ADC1$2 | A/D sensor 1 |
| PA2 | ADC | ADC1$3 | A/D sensor 1 |
| PA3 | ADC | ADC1$4 | A/D sensor 1 |
| PA4 | SPI (DA, AD) | NSS D/A | external DAC and ADC |

| | | | |
|---|---|---|---|
| PA5 | SPI (DA, AD) | SCK D/A | external DAC and ADC |
| PA6 | SPI (DA, AD) | MISO | external DAC and ADC |
| PA7 | SPI (DA, AD) | MOSI | external DAC and ADC |
| PA8 | Measure I/O | CS_DAC | Chip Select DAC |
| PA9 | Measure I/O | CS_ADC | Chip Select ADC |
| PA10 | O | HATCH_ON | Powering the Hatch |
| PA11 | I | HATCH_IN1 | Sensing if Hatch does open |
| PA12 | I | HATCH_IN2 | Sensing if Hatch does open |
| PA13 | JTAG | TMS | Programming |
| PA14 | JTAG | TCK | Programming |
| PA15 | JTAG | TDI | Programming |
| PB0 | ADC | ADC2$1 | A/D Sensor 2 |
| PB1 | ADC | ADC2$2 | A/D Sensor 2 |
| PB2 | I | HATCH_DONE | Sensing if CAP is charged |
| PB3 | JTAG | TDO | Programming |
| PB4 | JTAG | RST | Programming |
| PB5 | I | LO | REXUS-Interface |
| PB6 | I2C1 (TEMP) | SCL | Temperature Measure |
| PB7 | I2C1 (TEMP) | SDA | Temperature Measure |
| PB8 | LED_SOE | | - |
| PB9 | LED_STATUS | | - |
| PB10 | USART3(RS232, RS422) | TX | RS232-RS422 |
| PB11 | USART3(RS232, RS422) | RX | RS232-RS422 |
| PB12 | SPI2(SD Card) | NSS | - |
| PB13 | SPI2(SD Card) | SCK | - |
| PB14 | SPI2(SD Card) | MISO | - |
| PB15 | SPI2(SD Card) | MOSI | - |
| PC0 | ADC | ADC2$3 | A/D sensor 2 |
| PC1 | ADC | ADC2$4 | A/D sensor 2 |
| PC2 | ADC | ADC3$1 | A/D sensor 3 |
| PC3 | ADC | ADC3$2 | A/D sensor 3 |
| PC4 | ADC | ADC3$3 | A/D sensor 3 |
| PC5 | ADC | ADC3$4 | A/D sensor 3 |
| PC6 | PGA1$1 | O | Measure Range Sensor 1 |
| PC7 | PGA1$2 | O | Measure Range Sensor 1 |
| PC8 | PGA2$1 | O | Measure Range Sensor 2 |
| PC9 | PGA2$2 | O | Measure Range Sensor 2 |
| PC10 | PGA3$1 | O | Measure Range Sensor 3 |
| PC11 | PGA3$2 | O | Measure Range Sensor 3 |

| | | | |
|---|---|---|---|
| PC12 | O | Hatch_Charge | |
| PC13 | O | BAT_ON | |
| PC14 | Quarz | OSC | - |
| PC15 | Quarz | OSC | - |
| PD0 | Quarz | OSC | - |
| PD1 | Quarz | OSC | - |
| PD2 | - | - | - |

## JTAG-Interface

We use a 20-Pin JTAG interface for programming. Olimex standard layout for easy programming via an Olimex ARM-JTAG.

## RS-232

We use this interface is only used for testing. Via jumper you can choose between RS-232 and RS-422. Different gage converter support both interfaces.

## REXUS-Interface (RS-422)

This interface for sending data up and down. Via jumper you can choose between RS-232 and RS-422. Different gage converter support both interfaces.

## D/A-Controller

The D/A Controller is for setting the right sensor temperature and sensor voltage. Additional Information can be found in paragraph:

## Sensor Module

This is a separate PCB-Board. All connections are provided by the Power-Bus and Measure-Bus systems.

## A/D Controller

We use an external ADC for additional AD-Ports and because of higher resolution. Because of precise pressure sensors onboard we need to support an higher resolution than the internal 12 Bit. Additional we get feedback about power consumption and battery voltage level.

## SD-Card

The SD-Card is for data storage. We are not able to send all data down while flying, so data is kept on a SD-Card. The reject mechanism of the SD-card socket is good but for safety it has to be locked by some glue additionally.

## Power-Bus

We use a Power bus that connects all boards and provides the different voltage levels where needed. High current or critical voltage levels as well as the GND are at least doubled on this bus. There are some uncritical Signals on this bus-system like I2C, powering the battery and measuring of voltage too.

**Table 4-7: Power BUS: pin configuration**

| Pin | Signal | Pin | Signal2 | used for: | Type |
|---|---|---|---|---|---|
| **1** | GND | 2 | GND | | - |
| **3** | I2C1_SDA | 4 | I2C1_CLK | SDA of the mainboards 1 or 2 | Digital |
| **5** | I2C2_SDA | 6 | I2C2-CLK | CLK of the mainboards 1 or 2 | Digital |
| **7** | GND | 8 | GND | - | - |
| **9** | I_REX_SENS | 10 | 3V7 | Current Sense / 3.7V Battery Connection | Analog |
| **11** | I_BAT_SENS | 12 | BAT_HEATING | Current Sense / Heating Command | Analog |
| **13** | GND | 14 | GND | - | - |
| **15** | 5V | 16 | 5V | 5V Supply | Low Current |
| **17** | 12V | 18 | 12V | 12V Supply | Low Current |
| **19** | -12V | 20 | -12V | -12V Supply | Low Current |
| **21** | 24V | 22 | 24V | 24V Supply | Low Current |
| **23** | 12V_BAT | 24 | 12V_BAT | 12 Volt from Battery | High Current |
| **25** | 12V_RX | 26 | 12V_RX | 12 Volt from Rexus | High Current |
| **27** | GND | 28 | GND | - | - |
| **29** | RX_CHARGE+ | 30 | RX_CHARGE- | 28V connection between RX-battery interface and battery charger | High Voltage |
| **31** | RX28V | 32 | GND_RX | RX_Interface to Powerboard | High Voltage |
| **33** | RX28V | 34 | GND_RX | RX Interface to Powerboard | High Voltage |

**Table 4-8: Power BUS: pin configuration**

| Pin | Signal | Pin | Signal2 | used for: | Type |
|---|---|---|---|---|---|
| **1** | GND | 2 | GND | | - |
| **3** | I2C1_SDA | 4 | I2C1_CLK | SDA of the mainboards 1 or 2 | Digital |
| **5** | I2C2_SDA | 6 | I2C2-CLK | CLK of the mainboards 1 or 2 | Digital |
| **7** | GND | 8 | GND | - | - |
| **9** | I_REX_SENS | 10 | 3V7 | Current Sense / 3.7V Battery Connection | Analog |
| **11** | I_BAT_SENS | 12 | BAT_HEATING | Current Sense / Heating Command | Analog |
| **13** | GND | 14 | GND | - | - |
| **15** | 5V | 16 | 5V | 5V Supply | Low Current |
| **17** | 12V | 18 | 12V | 12V Supply | Low Current |
| **19** | -12V | 20 | -12V | -12V Supply | Low Current |
| **21** | 24V | 22 | 24V | 24V Supply | Low Current |
| **23** | 12V_BAT | 24 | 12V_BAT | 12 Volt from Battery | High Current |
| **25** | 12V_RX | 26 | 12V_RX | 12 Volt from Rexus | High Current |
| **27** | GND | 28 | GND | - | - |
| **29** | RX_CHARGE+ | 30 | RX_CHARGE- | 28V connection between RX-battery interface and battery charger | High Voltage |
| **31** | RX28V | 32 | GND_RX | RX_Interface to Powerboard | High Voltage |
| **33** | RX28V | 34 | GND_RX | RX Interface to Powerboard | High Voltage |

**Measure Bus**

This bus exists twice. One between Mainboard A and Sensor board A, the other between Mainboard B and Sensor board B. They are identical.

**Table 4-9: Measure BUS: pin configuration**

| Pin | Signal | Pin2 | Signal2 | Kind of signal |
|---|---|---|---|---|
| **1** | AGND | 2 | AGND | AGND directly connected to uC |
| **3** | ADC1$1 | 4 | ADC1$2 | sensor1 |
| **5** | ADC1$3 | 6 | ADC1$4 | sensor1 |
| **7** | DAC1$1 | 8 | DAC1$2 | sensor1 |
| **9** | ADC2$1 | 10 | ADC2$2 | sensor2 |
| **11** | ADC2$3 | 12 | ADC2$4 | sensor2 |
| **13** | DAC1$1 | 14 | DAC2$2 | sensor2 |
| **15** | ADC3$1 | 16 | ADC3$2 | sensor3 |
| **17** | ADC3$3 | 18 | ADC3$4 | sensor3 |
| **19** | DAC3$1 | 20 | DAC3$2 | sensor3 |
| **21** | PGA1$0 | 22 | PGA1$1 | gain select sensor 1 |
| **23** | PGA2$0 | 24 | PGA2$1 | gain select sensor 2 |
| **25** | PGA3$0 | 26 | PGA3$1 | gain select sensor 3 |
| **27** | GND | 28 | GND | GND connected to GND |

### 4.6.2 Sensor circuits (Sensorboard)

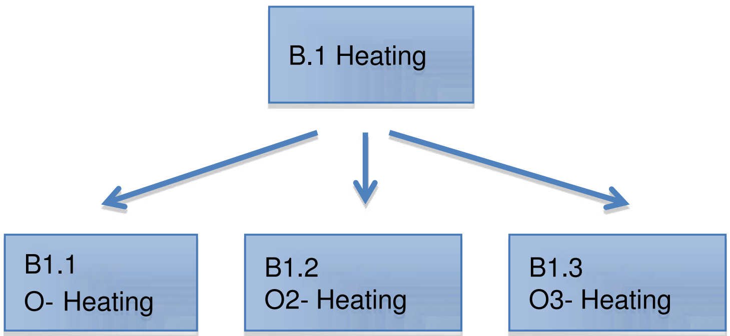



**fig. 38: Control & Data Flow diagram of the different sensors**

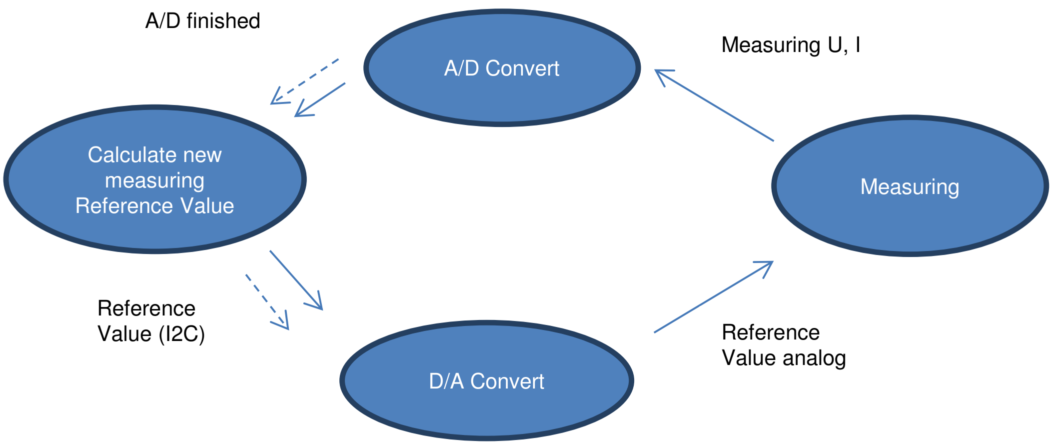



**fig. 39: Control & Data Flow Diagram of Sensors Measuring**

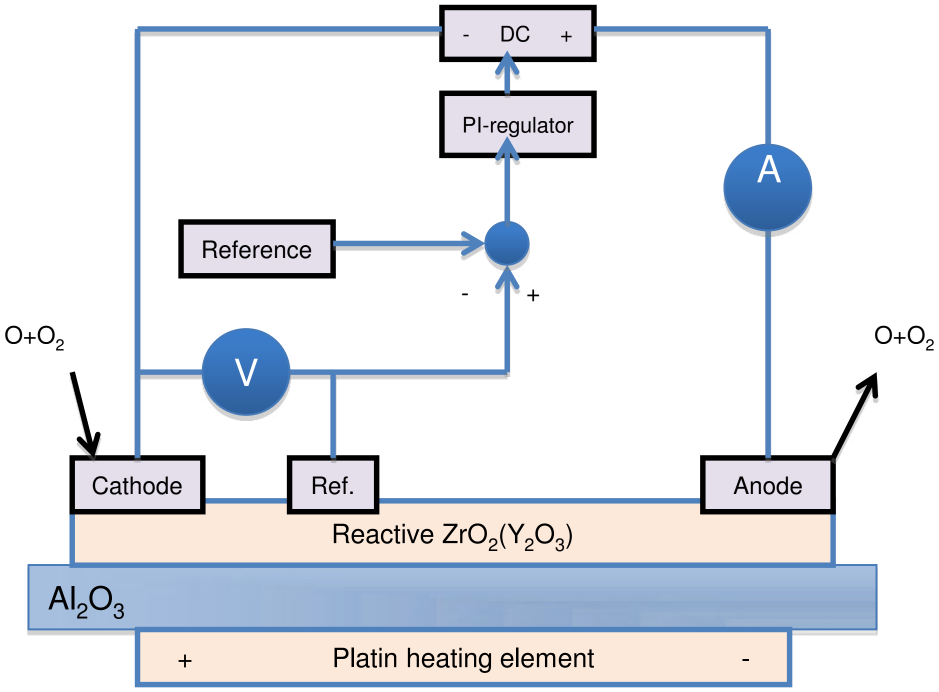



**fig. 40: Control & Data Flow Diagram of sensors measuring and feedback control**

The FIPEX sensor gets heated to a temperature about 650°C by a platinum-filament heating. This temperature has to be stable for at least one minute for atomic- and O2 sensors and 15 minutes for O3 sensors before measurement to eliminate contaminations on the sensor surfaces.

Voltage regulation:

This is done by setting a voltage between cathode and anode. Now the voltage between reference electrode and cathode is measured and compared with the reference voltage. The difference between those two signals sets the input of the

PI-Controller. The PI-Controller now adjusts the voltage. The current at the anode correlates directly with the amount of oxygen witch impinges on the substrate.

You can find the PDF document for circuits and board layout as well as the part lists at Annex C.

### 4.6.3 Power design ( Powerboard)

You can find the PDF document for circuits and board layout in Appendix C.

### 4.6.4 Temperature measurement

We support the temperature standard sensor LM75 on all PCBs inside our electronic box via I2C. We have little modules (11 mm x 11 mm) that can be connected via a small connector (JST-SH connector). You can find the pdf document for circuits and board layout in Annex C

### 4.6.5 Sensor boards

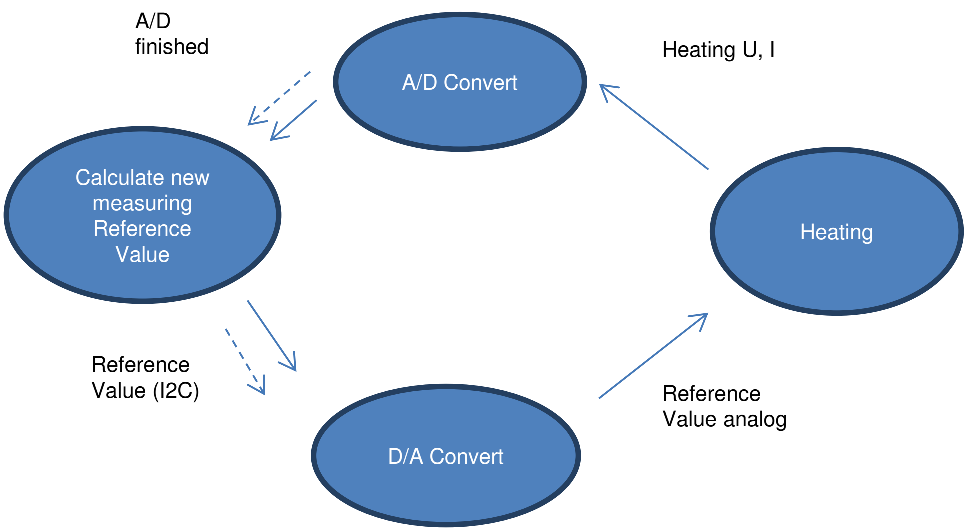



**fig. 41: Control & Data Flow diagrams of sensors heating**

Heating and measuring is nearly similar for O, O2, O3, the only difference is, that there is no reference electrode needed for ozone and O2 measuring.

You can find the PDF document for circuit and board layout in Annex C

### 4.6.6 Connectors

For connecting the circuits, we use mainly 2 different connectors manufactured by MOLEX and JST. We use the Molex standard KK CME Connectors in 2.54mm width. The Headers do have voided back walls and friction locks, that provide additional polarisation feature and mate retention. On the other hand we use JST-SH connectors that can be mounted at TU-Dresden for all signals etc. Here is a table of all connectors we use inside our rocket-module:

**Table 4-10: Connectors**

| Num | Name | Connector Side A: | Connect to: | Connector Side B | Connect to | Lenght | Kind of cable | Weight/g |
|---|---|---|---|---|---|---|---|---|
| 1 | Sens1$1 | Molex | Sensorboard 1 | Molex | Sensor AO Hatch | 300mm | 5 AWG24 | 11,2 |
| 2 | Sens1$2 | Molex | Sensorboard 1 | Molex | Sensor O2 Hatch | 300mm | 5 AWG24 | 11,2 |
| 3 | Sens1$3 | Molex | Sensorboard 1 | Molex | Sensor O3 Hatch | 300mm | 5 AWG24 | 11,2 |
| 4 | Sens2$1 | Molex | Sensorboard 2 | Molex | Sensor AO Cavity | 300mm | 5 AWG24 | 11,2 |
| 5 | Sens2$2 | Molex | Sensorboard 2 | Molex | Sensor O2 Cavity | 300mm | 5 AWG24 | 11,2 |
| 6 | Sens2$3 | Molex | Sensorboard 2 | Molex | Sensor O3 Cavity | 300mm | 5 AWG24 | 11,2 |
| 7 | Pressure 1 | JST-SH-4 | Mainboard 1 | Sensor-Plug | Pressure Hatch | 300mm | 4 AWG28 | 14 |
| 8 | Pressure 2 | JST-SH-5 | Mainboard 1 | Sensor-Plug | Pressure Cavity | 300mm | 4 AWG28 | 14 |
| 9 | Battery | Crimp-Hülse | Powerboard | Crimp-Hülse | Battery | 100mm | 2 min AWG10 | 25 |
| 10 | Magnet Control | JST-SH-4 | Mainboard 1 | JST-SH-4 | Magnet Control | 200mm | 4 AWG28 | 14 |
| 11a-c | Temperature LM75 | JST-SH-4 | Mainboard 1 | JST-SH-4 | Temperature sens | 100mm | 4 AWG28 | 42 |
| 11d-f | Temperature LM75 | JST-SH-4 | Mainboard 2 | JST-SH-4 | Temperature sens | 100mm | 4 AWG28 | 42 |
| 12 | Temperature PT1000 | Solder to Thermod 1 | Mainboard 1 | JST-SH-4 | Sensor T1 Hatch | 200mm | 4 AWG28 | 14 |
| 13 | Temperature PT1000 | Solder to Thermod 2 | Mainboard 2 | JST-SH-4 | Sensor T2 Cavity | 300mm | 4 AWG28 | 14 |
| 14 | CAP | Crimp-Hülse | Magnet Control | Crimp-Hülse | CAP | 150mm | 2 min AWG10 | 25 |
| 15 | Photo | Solder | Photosens | JST-SH-4 | Mainboard | 300mm | 4 AWG28 | 14 |
| 16 | ARM-PLUG | Solder | ARM-PLUG | Solder | Magnet Control | 180mm | 5 AWG28 | 25 |
| 17 | Magnet Power | Crimp-Hülse | Magnet Control | Solder | Solenoid | 200mm | 2 min AWG10 | 25 |
| | | | | | | | Total Mass [g]: | 335,2 |

## 4.7 Thermal Design

The thermal design is split in four parts. The temperature in the hatch, the inner chamber, the parts which are mounted in the module and these which are not in contact with the ambient air stream. The fourth part is the interplay between the electronic boards and the electronic box.

Temperature of the hatch

The hatch will not open until an altitude of 30 km is reached. Because of the low density in this altitude the friction on the lower edge of the now opened cavity is very low. That means that the hatch has to handle the temperature of the airstream that will be 120°C (outer shape of the rocket, measured on RX 11).

Therefore the hatch has to guarantee functionality between -20 and 120°C

During reentry, the hatch is open, hot gases hitting the parts which are looking in the airstream. At this state of the flight we don't want to measure anymore and we don't care if a sensor breaks. But hot gases must not come in the module itself. For that every way into the module is secured by heat resistant components.

Therefore the hatch has to guarantee leak tightness from -20 to 200°C.

Because the hatch is the only assembly group with moving parts there is a dilatation calculation in appendix C.

**Table 4-11: temperature profiles of components of hatch**

| Part | Temperature in °C |
|---|---|
| In-house production(AlMgSi1) | melt at +585 |
| Photo sensor | operating at-25 to 55<br>protected by hatch during hot flight phase |
| Solenoid | Operating temperature up to +300 |
| Gas sensors | Work on up to +500 |
| Pressure tube | Operating up to 1200 |
| springs | Operating temperature -40 to 120 |
| shafts | Medium thermal expansion coefficient at 200°C is $12.5x10^{-6}$ m/K |
| slide bush | Operating temperature -100 up to +250 |
| Sealing compound | Operating up to +300 |

Temperature of the inner chamber

The inner chamber has a very small inlet (2.54mm hole), but the air could stream very fast. So in worst case the inner chamber has to handle 250 °C. This is an assumption because real behavior of the airstream is very hard to calculate. The pressure difference between in and outlet could be up to one bar, but many influences like wall near effects and inaction of the stream prohibit a good calculation. We estimate the highest temperature with up to 250°C.

The inner chamber and the bond should be able to handle temperatures of -20 to 250°C

The Ramp outside should handle -20 to 600°C to be sure that the ramp wont separate from the module and damage the rocket.

**Table 4-12: temperature profiles of components of inner chamber**

| Part | Temperature in °C |
|---|---|
| In-house production (AlMgSi1) | melt at +585 |
| Ramp(X5CrNi18-10) | Medium thermal expansion coefficient at 500°C is $18x10^{-6}$ m/K |
| Gas sensors | Work on up to +500 |
| piezo sensor process attachment | Operating -25 up to +85 |
| Sealing compound | Operating up to + 300 |
| High temperature adhesive | Operating up to +982 |

Parts mounted in the module(except electronic box)

Inside the module we know that the temperatures, measured on the transmitters, having their maximum at 43°C.

All parts inside the module should be able to handle temperatures of -20 to 50°C

**Table 4-13: temperature profiles of components in module**

| Part | Temperature in °C |
|---|---|
| In-house production(AlMgSi1) | melt at +585 |
| Battery | Operating from -20 up to +60 |
| Battery rubber for fixation | Up to +100 |
| Battery Fixation (steel) | Up to 1600 |
| Piezo sensor | -40 up to +85 |
| Pirani sensor | Operating +5 to +50<br>Storage -20 to +70 |
| Pirani fix. dampers | operating from -20 to +80 |
| Pirani fix. Frame(AlMgSi1) | melt at +585 |
| cables | Operating Up to +60 |
| cable fixation | Up to +100 |
| Sealing compound | Operating up to +300 |
| Boxes for FYMTS<br>and board for hatch opening | Melting at +660 |

Interplay between the electronic boards and the electronic box

The heat which the electronics will produce and emit is hard to calculate so it will be tested.

So we determine no temperature range, but we show that the box can suffer the temperature and later, after the tests show how much heat the electronic will produce, to be sure everything will work or change the design.

**Table 4-14: temperature profiles of components of the electronic box**

| Part | Temperature in °C |
|---|---|
| In-house production(AlMgSi1) | melt at +585 |
| Distance pieces(steel) | Up to +1600 |
| Foam for fiction | Operating -20 up to +105 |
| Cable outlet | Operating at -20 up to +85 |

Screws

All screws are made of steel and will handle the temperature profile.

**Table 4-15: Heat Power Generation**

| Part | Power dissipation | Urgency |
|---|---|---|
| Switching Regulator | 40 mW | normal |
| DC/DC 3.3V | 750 mW | high |
| DC/DC 5V | 3000 mW | very high |
| DC/DC +/- 12V | 750 mW | high |
| uController | 95mW | low |

Temperature of the elements will be lowered by a heat sink design for the DC/DC Converters (direct connect to the aluminium case), by thermal vias and heat pads below the board for smaller thermal losses (microcontroller, switching regulators).

## 4.8 Power System

### 4.8.1 Power dissipation

The anticipated power dissipation is mostly caused by the sensors heating. The sensors resistance and therefore the power dissipation varies widely depending on the temperature of the platinum resistance and energy dissipated by heat convection.

The power dissipation of the sensors varies widely between the maximum value at startup with about 5 Watts, and the mean dissipation of about 0.95 Watts measured in high vacuum chamber.

During the flight power dissipation will vary between this two sizes in dependence of mass flow over the sensor surface and barometric pressure.

The heating element is made of platinum. The dependence between resistor and temperature is listed below.

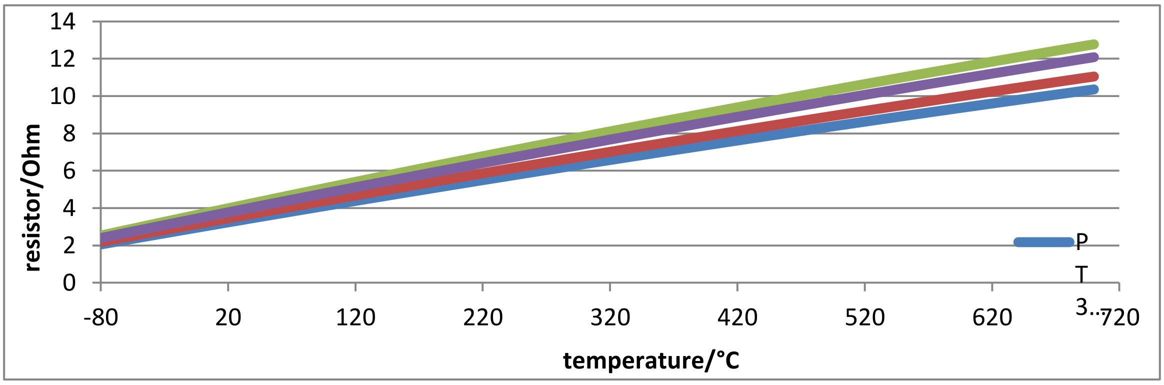



**fig. 42: Resistance (Min-Max) calculation**

To allow sensor calibration and removing of sensors contamination, the sensors will be heated up before the TO. Therefore, the highest power dissipation will occur before the launch, if all the sensors get heated up at once (6x 5 Watts). A lower power dissipation is expected during the first flight phase (0-30km) and the lowest at around the top. (6x1 Watts).

The maximum power dissipation during low pressure atmosphere will be estimated around 31 Watts in total by using battery supply and around 37 Watts by using the REXUS power interface.

**Table 4-16: Overview Dissipation**

| Part | Voltage | Current | Power Dissipation | Count | Total Dissipation |
|---|---|---|---|---|---|
| uController | 3,300 V | 29 mA | 95 mW | 2 | 190 mW |
| uC peripherie | 3,300 V | 10 mA | 33 mW | 2 | 66 mW |
| Fipex sensor heat | 7,000 V | 673 mA | 4711 mW | 6 | 28266 mW |
| Shunt | 0,020 V | 673 mA | 13 mW | 6 | 81 mW |
| MOSFET | 0,020 V | 673 mA | 80 mW | 6 | 480 mW |
| Measurement Peripherie (current side) | 12,000 V | 10 mA | 120 mW | 6 | 720 mW |
| Measurement Peripherie (voltage side) | 12,000 V | 10 mA | 120 mW | 6 | 720 mW |
| Pressure sensore | 12,000 V | 20 mA | 240 mW | 1 | 240 mW |
| Temp. sensor | 12,000 V | 20 mA | 240 mW | 1 | 240 mW |
| DC/DC Loss | | | | | 6000 mW |
| **Total Dissipation** | | | | | **37082 mW** |

To avoid excessive power usage, two possible designs can be implemented. The alternative switched heating might be implemented, but can only be used before the actual measurement. The second design includes batteries to lower the power withdrawal of the REXUS I/F.

### 4.8.2 Power System Design

High current batteries will be used to provide additional energy. A space-certified Li-Ion battery will be used. For safety, it will be placed in a separated compartment inside of the boardbox.

Assuming an average consumption of 20 Watts and a safety factor of 2, the required battery capacitance results to:

$$W = Q * U$$

$$Q = \frac{W}{U} * t = \frac{20W}{3.75V} * 12min * 2 * \frac{h}{60min} = 2.133\ mAh$$

The battery charging and handling will be implemented using an MAX8814 charging IC. The “Charging” line of the RX Interface will be used.

## 4.9 Software Design

### 4.9.1 Experiment Software Design

Each experiment will have their own Microcontroller and data system to create independence. The Experiments are controlled manually before LO and by Timeline after LO. According manual command for the *Sensors Heating* can be sent by the ground station. Automatic flight events like *Measurements*, *Data Acquiry, Shutdown* are controlled by an timeline. The opening of the hatch is controlled by MORABA.

In case of any reset the LO Signal will be analysed first and with LO present the measurements and data acquiry will immediately start.

The timing will be synchronized to the LO signal and data capture and acquiry will be performed. The timeline corresponds directly with Table 4-1.

**Table 4-17: Software Timeline**

| ToF [s] | -1000 | -900 | 0 | 50 | 350 | 600 |
|---|---|---|---|---|---|---|
| Height | 0 | 0 | 0 | 40 | 5 | 0 |
| Heating | | | | | | |
| Measurement | | | | | | |
| Hatch | | | | X | | |
| Shutdown | | | | | X | |
| Manual Events | Power ON | Heating | | | | Power OFF |
| Software State | IDLE | HEATING_O | FLIGHT | FLIGHT | FLIGHT | STOP |

**Table 4-18: List of Implemented States (Moxa Experiment)**

| # | State | FLIGHT STATES | Description |
|---|---|---|---|
| 0 | SETUP | X | Used at Controller Startup |
| 1 | IDLE | X | No Action is taken |
| 2 | HEATING_ONLY | X | Heating is Active (PreLaunch) |
| 3 | MEASURE | | Measurement is active |
| 4 | FLIGHT | X | Measurement is active with Time Synchronization |
| 5 | STOP | X | All Parts are Stopped |
| 6 | TEST, | | Various Assembly Test Modes |
| 7 | TESTPINS | | All Output Pins will blinks. |

### 4.9.2 Microcontroller Placement Considerations

Two autonomous measurement environments. Supplemental data transmission (1/s) from 1 out of 2 measurement devices.

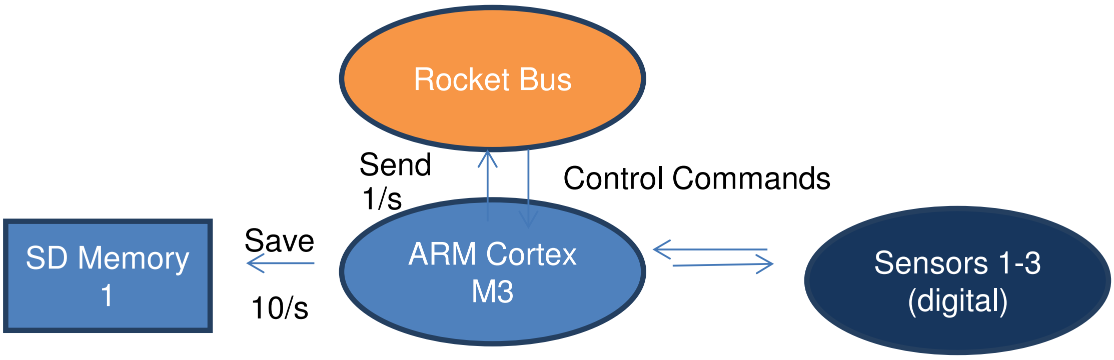



**fig. 43: Microcontroller Placement Considerations**

### 4.9.3 Software Flow Diagram

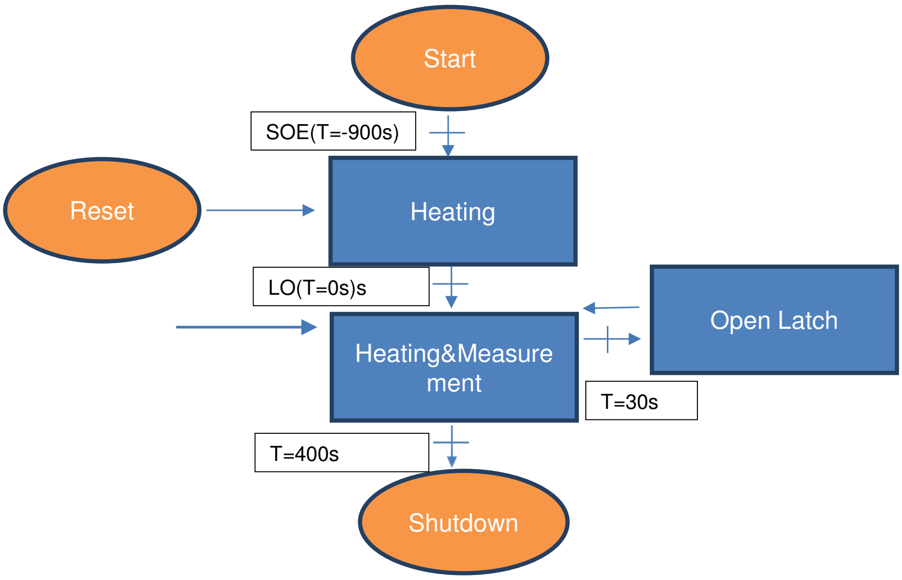



**fig. 44: Software Flow Diagram**

### 4.9.4 Implementation of a Minimalistic Operating System (MOS)

Minimalistic Operating System with continuous scheduler and basic task overview. The different flight states are represented in the microcontroller using a state machine to perform the according tasks.

The following figure shows the basic flow of the onboard microcontroller software. The control loop and the scheduler (housekeeping) tick rate confirm to real time operation as described in the requirements (10Hz) by using interrupts. Other components are driven with the lowest achievable latency.

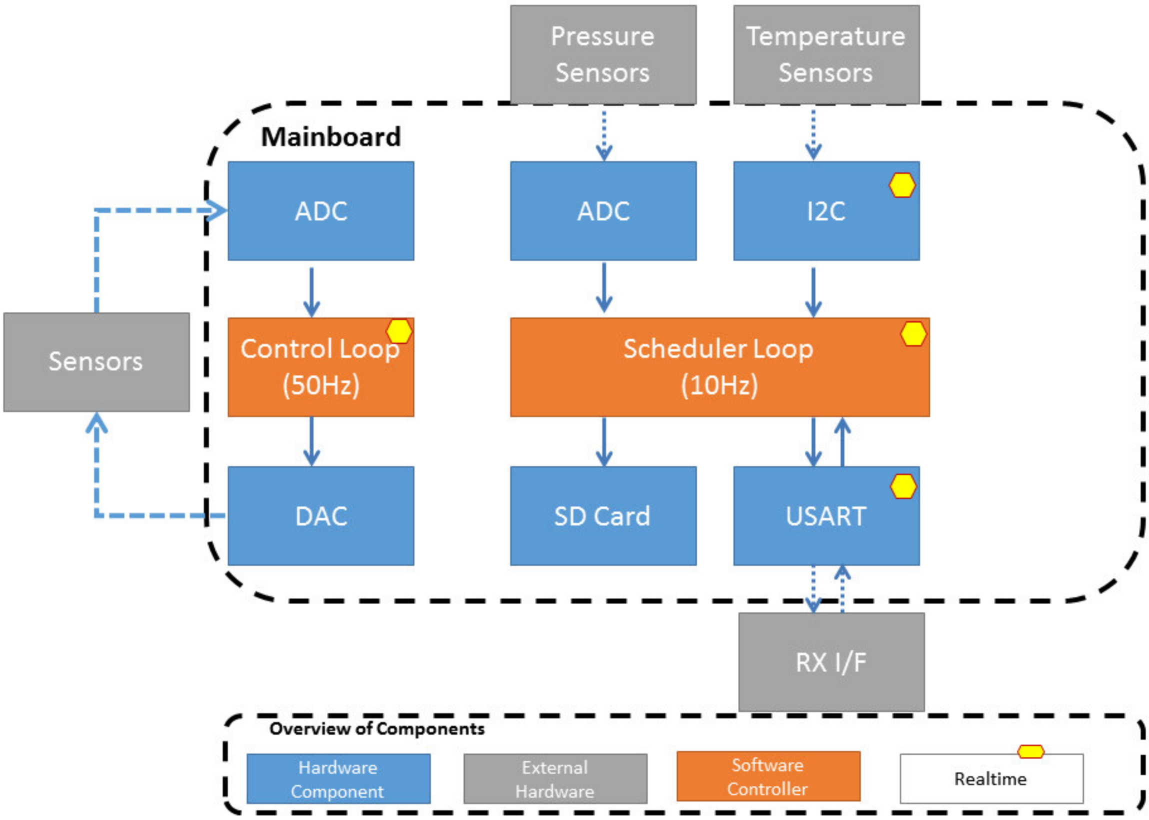



**fig. 45: Implementation of a Minimalistic Real Time Operating System (RTOS)**

### 4.9.5 Data Communication Implementation

Active time of flight measurement during 300s with 10Hz will results in 3000 Measurements. By efficient compression of data all packages will be send down to the ground station as redundancy for SD-card failure. The overall measurement data per measurement is roughly 150 Byte, and hence 1500 Byte/s.

### 4.9.6 Data Protocol Implementation

According to the REXUS experiment documentation a data protocol has been implemented.

A 16Bit CRC-CCIT (0xFFFF) algorithm has been implemented at ground station at all communication participants to check for bit errors. The upstream and downstream protocol use different package sizes, since upstream is solely required for commanding and does not carry many data. Each message consists out of a 6 Byte header, containing the identifying Message ID (MSGID) as well as a consecutive message number. In addition a 2 Byte CRC is included, containing the CRC for all data after SYNC.

**Table 4-19: Description of 30-Byte Data Package (Downstream)**

| | | | | | | |
|---|---|---|---|---|---|---|
| SYNC | SYNC | MSGID | MSGCNT | DATA0..23 | CRC | CRC |

**Table 4-20: Description of 22-Byte Data Package (Upstream)**

| | | | | | | |
|---|---|---|---|---|---|---|
| SYNC | SYNC | MSGID | MSGCNT | DATA0..15 | CRC | CRC |

A upstream command protocol will be used that allows setting of all elementary experiment parameters by remote, most significantly the status and control parameters, and allows remote triggering for the hatch and the sensors.

### 4.9.7 Control Loop

An digital PID controller has been implemented to control the heating. The process parameters are flexible and can be adjusted before launch. For good performance the control route parameters are determined experimentally and will then be used to establish the PID parameters using an analytic model with SIMULINK software.

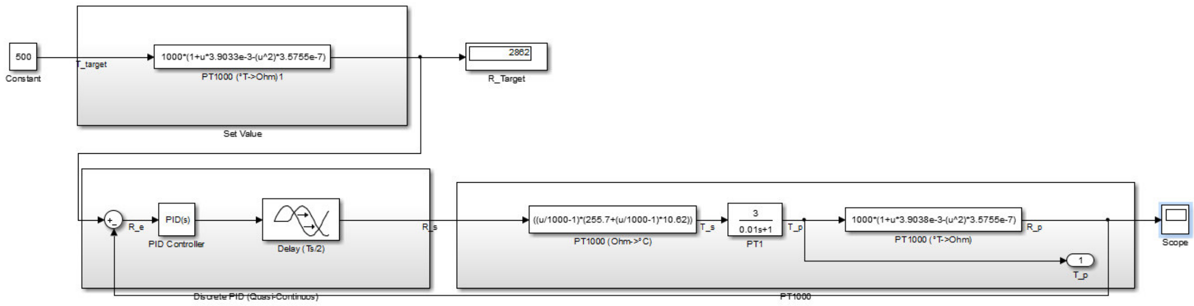



**fig. 46: Analytic Simulink Model of the Heating with quasi-continuous PID controller**

### 4.9.8 Ground Station Software Design

The ground station will be used to survey and save the received measurement data. The ground station software is developed in Java language. To access serial features, the RXTX Library will be used. For visualisation the open JFreeChart library is used. All commands can be executed by sending an ASCII Code through a serial interface.

- Start/Stop Heating
- Start/Stop Sensors
- Set Experiment Parameters (Control Parameters)
- Start/Stop Battery
- Read/Save all Analog Values (Currents, Voltages, Pressures)
- Read/Save all Temperature Values

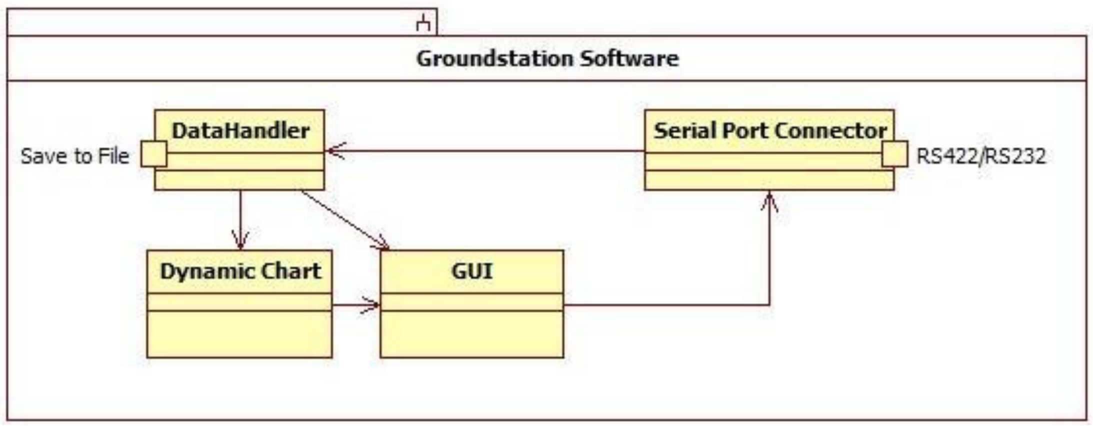



**fig. 47: UML Diagram of Groundstation software classes.**

The software is accessible online via a revision software (Git) to allow collaboration and sharing of the software with fellow/future teams.

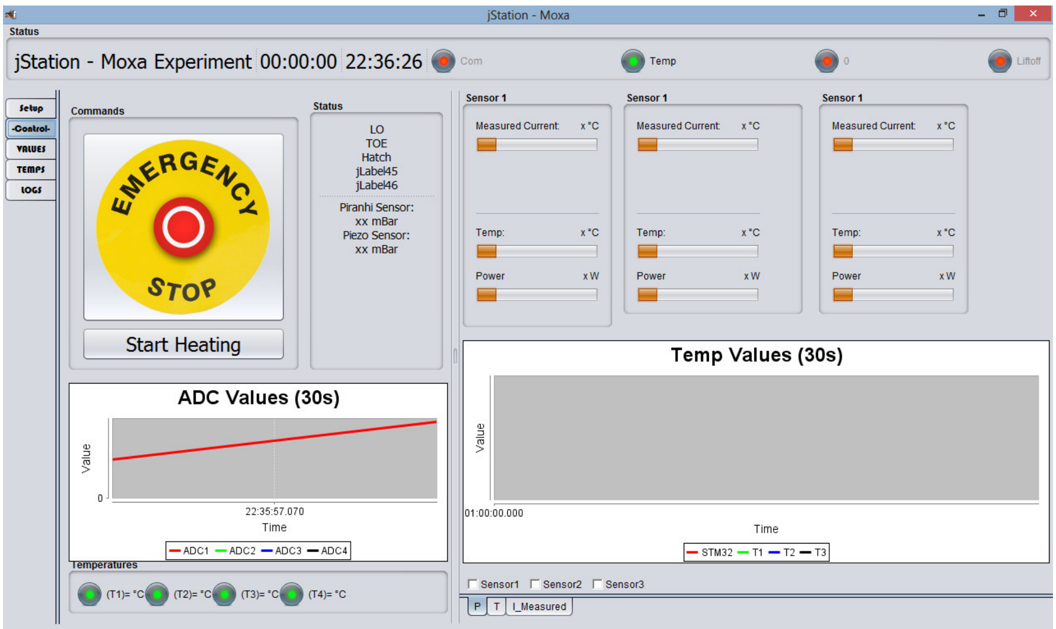



**fig. 48: Preliminary GUI of the Ground Station**

## 4.10 Ground Support Equipment

Two laptops: The ground support equipment will receive the data from the REXUS Interface and will analyse it for transmission error, process and save the data.

We need at launch site precise temperature and pressure data to correlate our measurements with atmosphere models.

# 5 EXPERIMENT VERIFICATION AND TESTING

## 5.1 Verification Matrix

**Table 5-1: Verification table**

| ID | Requirement text | Verification | Status |
|---|---|---|---|
| F.1 | The experiment shall measure ozone on the outer shape of the RX rocket during the flight with two different electronic boards. | T, R | done |
| F.2 | The experiment shall measure atomic oxygen on the outer shape of the RX rocket the whole flight with two different electronic boards. | T, R | done |
| F.3 | The experiment shall measure molecular oxygen on the outer shape of the RX rocket the whole flight with two different electronic boards. | T, R | done |
| F.4 | The experiment shall measure pressure on the outer shape of the RX rocket the whole flight with two different electronic boards. | T, R | done |
| F.5 | The experiment shall measure temperature on the outer shape of the RX rocket the whole flight with two different electronic boards. | T, R | done |
| P.1 | The ozone measurement (partial pressure) shall be possible between $10^{-6}$ bar and 1bar. | R | done |
| P.2 | The ozone measurement (partial pressure) shall be made with an accuracy of 2% (between an attitude of 30 to 90km) | R | done |
| P.3 | The ozone measurement (partial pressure) shall be made with an rate of 100 measurements every second | T, R | done |
| P.4 | The atomic oxygen measurement (partial pressure) shall be possible between $10^{-6}$ bar and 1bar. | R | done |
| P.5 | The atomic oxygen measurement (partial pressure) shall be made with an accuracy of 1% (between an attitude of 30 to 90km) | R | done |
| P.6 | The atomic oxygen measurement (partial pressure) shall be made with an rate of 100 measurements | T, R | done |

| | | | |
|---|---|---|---|
| | every second. | | |
| P.7 | The molecular oxygen measurement (partial pressure) shall be possible between $10^{-6}$ bar and 1bar. | R | done |
| P.8 | The molecular oxygen measurement (partial pressure) shall be made with an accuracy of 1% (between an attitude of 30 to 90km) | R | done |
| P.9 | The molecular oxygen measurement (partial pressure) shall be made with a rate of 100 measurements every second. | T, R | done |
| P.10 | The pressure measurement shall be possible between $10^{-4}$ bar and 1,5 bar. | R | done |
| P.11 | The pressure measurement from 20mbar to 3 bar shall be made with an accuracy of 1.5%. | R | done |
| P.12 | The pressure measurement shall be made with an rate of 100 measurement every second. | T, R | done |
| P.13 | The temperature measurement shall be possible between -100°C and 200°C. | R | **done** |
| **P.14** | The temperature measurement shall be made with an accuracy of +/- 1°C. | R | **done** |
| **P.15** | The temperature measurement shall be made with a rate of 100 measurement per second. | T, R | **done** |
| **P.16** | The pressure measurement from 0.001 to 20mbar shall be made with an accuracy of 10%. | R | **done** |
| **P.17** | The Experiment shall save and process the data at a rate of 10 Hz. | T | **done** |
| **P.18** | The Experiment control loop shall process at 50 Hz. | T | **done** |
| **D.1** | The experiment shall be designed to operate in the vibration profile of the RX rocket. | T | **done** |
| **D.2** | The experiment shall be designed in such a way that it shall not disturb and harm the RX rocket and the other experiments. | T, I | **done** |
| **D.3** | The experiment batteries shall be qualified for the rocket flight. | A | **done** |
| **D.4** | The experiment batteries shall be rechargeable to run the experiment during pre-flight test, flight | T, A | **done** |

| | | | |
|---|---|---|---|
| | preparation and flight. | | |
| **D.5** | The experiment batteries interface shall be accessible for recharging. | I | **done** |
| **D.6** | The experiment sensors shall be reachable for a late exchange. | I | **not possible** |
| **D.7** | The experiment sensors shall be put on the outer shape of the rocket for a convenient approaching flow. | T, A, I | **done** |
| **D.8** | The electronic boards have to be fixed and hedged against humidity and electromagnetic influences. | T, I | **done** |
| **D.9** | The hatch shall work (opening time, mechanism). | T, I | **done** |
| **D.10** | The heat, produced by the electric, shall be led away. | T | **done** |
| **O.1** | The experiment shall operate automatically. | T | **done** |
| **O.2** | The experiment shall release the hatch for the sensor protection automatically. | T | **done** |
| **O.3** | The experiment shall accept a request for radio silence at any time while on the launch pad. | T | **done** |
| **O.4** | The experiment shall store the measured data on a SD-card. | T | **done** |
| **O.5** | The experiment shall send a part of the measured data down to the ground station. | T, A | **done** |
| **O.6** | The experiment shall be able to turn off all electrical parts for landing. | T | **done** |
| **O.7** | The experiment electrics shall control the sensors all the time. | T | **done** |
| **O.8** | The sensors must not be touched when they are hot. | | |
| **O.9** | The automatic events shall automatically triggered by Timeline after liftoff. | T | **done** |
| **O.10** | **The manual events shall be transmitted over the REXUS Interface** | **T** | **done** |

## 5.2 Test Plan

**Table 5-1: Test description T1**

| | |
|---|---|
| **Test number** | **T1** |
| **Test type** | **Functionality** |
| **Test facility** | **TUD** |
| **Tested item** | **Hatch** |
| **Test level/procedure and duration** | **Qualification test** |
| **Test campaign duration** | **1 day** |

**Table 5-2: Test description T2**

| | |
|---|---|
| **Test number** | **T2** |
| **Test type** | **Electronic** |
| **Test facility** | **Not clear yet** |
| **Tested item** | **Curve for regulation parameter** |
| **Test level/procedure and duration** | **Qualification test** |
| **Test campaign duration** | **1 day** |

Table 5-3: Test description T3

| | |
|---|---|
| Test number | T3 |
| Test type | Functionality |
| Test facility | TUD |
| Tested item | Sensors |
| Test level/procedure and duration | Acceptance test |
| Test campaign duration | 21 day |

**Table 5-4: Test description T4**

| | |
|---|---|
| Test number | T4 |
| Test type | Vibration |
| Test facility | TUD, ZARM |
| Tested item | Assembled Experiment |
| Test level/procedure and duration | Qualification test |
| Test campaign duration | 5 days |

**Table 5-5: Test description T5**

| | |
|---|---|
| Test number | T5 |
| Test type | Software |
| Test facility | None |
| Tested item | Microcontroller Software, Ground station Software |
| Test level/procedure and duration | Acceptance test |
| Test campaign duration | 15 day |

## 5.3 Vibration Test

To ensure the safety of our module and assembly, we will do vibration tests with our complete module. The tests will take part at the Dresden University of Technology, previously it´s necessary to prepare the tests in detail. All parts will be mounted for the tests on a vibration table, for inspection and functional checks we need relevant equipment.

**Module**

The testing of the module will take part after the final assembly of our module to ensure safety and functionality of our project.. Inspection of structure, fixation of wiring and functional tests are necessary after each axis of vibration. The opening mechanism of the hatch has to be tested during every vibration test to ensure functionality after launch. Additional accelerometers for each axis need to be mounted onto the board box, the hatch and the pirani sensor.

**Pirani Sensor**

In order to check the efficiency and capacitance of the Pirani sensor, we will test the sensor within the whole module in functionality and simulate the conditions of the flight.

First we will check the qualification level of vibration, therefore it´s necessary to mount accelerometers for each axis (X, Y and Z) and inspect the functionality of the sensor after the test for each axis.

**Search for Eigenfrequencies:**

**Table 5-9: Sinusoidal frequency vibration**

| Axis | Frequency | Input Level |
|---|---|---|
| X,Y | 5-2000Hz | 0.25g |
| (Z | 5-2000Hz | 0.25g |

**Table 5-9:Random frequency vibration**

| Axes | Frequency | Level | Remark |
|---|---|---|---|
| All Axes | (20-2000)Hz | 6.34gRMS | 0.018 $g^2$/Hz |
| Duration<br>%-Input | 10s/10s/10s/60s<br>25%/50%/75%/100% | | |

During the Bench-Test at Oberpfaffenhofen a second vibration test was performed by DLR at a 12gRMS level to ensure the safety of the Hatch.

Test results are documented in the Appendix E.

## 5.4 Thermal test

The thermal test consistent with the expected maximum and minimum of temperatures on each assembly group or measure the produced and emitted heat flow during operation (electronics).

During a test the emitted heat due to the operating electronics was measured. In the end the produced heat was harmless to the experiment.

Single components have been tested to their thermal sensitivity. But tests of the electronic box with the boards or the sensors were not possible due to the state of development of these parts.

## 5.5 Test Results

### 5.5.1 T5 Software Tests

- (P.3, P.6, P.9) The software is fast enough to control 100 Measurements/Second
- (D.9, O.1, O.2) Timeline events can be performed
- (O.3) The experiment can be deactivated by RX I/F(State Change)
- (O.4) Data can be captured & saved onto an SD Card
- (O.5) The RX I/F is implemented and working using upstream commands and downstreaming of measurement data
- (O.6) The Experiment can be deactivated automatically(Timeline)

The Test using a RS232 connection has been successful and proven that the necessary software parts are implemented as required beforehand, both on the experiments microcontroller as well on the groundstation.

### 5.5.2 T4 Vibration Test

see APPENDIX E

# 6 LAUNCH CAMPAIGN PREPARATION

## 6.1 Input for the Campaign / Flight Requirement Plans

### 6.1.1 Dimensions and mass

**Table 6-1: Experiment mass and volume**

| Attribute | Dimension |
|---|---|
| Experiment mass (in kg): | 8.973kg including module and bulkhead |
| Experiment dimensions (in m): | Ø 0,348 x 0,130 |
| Experiment footprint area (in $m^2$): | 0,0657 |
| Experiment volume (in $m^3$): | 0,012 |
| Experiment expected COG (centre of gravity) position: | (x=137, y=106, z=0.191) |

### 6.1.2 Safety risks

Hot surface of one of the sensors (500°C) when heated. The risk occurs between t=-900s and t=600s during flight and during active tests which include heating of the sensors. Before launch and during testing the surface will be covered by the hatch and are not touchable. After Power-off the sensors cool down within seconds and are not hazardous during recovery. For additional safety a warning sign marks the area on hull.

The sensors will have a protective cap during tests.

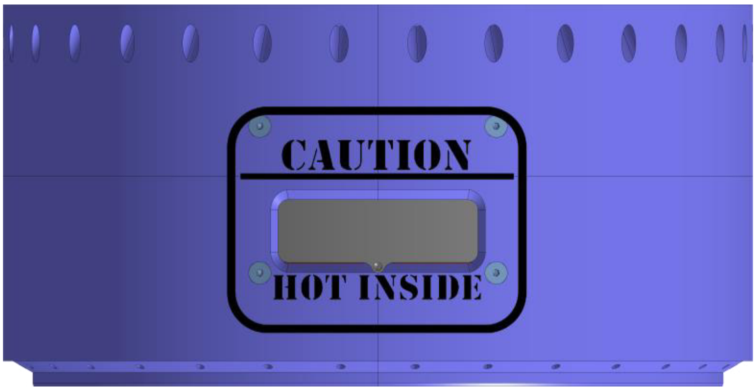



fig. 49: Warning sign at outer hull

**Hatch safety issues**

It has already been mentioned, that the hatch will not be closed again. So it will be open during reentry and landing. To ensure that no hot gas will get access to the inner parts of the module we use some mechanism/parts.

When an airflow with over estimated 200°C flows permanent over the sensors (e.g. reentry) the sensor could be damaged, but this is set. Our goal is to get as much data as possible which means we measure till the sensors are damaged.

A weak point is the photo sensor. It is also made of plastic and could melt during reentry. The hole that arises due to that is protected with an aluminum box shown in the picture below.

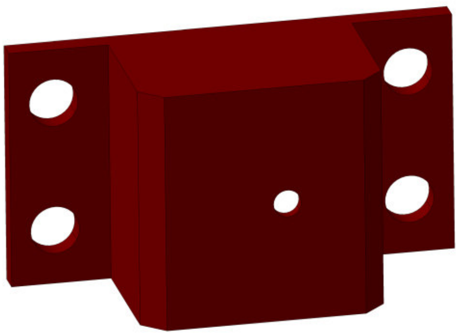


**fig. 50: aluminium box**

All contact faces between different parts or at places where cables will come through the structure will be secured with a paste that is temperature resistant.

Owing to the fact that the pyrocutter contains explosives there have to be some security constraints. To prevent early ignition and damage to men or material the electric circuit have to be capsuled and seperated from other cords.

### 6.1.3 Electrical interfaces

| REXUS Electrical Interfaces | | |
|---|---|---|
| Service module interface required? Yes/No (usually yes) | | |
| | Number of service module interfaces: | Two |
| | TV channel required?<br>If yes, when is it required: | no |
| Up-/Downlink (RS-422) required? Yes | | |
| | Data rate - downlink: | 19'2 Kbit/s |
| | Data rate – uplink | 0 Kbit/s |
| Power system: Service module power required? Yes | | |
| | Peak power consumption: | 50 W |
| | Average power consumption: | 37 W |
| | Total power consumption after lift-off (until T+600s) | 7 Wh |
| | Power ON | t=-1000s |
| | Power OFF | t=600s |
| | Battery recharging through service module: | Yes |
| Experiment signals: Signals from service module required? Yes/No | | |
| | LO: | Yes |
| | SOE: | t=-900s |
| | SODS: | t=0s |

### 6.1.4 Launch Site Requirements

The Experiment must be kept above 7°C at all times to avoid freezing of the electrolyte within the sensors. Heating and Isolation to keep the temperature above this level is necessary for transportation and launch pad during times without experiment power.

At the launch site we require at Liftoff:

- Local Temperature
- Local Pressure

## 6.2 Preparation and Test Activities at Esrange

1. Installation and test of our ground station equipment
2. Prove of integrity of all components after transport
3. Change/Installation of the battery
4. Change/Installation of all gas sensors
5. Test of the functionality of the hatch (pyrocutter)
6. Test of the functionality of electronics and the sensors
7. Secure the reject mechanism of the SD-Card with some glue
8. Use test signals from the REXUS bus and test the right reaction
9. Final fixation of the inner chamber with adhesive
10. All contact faces in the hatch between different parts or at places where cables will come through the structure will be secured with a paste that is temperature resistant.
11. Installation of the new pyrocutter
    Assemble everything for flight/ secure screws with LOCTITE
    see APPENDIX F for detailed information

## 6.3 Timeline for countdown and flight

The Sensors used for this experiment need a time for preheating and calibration. This time is sensor-dependant and should take up to 15 minutes before the measurements and therefore should be performed before Lift Off. The protective hatch will be opened after the burnout of the motor.

**Table 6-2: Timeline**

| Time | Event |
| --- | --- |
| T-1000 | Power on |
| T-900 | SOE (Preheating of the sensors) |
| T+0 | Lift Off |
| T+28 | Hatch opening (Pyrocutter fired by service system) |
| T+600 | Power Off |

## 6.4 Post Flight Activities

### 6.4.1 After Recovery

6.4

1. Disassembly of the experiment and clean it/documentation
2. Disassembly of the electronic box, to get the SD-Card
3. Examine all mechanical parts /documentation
4. First analysis of data
5. Interpretation if the sensor worked or not
6. Celebrate the hopefully successful launch ☺

### 6.4.2 After launch campaign

1. Data analysis in detail
2. Functionality test of all components (sensors, electronic, material)
3. Final Report

6.4

6.4

6.4

6.4

# 7 DATA ANALYSIS PLAN

## 7.1 Data Analysis Plan

We will start with a rough estimation in Kiruna if the sensors work or not.

After that we will analyse the gained data in cooperation with the Institute of Aerospace Engineering in Dresden. The result of this investigation will be a partial pressure against time diagram for every measured gas.

Then we will compare these data with the GPS data of REXUS, to get the partial pressure of each gas against flight altitude.

In comparison with the pressure we measured and the density against altitude we can calculate the density of each gas for every altitude.

Afterwards resulting distribution diagram will be compared with known data from various sources, to value the functionality of the sensors and the electronic control.

## 7.2 Launch Campaign

After arriving in ESRANGE we shall inspect every part of the experiment.

First we disassemble every assembly group of the experiment, which screws are not secured with Loctite already.

After that just the electronic boards and software will be tested by their own to check if there is a possible damage caused by transportation. If these test run well the electronic boards will be connected to the sensors and tested as well.

In the end we shall simulate a flight using the RX simulator. After passing all tests the experiment will be assembled and secured with Loctite in the module.

After the flight we will start a rough estimation in Kiruna if the Sensor works or not.

## 7.3 Results

### 7.3.1 Main goal

The main outcome of MOXA is that we built an experiment that is able to fulfil the scientific goal we announced in the proposal for the REXUS campaign. We wanted to measure primary ozone, atomic and molecular oxygen and secondary local pressure and temperature during the whole flight.

But what has to be discussed is the quality of the measurements. Mainly the thermodynamic flight environment was a cause for unexpected quality penalty of the data. This has to be discussed in detail with the gas sensor provider (ILR at TUD).

### 7.3.2 Elektronic

Up to the moment we received the signal Start Of Experiment (SOE) all electronic systems worked well. The sensors did heat up properly and we received a status of our experiment every second via the ground station. Because of two similar ground stations we saw all 6 sensors, the temperature sensors and the pressure sensors – everything worked as expected and already tested at the bench test.

This did not change at liftoff and during the flight (except the sensors, but more about that later on).

On the point of view of an electrician it was a great success.

Problems:

None on electrical side

### 7.3.3 Software

The Software was full working; we lost two of 14000 measured values so we can say this is a great success too! The ground station gave us live feedback for all sensors so we saw much more of the rocket flight even though the others stood on the radar hill and we sat next to a computer in the control room. It was quite a lot of gratification to watch the sensor graphs varying in dependence of the rocket height.

### 7.3.4 Mechanic

**Hatch:**

During the flight the pyro cutter fired after it received the signal from the RX-bus. The cutter sliced the steel wire, which holds the hatch down, and then the springs could push the hatch up.

That the hatch really opened is confirmed by a photo sensor in the hatch, the vibration measurement of another experiment (FOVS) and you can hear it in the flight video (GoPro looking outside the rocket).

**Inner Chamber:**

The design of the inner chamber should enable to take samples of the ambient airstream around the rocket, slow the air down and make it so suitable for our gas sensors.

The design based on simplifications of the airstream. Tumbling caused by the rotation stabilized flight and the resulting dynamic boundary layer couldn't be predicted. But especially the boundary layer around the rocket leads to much lower fluid velocity which the inner chamber was not designed for.

In conclusion we assume very little air exchange in the chamber, but this has to studied in further investigations.

**Pirani pressure sensor:**

One of the most sensitive component is the Pirani sensor. This device sensor was designed for vacuum chambers in a laboratory and not for a rocket launch with high vibrations and a large temperature range.

To make the sensor suitable for our experiment we placed designed a damping bracket to avoid vibrations and placed it near the center of the bulkhead where a small temperature range was expected.

After the flight we recognized that the sensor is still operational. This means that the damping bracket even could handle the payload touchdown.

**Electronic Box:**

The box wasn't damaged and cared for the storage of the electronic boards very well.

**Gas Sensors:**

The results of the inner resistance of the sensors show, that the sensors did not heat up properly as shown in the following figure:

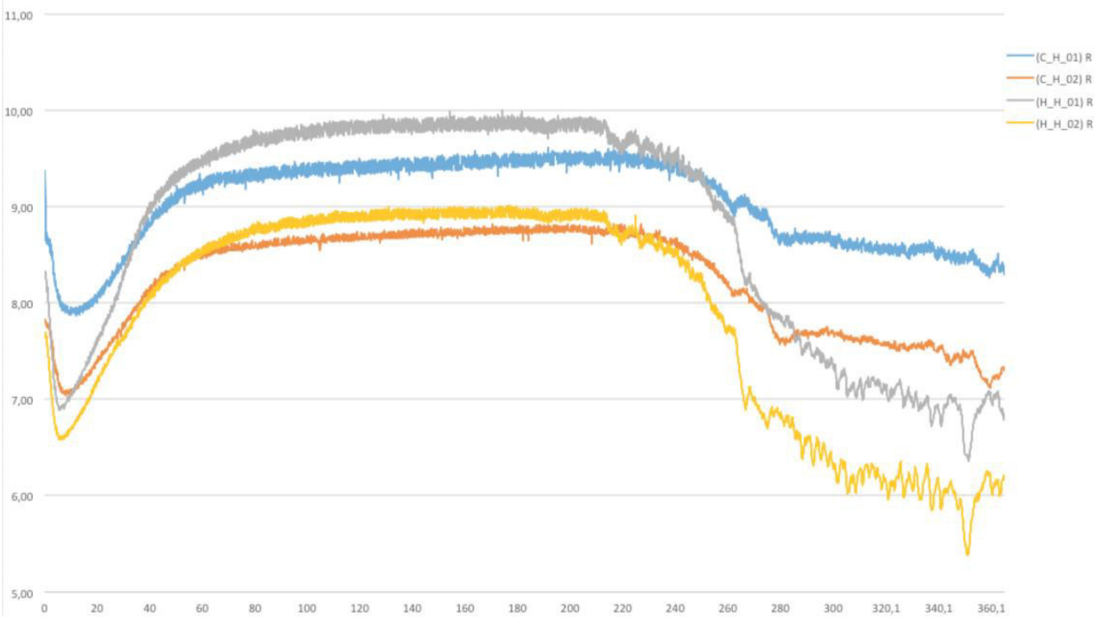



**fig. 51:** Sensor resistance during the flight

The figure 52 shows the inner resistance from liftoff till shutdown of the electronic (360s). At the beginning the high velocity cooled down the sensors. Our sensor control loop normally prevents that, but two things went wrong. On the one hand the PID values have not been that aggressive as they should be, so the control loop was too slow for the fast changing in air speed and density. The much more important fact and the reason why our sensors have been cooled down so far is, that the current to a sensor has had to be regulated down to 500mA because of a bonding wire that is 0.025mm thick which is rated for at maximum that current. This would not have been a problem at all but the sensors we got from the institute have had very low inner resistances. Lower resistance means lower voltages (at same current) lower voltage at the same current means less power and therefore less heat. More bonding wires parallel would be able to capture a much higher current, but are very different to mount. So finally only the data between 80s and 220s are useable for upcoming data consideration.

## 7.4 First Data Results

The figure 52 shows the pressure of the inner chamber and the hatch time resolved. The pressure of the hatch is marked blue and shows an inverted parabolic curve like our rocket flight, this is as expected. The black curve shows the same results at the beginning, what was very unexpected for us, because we expected a much higher pressure – maybe the hole at the ramp was to small, so there could not get enough air inside the chamber. As the sensor was not selected for that low values it is normal that it could not follow the blue line.

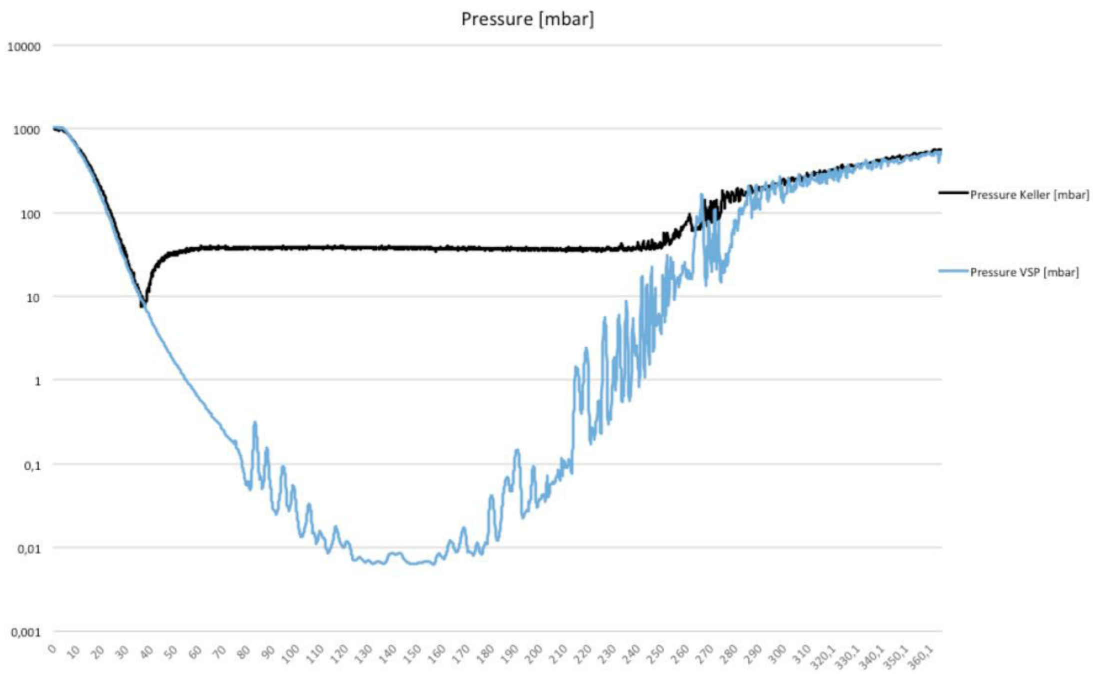



fig. 52: The pressure of the inner chamber and the hatch time resolved

In Figure 53 the time resolved ozone measurement is shown. The sensor in the hatch didn't work and the other one in the inner chamber slowly rise and jump to zero at 110 s. This trend could have several reasons, mentioned below. The ozone sensors are prototypes, that where finished two weeks before launch. In laboratory environment the sensors worked very well, but a rocket launch is a very harsh stress test for these sensors.

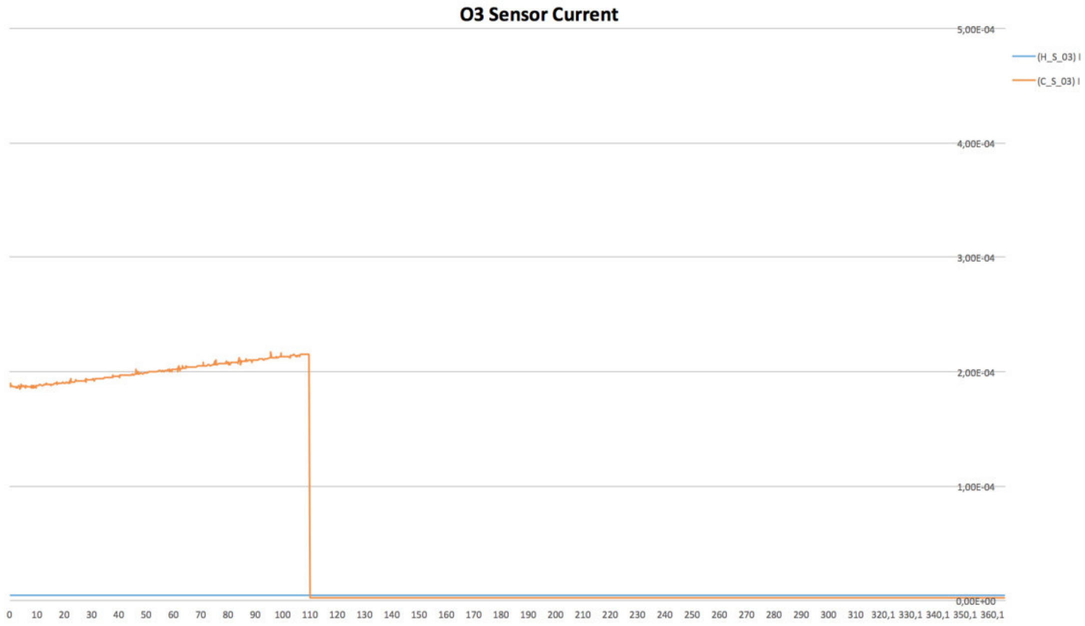



**fig. 53: Ozone time resolved**

The ozone sensor needs to be filled with a water carrying fluid to guarantee a permanent humidification of special foil. This foil and two electrodes measure incoming ozone. If the humidification is not stable or not available anymore the sensor does not work. The sensor itself and especially fluid inside could be influenced by varies factors:

- High velocity of the rocket (up to 1400m/s) and resulting airstream conditions that hits the sensor
- High acceleration (18g)
- Boundary layer effects on the rocket
- Different environments after inflation (integration hall; Launchpad; flight)
- High variations of local pressure and temperature during flight
- Mistakes during inflation or bonding

The sensors were installed protective as possible, but the extreme airstream conditions during flight couldn't be simulated. In Conclusion the prototype has to developed further, but we learned very much about the handling of the sensor.

## 7.5 Discussion and Conclusions

In conclusion MOXA mostly fulfilled its objectives. There are two points that didn't worked as we expected. One is the sensor heating in the beginning of the flight and other one are the flow conditions in the inner chamber, as mentioned in chapter 7.3.4.

Conclusions:

- In this configuration the gas sensor are more suitable for low airstream velocities. This achieved partially in the inner chamber.
- Electronics and software operated very well and should be used for further operations of the gas sensors.
- The exact analysis of the measurements shall be done in a student research project.

MOXA was successful in the main intention of REXUS, because we learned so much about procedures of projects from the very first beginning of a proposal to the final presentation of the results. It was the first time for the most of us to get to know the difficulties and benefits of teamwork.

We would like to thank ZARM, DLR, ESA, MORABA and SSC for this great experience. We learned so much and we are glad that you make it possible to put our idea on your rocket.

Thank you!

## 7.6 Lessons Learned

We learned very much, especially how an aerospace project has to be done from the very beginning to the end. Here is a list of the most important things:

- Very much about time management (project phases, manufacturing durations, testing procedures and even response time for e-mails)
- Define clear responsibilities in the team
- Team work is challenging
- Always review working packages in the team
- Weekly meetings, even when we didn't had so much to discuss, are mandatory

- Important points have to be mentioned again and again to make sure everybody understood them
- How to express the current project status in a presentation
- Take deadlines seriously
- Electronic engineers are rare but most important
- Working independently on a project besides our studies
- To elaborate the details is 90% of the work
- Double check production orders
- Learned a lot about Murphy’s law

# 8 ABBREVIATIONS AND REFERENCES

## 8.1 Abbreviations

This section contains a list of all abbreviations used in the document.
Add abbreviations to the list below, as appropriate.
In version 5 of the SED (final version), delete unused abbreviations.

| | |
|---|---|
| AIT | Assembly, Integration and Test |
| asap | as soon as possible |
| BO | Bonn, DLR, German Space Agency |
| BR | Bremen, DLR Institute of Space Systems |
| CDR | Critical Design Review |
| COG | Centre of gravity |
| CRP | Campaign Requirement Plan |
| DLR | Deutsches Zentrum für Luft- und Raumfahrt |
| EAT | Experiment Acceptance Test |
| EAR | Experiment Acceptance Review |
| ECTS | European Credit Transfer System |
| EIT | Electrical Interface Test |
| EPM | Esrange Project Manager |
| 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 |
| FST | Flight Simulation Test |
| FRP | Flight Requirement Plan |
| FRR | Flight Readiness Review |
| GSE | Ground Support Equipment |
| HK | House Keeping |
| H/W | Hardware |
| ICD | Interface Control Document |
| I/F | Interface |
| IPR | Interim Progress Review |
| LO | Lift Off |
| LT | Local Time |
| LOS | Line of sight |
| Mbps | Mega Bits per second |
| MFH | Mission Flight Handbook |
| MORABA | Mobile Raketen Basis (DLR, EuroLaunch) |
| OP | Oberpfaffenhofen, DLR Center |

| | |
|---|---|
| PCB | Printed Circuit Board (electronic card) |
| PDR | Preliminary Design Review |
| PST | Payload System Test |
| SED | Student Experiment Documentation |
| SNSB | Swedish National Space Board |
| SODS | Start Of Data Storage |
| SOE | Start Of Experiment |
| STW | Student Training Week |
| S/W | Software |
| T | Time before and after launch noted with + or - |
| TBC | To be confirmed |
| TBD | To be determined |
| WBS | Work Breakdown Structure |
| AO | Atomic oxygen |
| O2 | Molecular oxygen |
| O3 | Ozone |
| d.n.y | Not clear at the state of development |

## 8.2 References

(Books, Paper, Proceedings)

[1] **Tino Schmiel:** Entwicklung, Weltraumqualifikation und erste Ergebnisse eines Sensorinstruments zur Messung von atomaren Sauerstoff im niedrigen Erdorbit. (2009)

[2] **S. Dikty, H. Schmidt, M. Weber, C. von Savigny and M. G. Mlynczak:** Daytime ozone and temperature variations in the mesosphere: a comparison between SABER observations and HAMMONIA model. (2010)

[3] **Interface for atmospheric models:** http://www.spenvis.oma.be/

[4] Database of **geomagnetic indicies** and **solar indicies** as input parameters for atmospheric models:http://www.swpc.noaa.gov/ftpmenu/indices/old_indices.html

[5] **KYOUNGSIK CHANG**Analysis of the flow and mass transfer processes for the incompressible flow past an open cavity with a laminar and a fully turbulent incoming boundary layer (2006)

[6] EuroLaunch: **BEXUS User Manual** (2012), **REXUS User Manual** (2012)

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

[8] SSC Esrange: **Esrange Safety Manual**, REA00-E60 , 23June 2010

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

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

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

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

# APPENDIX A – EXPERIMENT REVIEWS

# REXUS / BEXUS
## Experiment Preliminary Design Review

**Flight:** REXUS-15/16

**Payload Manager:** Mikael Inga/Alexander Schmidt

**Experiment:** MOXA

**Location:** DLR, Oberpfaffenhofen, Germany **Date:** 07 Feb 2013

### 1. Review Board members

| | |
|---|---|
| Andreas Stamminger (chair) | DLR – Mobile Rocket Base |
| Martin Siegl (minutes) | DLR – Institute of Space Systems |
| Hans Henricsson | SSC – Science Services |
| Mikael Inga | SSC – Science Services |
| Markus Pinzer | DLR – Mobile Rocket Base |
| Maria Roth | DLR – Space Administration |

### 2. Experiment Team members

Alexander Mager
Patrick Geigengack
Alexander Schultze

### 3. General Comments

- Presentation
    - Very good presentation with lots of good information.
    - Make sure to keep the time.
    - Please explain the meanings of acronyms used in the presentation.
- SED
    - Make sure your document looks good (e.g. “Fehler: Verweisquelle…”)
    - Some sections are omitted – fill all of them, if required with “N/A”.
    - Please accept our apologies for the wrong EuroLaunch-logo in the template. Please replace it on our behalf.

### 4. Panel Comments and Recommendations

- Requirements and constraints (SED chapter 2)
    - Very good functional requirements.
    - P.11.: Check the required accuracy.
    - Design requirement: Status messages shall be sent to the ground station.
- Mechanics (SED chapter 4.2.1 & 4.4)
    - **Use a 120mm or 150mm rocket module.**
    - **Consider rearranging the PCBs and electronics boxes.**
    - Feed-through cable hole in the bulkhead requested.
    - **Current hatch design is interesting – it can be implemented if it is tested**

**thoroughly and early on in the project (breadboarding/prototyping before the CDR, vibration tests).**
  - Simplification of hatch design can be considered if it is not required to close: Use of pyrocutters or melting wires in combination with springs is recommended in this case.
  - Pyrocutters of hatch could be controlled directly by the experiment (not by EuroLaunch).
  - Positioning of vibration sensor should not pose a problem as the rocket is spinning at 4Hz.
  - Pirani sensor is critical in terms of handling – consider a different, ruggedized sensor.

- Electronics and data management (SED chapter 4.2.2, 4.2.3, 4.5 & 4.7)
  - **Use of uplink (on ground) is mandatory.**
  - Use telecommands before LO, not signals (timeline before launch is not automated).
  - GPS data is only available after the flight.
  - More accurate definition of power budget required.
  - Carefully describe the use of the on-board charging system, if required.
  - Hatches might be required to open with a short time difference to avoid high overall currents.

- Thermal (SED chapter 4.2.4 & 4.6)
  - **Consider thermal design of the hatch.**

- Software (SED chapter 4.8)
  - Software section is well developed.
  - Communication protocol might have to be refined.

- Verification and testing (SED chapter 5)
  - Note that several tests will be scheduled prior to launch.
  - Consider the use of safe-arm devices.

- Safety and risk analysis (SED chapter 3.4)
  - Include project risks in the risk register.
  - DC/DC converter-related risk: a ranking of 4 is enough.
  - Risk of hot surface of sensor mitigated by low thermal capacity.
  - Hatch opening-related risk: Not critical to rocket (only experiment), ranking of 4 is sufficient.

- Launch and operations (SED chapter 6)
  - Power on of experiments is at 600s.
  - Consider how a hold in the countdown affects the experiment.
  - Change of sensors after testing and before roll-out is recommended.
  - **Extensive late access of rocket on the launcher is to be avoided by all means.**
  - If required, a foil covering the hatches could be pulled off the rocket skin before launch.
  - Consider flushing with nitrogen.

- Organisation, project planning & outreach (SED chapters 3.1, 3.2 & 3.3)
  - Table 6.1.1 is empty, please fill it.
  - “Fly your message”: Paper will get heavy, try to make it light and limit it.
  - Note that REXUS is not flying to outer space.
  - Include an atmospheric physicist in your team, as discussed during selection.
  - p.21: If most students stop by September this year, find additional team members.

**5. Internal Panel Discussion**

- PDR Result: PDR passed

- Next SED version due:

  - Version 2 two weeks before CDR.

# BEXUS
## Experiment Critical Design Review

**Flight:** REXUS 15/16

**Payload Manager:** Alexander Schmidt or Mikael Inga

**Experiment:** MOXA

**Location:** DLR Oberpfaffenhofen **Date:** 26th June 2013

**1. Review Board members**

| | |
|---|---|
| Mikael Inga | SSC Science Services |
| Martin Siegl (min.) | DLR Institute of Space Systems |
| Alexander Schmidt | DLR MORABA |
| Alex Kinnaird | ESA Policies Dept. – Education and Knowledge Management Office. |
| Natacha Callens | ESA Policies Dept. – Education and Knowledge Management Office. |
| Koen Debeule | ESA Technical Directorate – Mechanical Engineering Dept., Test Centre Div. |
| Andreas Stamminger | DLR MORABA |
| Markus Pinzer | DLR MORABA |
| Frank Hassenpflug | DLR MORABA |
| Maria Roth | DLR Space Administration |
| Mark Fittock (chair) | DLR Institute of Space Systems |

**2. Experiment Team members**

| | |
|---|---|
| Alexander Mager (TL) | Bastian Klose ??? |
| Daniel Becker | Susann Knapik |
| Patrick Geigengack | Alexander Schultze |

Formatiert: Englisch (USA)
Formatiert: Deutsch (Deutschland)
Formatiert: Deutsch (Deutschland)
Formatiert: Deutsch (Deutschland)
Formatiert: Deutsch (Deutschland)

**3. General Comments**

- Presentation
  - The presentation clarified several items.
  - Additional team members should stand with the team (not sit at the table).
  - Some subjects were treated in too much detail, some other (like electronics) haven't been covered enough.
  - Graph showing the timeline of flight is very good.

- SED
  - Some information is hard to find / not located in the standard places.
  - Use wording 'Exploded view', not 'Explosion view'.
  - Write CoG, LoS, etc. (lowercase 'o')
  - Document is not to be approved by Payload manager; should be approved by professor etc.
  - Document ID does not follow the naming convention.

**4. Panel Comments and Recommendations**

- Requirements and constraints (SED chapter 2)
  - F.2 - F.3 word 'during' is missing
  - Performance requirements are good.

- Design requirements have to be extended (power usage, weight, data rate, …)
- Shortest design requirements list among all CDR SEDs.

- Mechanics (SED chapter 4.2.1 & 4.4)
  - Considerable progress since the last review.
  - Mechanical interface information should be collected in one place in the SED.
  - **Hatch solution will still require improvement.**
  - **Consider using a linear actuator that would also allow closing of the hatch.???**
  - Solenoids may cause EMC problems (has been considered by the team).
  - **Consider the risk of desoldered joints due to hot gas in the hatch compartment.**
  - **Perfect solution would be to open and close the hatch again.**
  - Current hatch design requires an arm plug for testing.
  - **Beware of thermal expansion with regard to manufacturing tolerances in the hatch.**
  - **Air inlets: Should be discussed with EuroLaunch (CDR panel not sufficient)**
  - Steel wool poses risk of combustion in the module.

- Electronics and data management (SED chapter 4.2.2, 4.2.3, 4.5 & 4.7)
  - **Deliver detailed electronics schematics.**
  - Service module interface schematics not complete in the SED.
  - Capacitor: Should be included in the schematic, provide further details.
  - **Consider sparking due to high voltage. Perform tests accordingly.**
  - Test the vacuum compatibility of the capacitor.

- Thermal (SED chapter 4.2.4 & 4.6)
  - **Thermal section severely lacking.**
  - Provide details regarding the expected thermal environment, component ranges, etc.
  - Battery heating: Not required.

- Software (SED chapter 4.8)
  - **Software risks are missing in the risk register.**
  - Develop early, try not to wait for flight hardware to arrive.
  - Provide details on signals and timeline.

- Verification and testing (SED chapter 5)
  - Design requirement 3: Cannot be done by analysis.
  - Verify early and start with the easiest verification method. Verification should not rely on a single test in the end.
  - Most important tests (vibration/thermal) are covered correctly, but subsystem tests are missing.
  - Details tests to be performed on the hatch.

- Safety and risk analysis (SED chapter 3.4)
  - **Safety risk of steel wool combustion**
  - **Risk register: Rating of 5 partly unrealistic**
  - Risk ratings are not consistent.
  - List of risks really limited.
  - **Personnel, budget risks, and project risks are not included.**
  - **Hot surface risk not properly mitigated (e.g. safety covers etc.)**

- Launch and operations (SED chapter 6)
  - Oscilloscope requirement: Note that no development work can be performed at Esrange.

- Organisation, project planning & outreach (SED chapters 3.1, 3.2 & 3.3)
  - Availability of team members critical after the summer: serious problem
  - Webpage: Include sponsors
  - In a blog/news list, the newest entry should be on top.
  - Clarify the meaning of the word “start” (should be launch).
  - Include the Final Report in the project plan.
  - Commitment (work hour) percentages have to be properly defined.
  - Include a sponsorship column in the budget overview.

Formatiert: Schriftartfarbe: Hellblau

Formatiert: Schriftartfarbe: Hellblau

- Provide a complete budget.
- Include all team members, also on the Facebook picture.
- Fly your message will be 2-3 A4 pages.
- Appendix B: add more information, add link to PDF copies.

**5. Internal Panel Discussion**

- Summary of main actions for the experiment team (see bold print)

- CDR Result: pass / conditional pass / fail
  - **Conditional pass** under the prerequisite that a new version of the CDR SED is submitted within 4 weeks, addressing all above points.

- Next SED version due
  - Resubmission of SED within 4 weeks

# APPENDIX B – OUTREACH AND MEDIA COVERAGE

## LIST OF APPEARING ARTICLES:

- HI:TECH CAMPUS
- atp edition
- Die Welt
- TU Dresden
    1. Main Homepage
    2. Hompage of mechanical engineering
    3. Twitter
    4. Facebook
- Sachsische Zeitung
- Kanal 8
- Dresdner Neuste Nachrichten
- Bild online
- Unijournal
- Freie Presse
- CAZ
- LVZ online
- Mein Infodienst

## INTERVIEWS:

- MDR Figaro
- Campusradio
  http://campusradiodresden.de/2013/01/31/vom-horsaal-ins-all/#more-5740

## MEDIA:

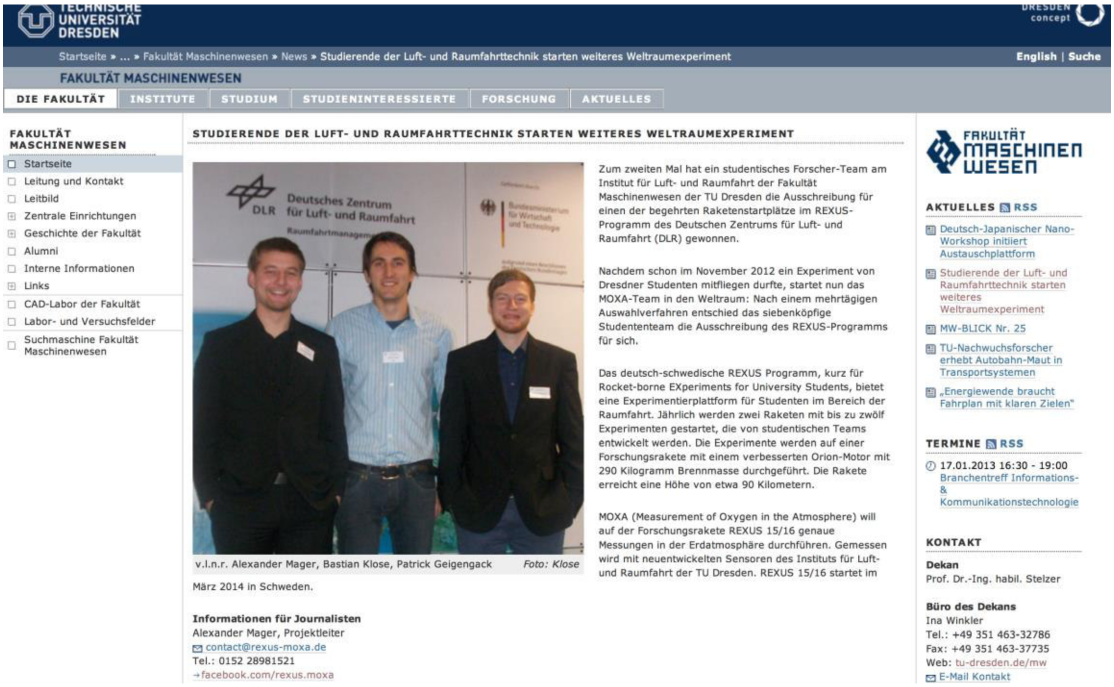
- Website: www.rexus-moxa.de
- Facebook: www.facebook.com/rexus.moxa

## Other:

- Buttons
- Posters
- Flyer
- Send your Message to space


**fig. 54: MOXA Flyer**

**fig. 55: MOXA Buttons**



TECHNISCHE UNIVERSITÄT DRESDEN

Startseite » ... » Fakultät Maschinenwesen » News » Studierende der Luft- und Raumfahrttechnik starten weiteres Weltraumexperiment — English | Suche

FAKULTÄT MASCHINENWESEN

DIE FAKULTÄT | INSTITUTE | STUDIUM | STUDIENINTERESSIERTE | FORSCHUNG | AKTUELLES

**FAKULTÄT MASCHINENWESEN**

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- Labor- und Versuchsfelder
- Suchmaschine Fakultät Maschinenwesen

**STUDIERENDE DER LUFT- UND RAUMFAHRTTECHNIK STARTEN WEITERES WELTRAUMEXPERIMENT**



v.l.n.r. Alexander Mager, Bastian Klose, Patrick Geigengack *Foto: Klose*

Zum zweiten Mal hat ein studentisches Forscher-Team am Institut für Luft- und Raumfahrt der Fakultät Maschinenwesen der TU Dresden die Ausschreibung für einen der begehrten Raketenstartplätze im REXUS-Programm des Deutschen Zentrums für Luft- und Raumfahrt (DLR) gewonnen.

Nachdem schon im November 2012 ein Experiment von Dresdner Studenten mitfliegen durfte, startet nun das MOXA-Team in den Weltraum: Nach einem mehrtägigen Auswahlverfahren entschied das siebenköpfige Studententeam die Ausschreibung des REXUS-Programms für sich.

Das deutsch-schwedische REXUS Programm, kurz für Rocket-borne EXperiments for University Students, bietet eine Experimentierplattform für Studenten im Bereich der Raumfahrt. Jährlich werden zwei Raketen mit bis zu zwölf Experimenten gestartet, die von studentischen Teams entwickelt werden. Die Experimente werden auf einer Forschungsrakete mit einem verbesserten Orion-Motor mit 290 Kilogramm Brennmasse durchgeführt. Die Rakete erreicht eine Höhe von etwa 90 Kilometern.

MOXA (Measurement of Oxygen in the Atmosphere) will auf der Forschungsrakete REXUS 15/16 genaue Messungen in der Erdatmosphäre durchführen. Gemessen wird mit neuentwickelten Sensoren des Instituts für Luft- und Raumfahrt der TU Dresden. REXUS 15/16 startet im März 2014 in Schweden.

**Informationen für Journalisten**
Alexander Mager, Projektleiter
contact@rexus-moxa.de
Tel.: 0152 28981521
→facebook.com/rexus.moxa

FAKULTÄT MASCHINEN WESEN

**AKTUELLES** RSS

- Deutsch-Japanischer Nano-Workshop initiiert Austauschplattform
- Studierende der Luft- und Raumfahrttechnik starten weiteres Weltraumexperiment
- MW-BLICK Nr. 25
- TU-Nachwuchsforscher erhebt Autobahn-Maut in Transportsystemen
- „Energiewende braucht Fahrplan mit klaren Zielen"

**TERMINE** RSS

17.01.2013 16:30 - 19:00
Branchentreff Informations- & Kommunikationstechnologie

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E-Mail Kontakt

**fig. 56: article on TU Dresden homepage**

## APPENDIX C – ADDITIONAL TECHNICAL INFORMATION

see PDF: SED 2.2 APPENDIX C

# APPENDIX D – REQUEST FOR WAIVERS

# APPENDIX E – VIBRATION TEST

# REXUS-MOXA

## Vibration Test Report

# Table of contens

# Outline

## Introduction

This test report involves guidelines, organisation, execution and analysis to qualificate the REXUS-MOXA experiment. The vibration test was executed at the institution for light construction and plastics engeneering of the technical university of Dresden.

## Test objective

The aim of the vibration test is the safety case and the functional demonstration of the installation of the module and of the experimental set-up in direction of the X-, Y-, Z-axis with given vibration stain from the current REXUS User Manual.

Furthermore multiple tests with different experimental set-ups were executed on the sensitive Pirani-sensor.

Following tests were executed:

- Sinus eigen frequency search before Random conducted on each axis
- Random strain test conducted on each axis
- Sinus eigen frequency search after Random conducted in each axis
- Eigen frequency search with differently damped Pirani-Sensors
- Random tests in Z-direction with instantly applied full load as flight simulation
- Function tests of the mechanics

# Documents

## Important points for the execution of the tests and strain levels

- Aktuelles REXUS User Manual;

Document ID: RX_UserManual_v7-11_08Jan14.doc

## Data sheets of the test equipment

- Shaker-Systemdescription;

Document ID: 3000241D-V8-V3_System.pdf

- Shaker-Softwaredescription;

Document ID: Dactron_Software_Beschreibung.pdf

- PCB acceleration sensor;

Document ID: PCB-353B03.pdf

- PCB acceleration sensor;

Document ID: PCB-M353B18.pdf

- Brüel&Kjaer 3-Axis acceleration sensor;

Documet ID: 4504A_triaxial_CCLD_accelerometer.pdf

# Test organisation

The vibration test was executed at the institution of light construction and plastics engineering (ILK) in Dresden-Johannstadt. The necessary test equipment with software, sensor acceleration and required tools was provided. Furthermore the test adapter, which is a second little REXUS-module with a bulkhead for the test period, was provided from ZARM Bremen. The tests take 3 days and was executed on the 7th of January and 13$^{th}$ of January. The interposition occurred by Dr. Tino Schmiel and Paul Rossman from the institution of aerospace and space flight at the ILK.

## Cooperators

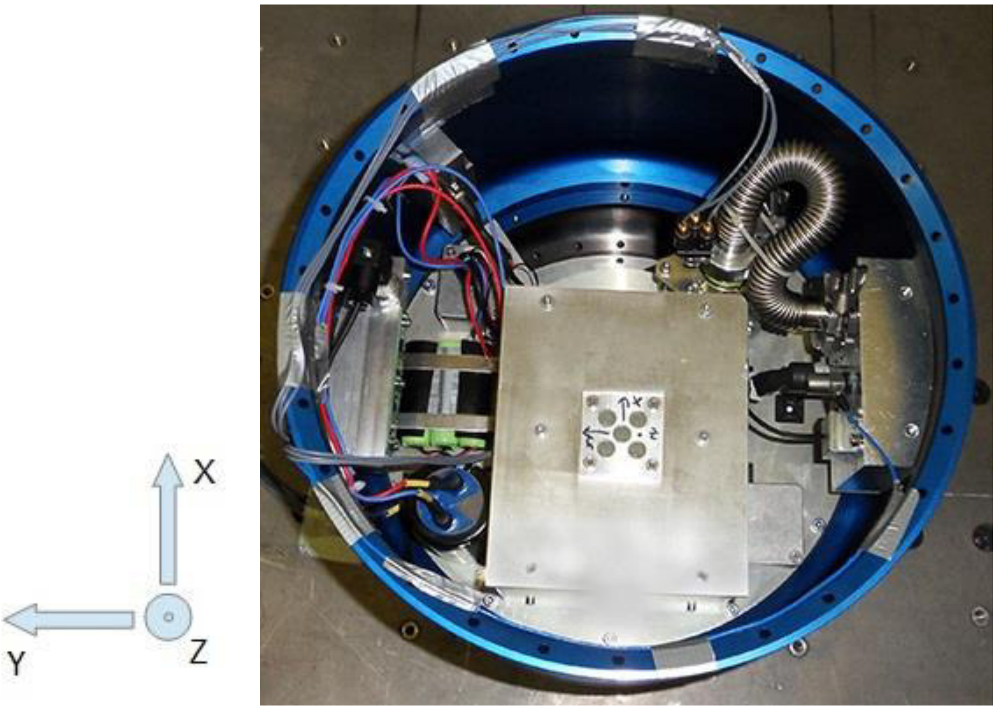
- Rainer Saalfeld, test bed leader of the ILK
- Alexander Mager, Team leader
- Nathanael Warth, Responsible for the test and mechanics
- Max Oswald, Mechanics
- Sebastian Weixler, Mechanics

## Ambience conditions

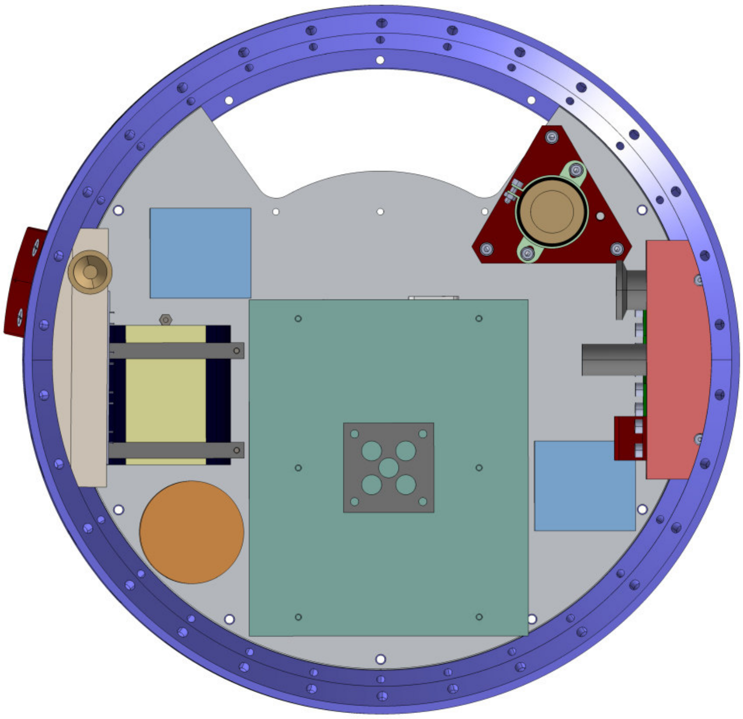
During the tests the temperature was around 20°C, the relative humidity 55 ±10% at normal air pressure. The shaker stood in a big dead room with aeration. In each case a hydraulic pump was engaging to achieve a constant operating temperature.

## Test object

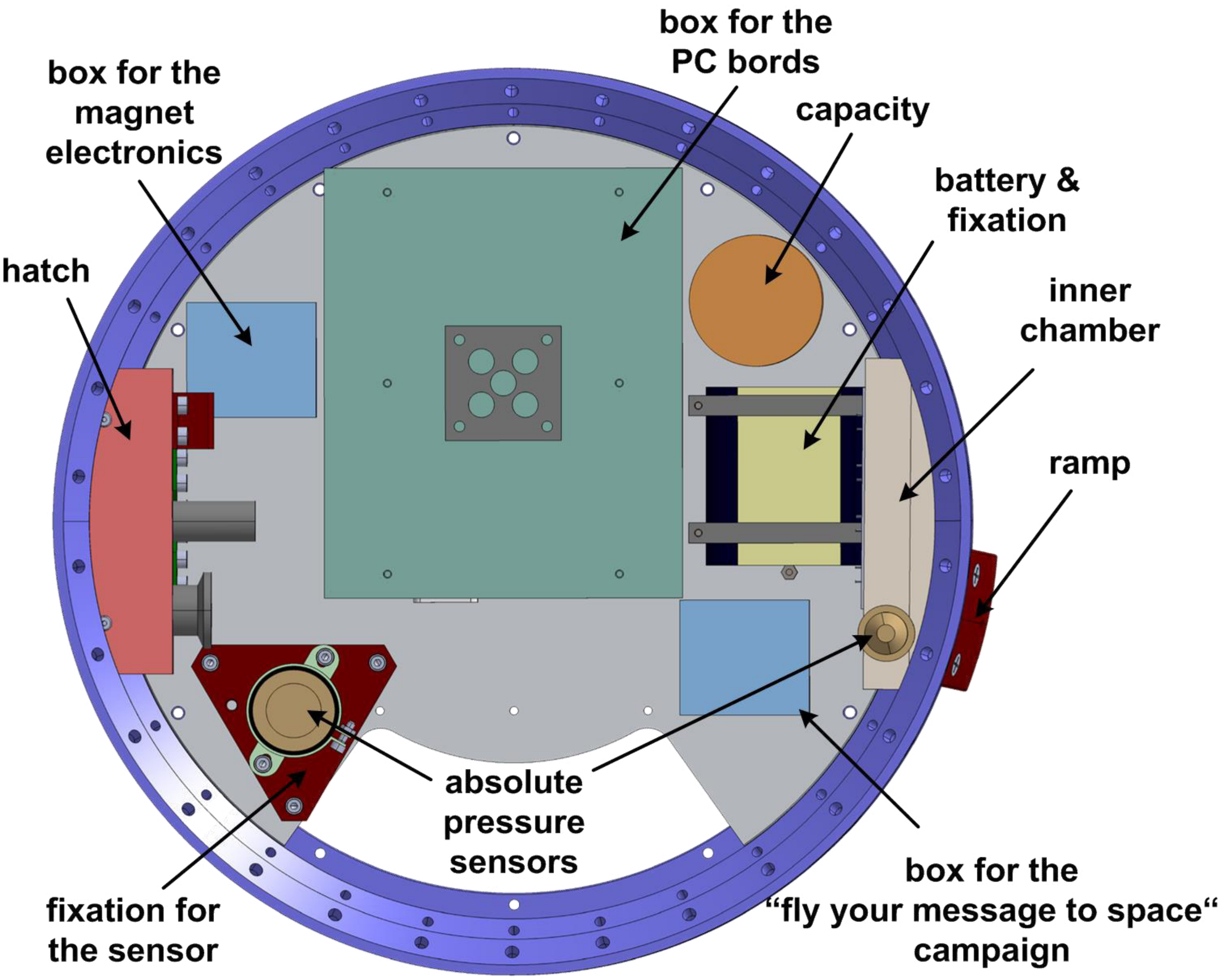
The complete module was tested in the experiment organization which is complete for the flight. In order to the test it should be simulate a realistic behavior as possible. Except the boards, the oxide sensors and the skirt battery weren’t used in this test. Boards and skirt batteries were replaced by dummies with an approximate similar mass and were built in like in the flight configuration. The oxide sensors could be neglected because of the low mass and the retain assembly.




*Picture 1: Test arrangement, X-Axis*



*Picture 2: Experiment organisation, X-Axis*




***Picture 3: Experiment organisation with components description, X-Axis***

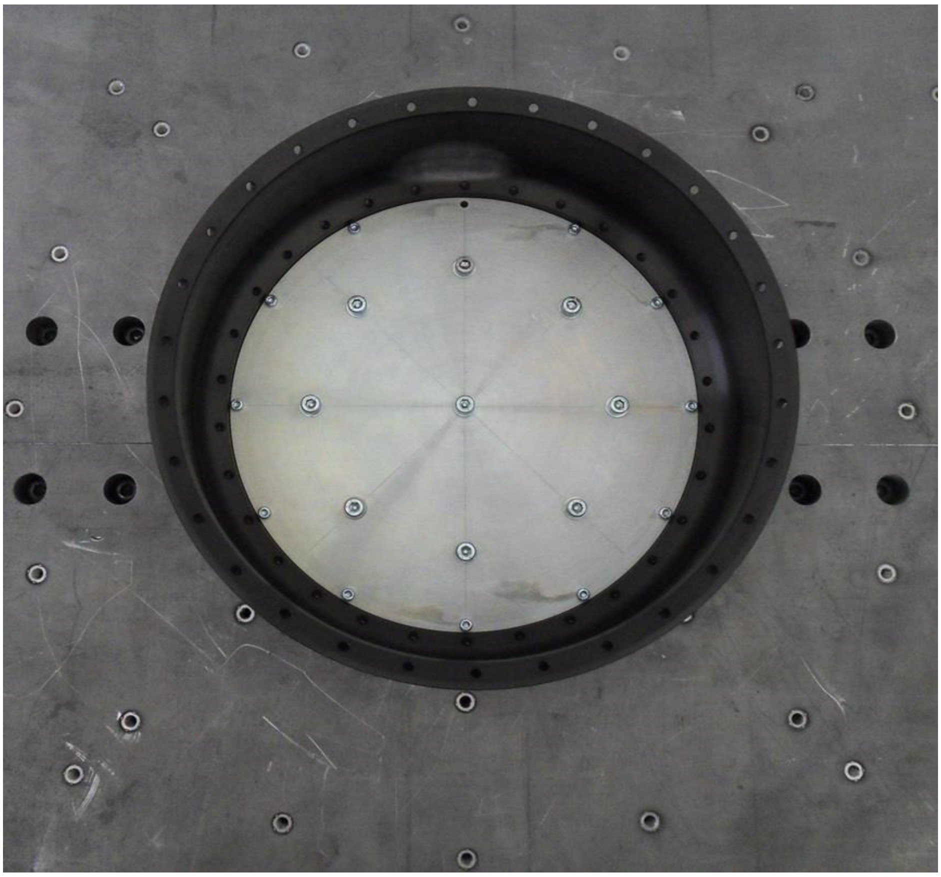
# Test configuration

## Test equipment

| Nr.: | Equipment | Manufacturer |
|---|---|---|
| 1 | 56kN Shaker System V8-440 | LDS Dactron |
| 2 | Power amplifier SPA56K | LDS Dactron |
| 3 | Vibration adapter | Deutsches Zentrum für Luft- und Raumfahrt |
| 4 | Acceleration sensor | PCB, Brüel&Kjaer |

## Adapter of vibration

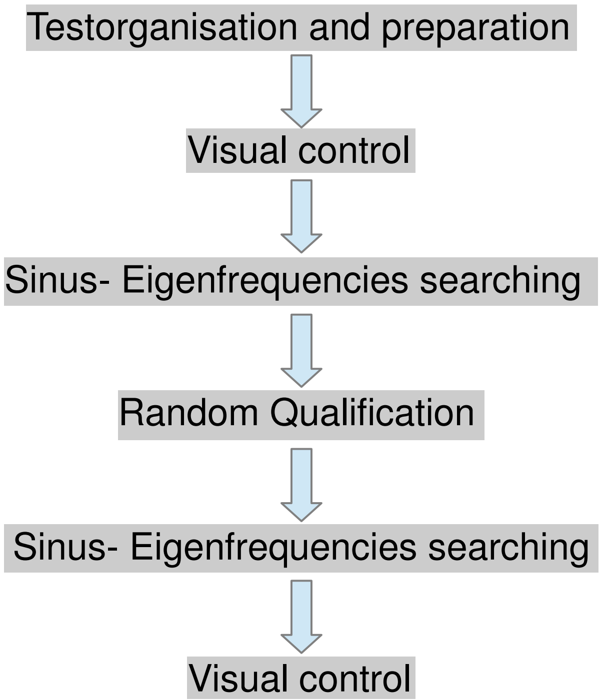
To realize a facsimile test behavior as possible the module which should be tested was screwed on a second, empty REXUS-module. Thereby it was achieved an almost original fixing. The lower empty module was screwed over his own bulkhead (ground) with the vibration desk.



***Picture 4: Vibration adapter on the vibration desk***

## Test process

The test process for the X, Y, and Z-Axis was in each time as follows:




## Visual control

During the visual control the components, cable management and all boltings were checked before and after every test run for subsidence, damage and bulking blasting phenomenon.

## Test requirement

The vibration test for the module is passed if following points are given:

- For each axis (X, Y and Z) the test was executed according to the test run and the particular results logged
- The defined test values which are fixed in the tables 6.4.1 and 6.4.2 were achieved in all axis directions
- The eigen frequency progress before and after the particular random tests accord approximately and show:
    - Relative to the resonance frequency discrepancies are less than ± 5%
    - Relative to the strain at resonance frequency displacement is less than ± 25%
- The visual control after every test run doesn't show hardware damages or other damages

# Test structure and sensor configuration

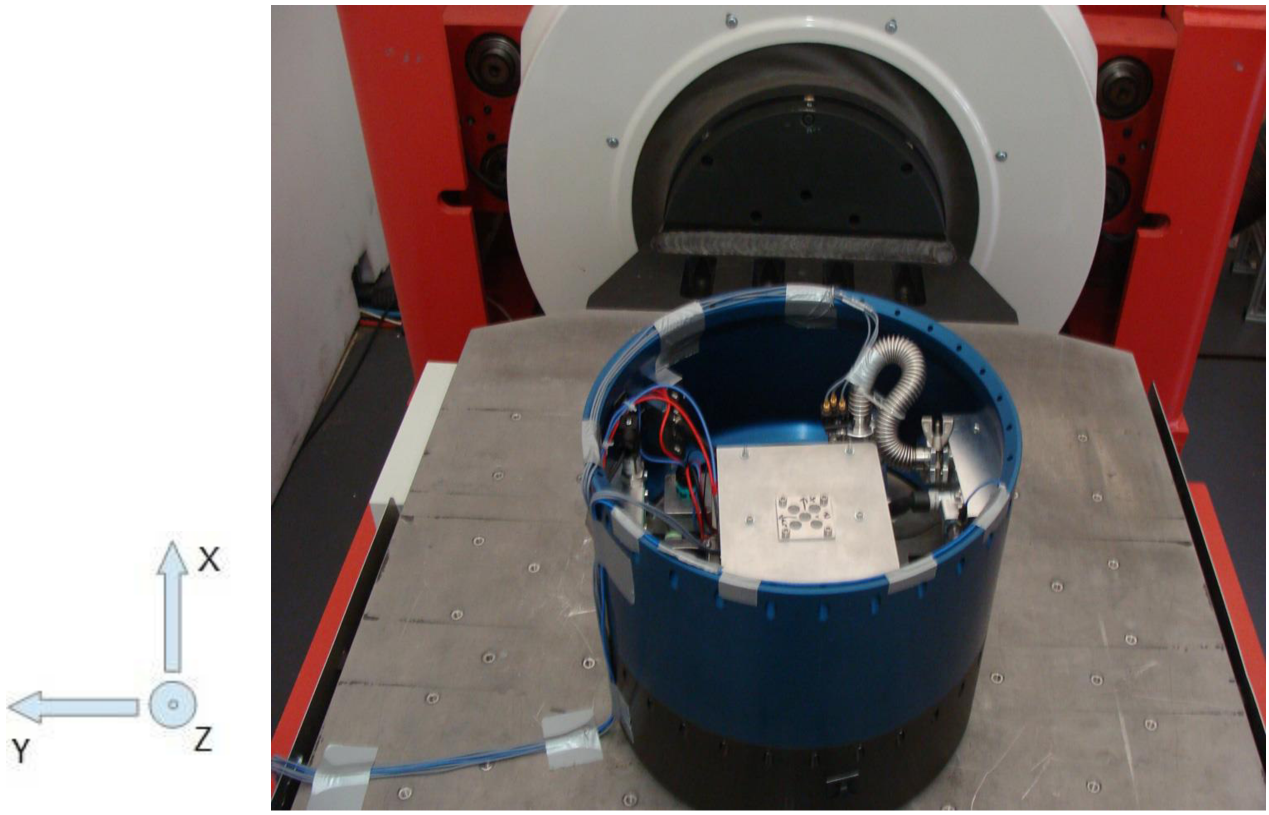
## Test structure on the shaker

The module was mounted on a test adapter with 30 M5x16 cheese head screws with hexagon socket. The clamping torque betrug 5,4 Nm (maximal allowed 6,5Nm).

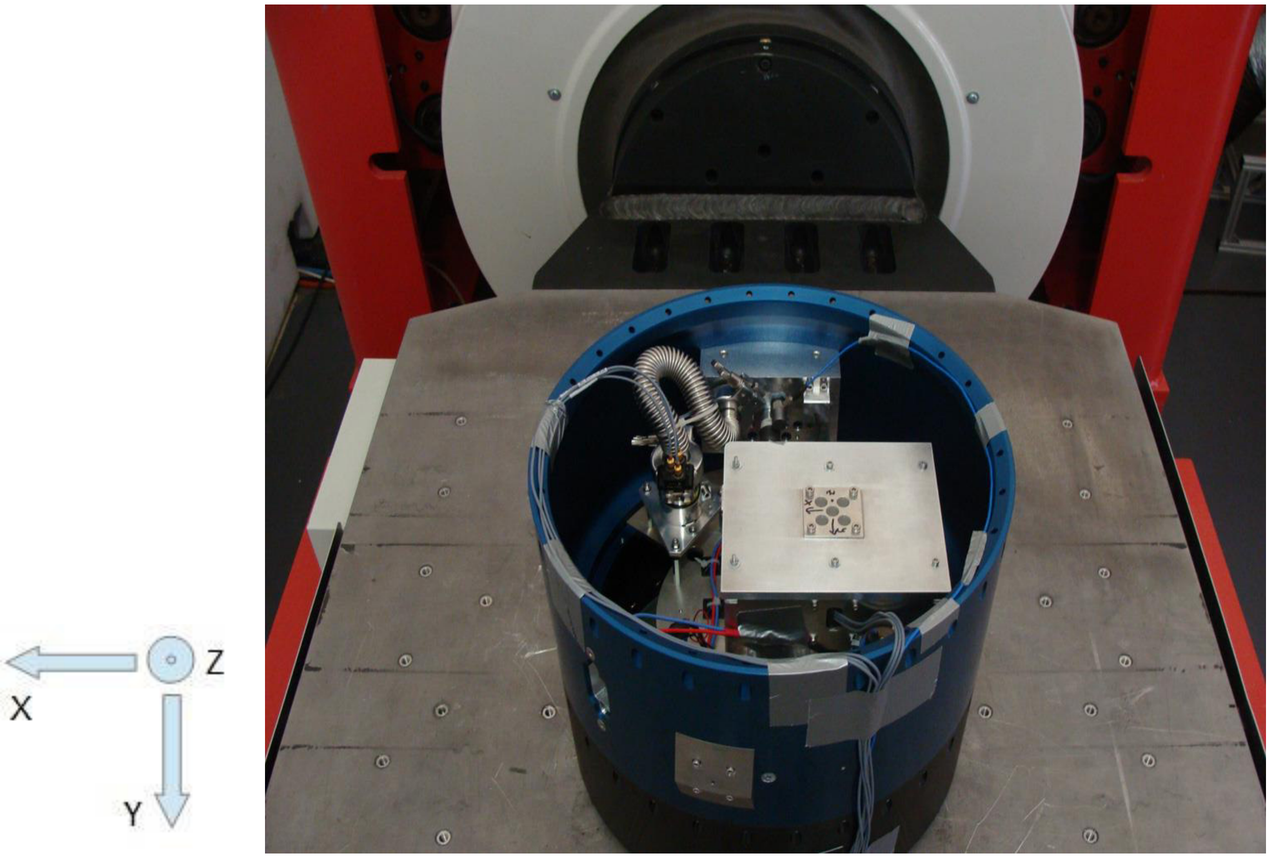
The test adapter was screwed on the vibration desk with 9 M8 cheese head screws with hexagon socket and 24 Nm of clamping torque for the X- and Y-tests. All screws were fixed with a dynamometric key.

Between the bulkhead of the adapter and the vibration desk is a distance of 8mm. That's why around every  9 screws was laid a big M10 screw nut (height 7,8mm) to beware a bending and so a damage of the bulkhead and of the adapter module. The 30 cheese head screws were released for the conversion from the X- to the Y-axis. Then the test module was turned by 90° to the left and stabilized again.

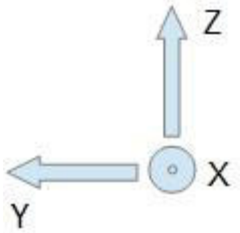
The swing unit was disconnected with the vibration test for the Z-axis test and was straighten up from the horizontal to the vertical. The adapter with test module was screwed directly on the swing unit for the Z-axis. The reason for this procedure is that the swing unit uses the same mount as the vibration desk.

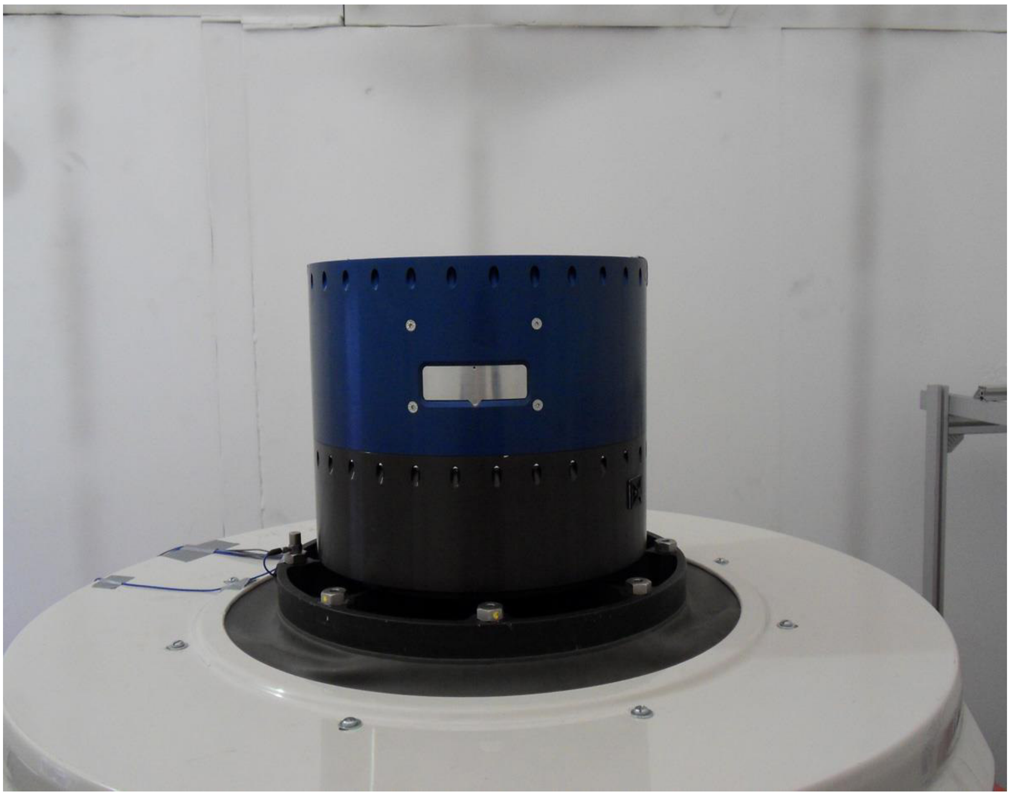



***Picture 5: Test organisation, X-Axis***




***Picture 6: Test organisation, Y-Axis***



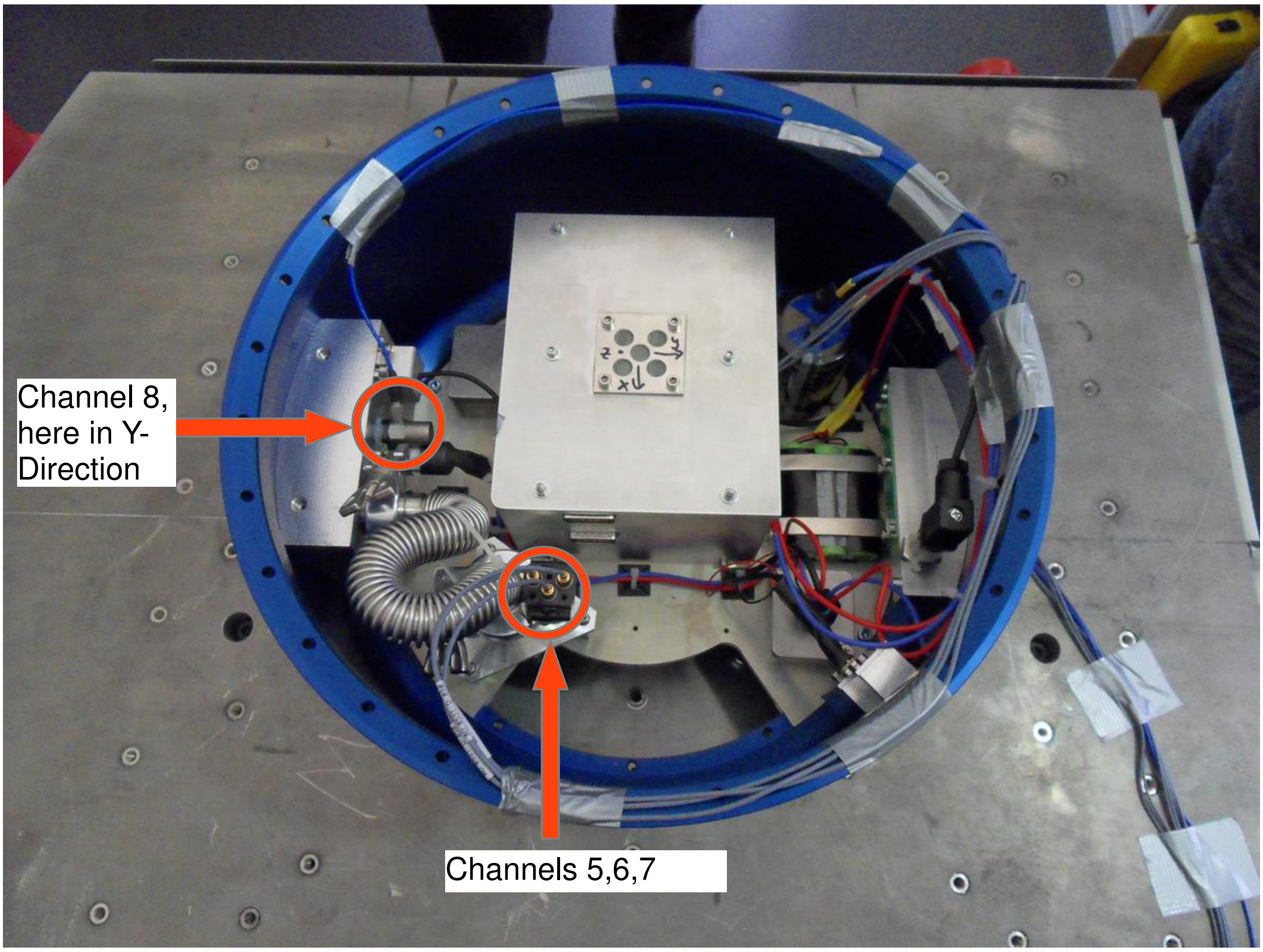
***Picture 7: Test organisation, Z-Axis***

## Monitoring of the incoming power flux

The incoming power was measured for each test by an acceleration sensor (type PCB-353B03). The sensor was mounted on the Hatch close to the module always in the direction of the axis which was under investigation. The Hatch perfectly suites for this application due to it’s rigid fixation.

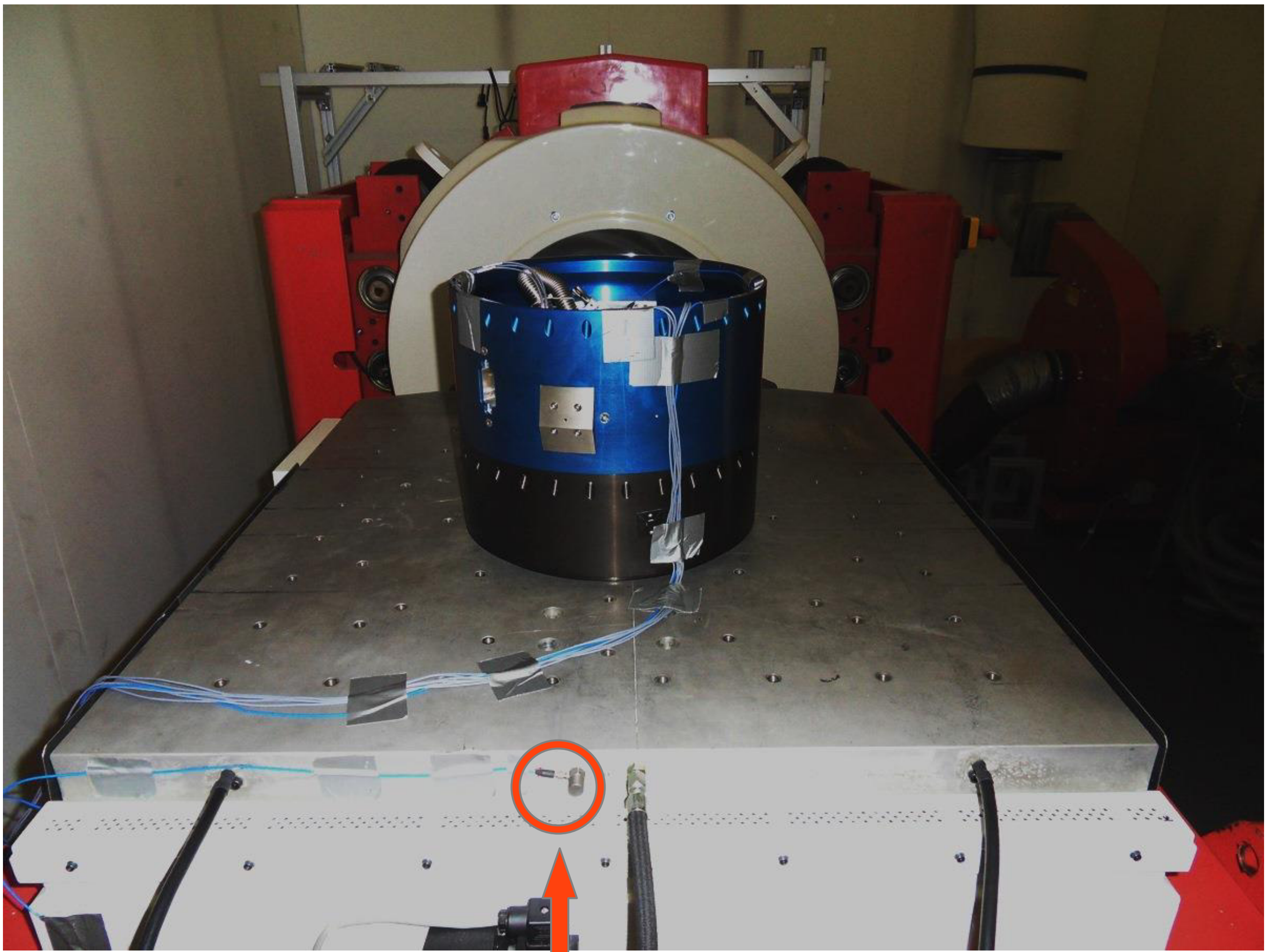
## Sensors, Positions, Channeloccupation und Fixing

| Sensor Nr. | Type | Measuring direction | Channel | Position, Function | Fixing |
|---|---|---|---|---|---|
| A-1 | PCB-353B03 | Uniaxial | 1 | Vibration desk, oscillation bin; in each direction of excitation, Referencesensor for the power output | Screwed |
| M-1 | Brüel&Kjaer 4505A triaxial CCLD | X,Y,Z | 2(X),3(Y), 4(Z) | In the electronic box, of the third platine from below | Sticked (hot glue) |
| M-2 | Brüel&Kjaer 4505A triaxial CCLD | X,Y,Z | 5(X),6(Y), 7(Z) | On the hose clamp of the Pirani-Sensors | Sticked (hot glue) |
| R-1 | PCB-353B03 | Uniaxial | 8 | Hatch, in each direction of excitation, referencesensor for the power input | Sticked (wax) |




***Picture 8: Sensor arrangement, X-Axis***

Cable feedthrough Channels 2,3,4; The 3-Axis sensor is arranged in the box



***Picture 9: Sensor arrangement referencesensor***

Channel 1,
Referencesensor in

## Testlevels

The test procedure and the test levels were set and defined on the bases of intense discussions and consultations with Mr Dieter Bischoff (ZARM Bremen) prior to the execution of the experiments.

### Eigenfrequencies searching

| Sinus Eigenfrequencies searching | | |
|---|---|---|
| Axis | Frequency spectrum | Input level |
| X,Y | 5-2000 Hz | 0,25g |
| Z | 5-2000 Hz | 0,5g |
| Sweep Rate: | 2 Oct/min | |

### Randomstrain

| Random | | |
|---|---|---|
| Axis | Frequency spectrum | Input Level |
| All Axis | 20-2000 Hz | 6,34gRMS - 0,018$g^2$/Hz |
| Duration:<br>%-Input: | 10s/10s/10s/60s<br>25%/50%/75%/100% | |

# Results

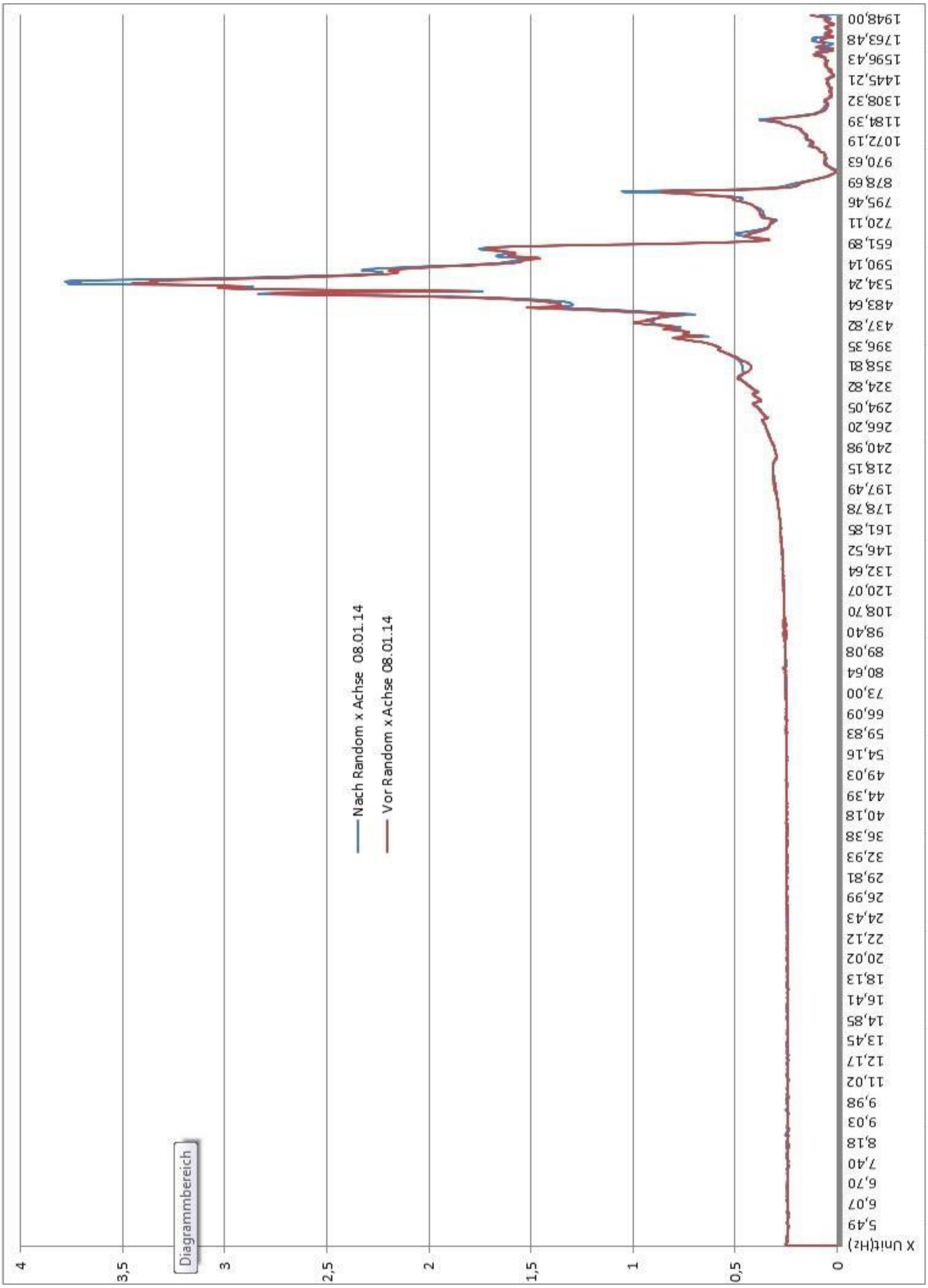
In the following subsection the eigen frequencies of the respective axis are given. Concerning the structural investigations, only eigen frequencies lower than 1000 Hz are of interest. The data of measurements conducted under higher frequencies would not be very precise due to smaller amplitudes. Because of this fact the software finds eigen frequencies which differ extremely from measurement to measurement. Concerning these findings the graphs, which plot the eigen frequency of the two measurements, are of significance.

## X-Axis

After the first test measurements of the shaker were conducted, the scan for the eigen frequency of the x axis from 5 to 2000Hz with 0.25g was started. Concerning the structural analysis the first three eigen frequencies are of interest:

| Time | Eigen frequency before Random | Eigen frequency after Random |
|---|---|---|
| 00:00:02 | Start at 5,00 Hz | Start at 5,00 Hz |
| 00:03:26 | 514,30 Hz | 512,79 Hz |
| 00:03:29 | 538,95 Hz | 545,30 Hz |
| 00:03:47 | 840,94 Hz | 840,94 Hz |
| 00:03:51 | 926,22 Hz | - |
| 00:04:02 | 1194,83 Hz | - |
| 00:04:07 | 1312,15 Hz | - |
| 00:04:09 | 1379,09 Hz | - |
| 00:04:11 | 1428,39 Hz | - |
| 00:04:13 | 1518,94 Hz | - |
| 00:04:16 | 1643,85 Hz | - |

We assume a very stiff constriction of our module due to the fact that the eigen frequencies are found at 514 and 539 Hertz. The eigen frequency plots before and after the Randomtest in direction of the x-axis are within the range of errors identical. The eigen frequencies show only small shifts and are position within the rage of errors of ± 5%. Also the strain of the eigen frequencies are within the range of errors of ±25%.

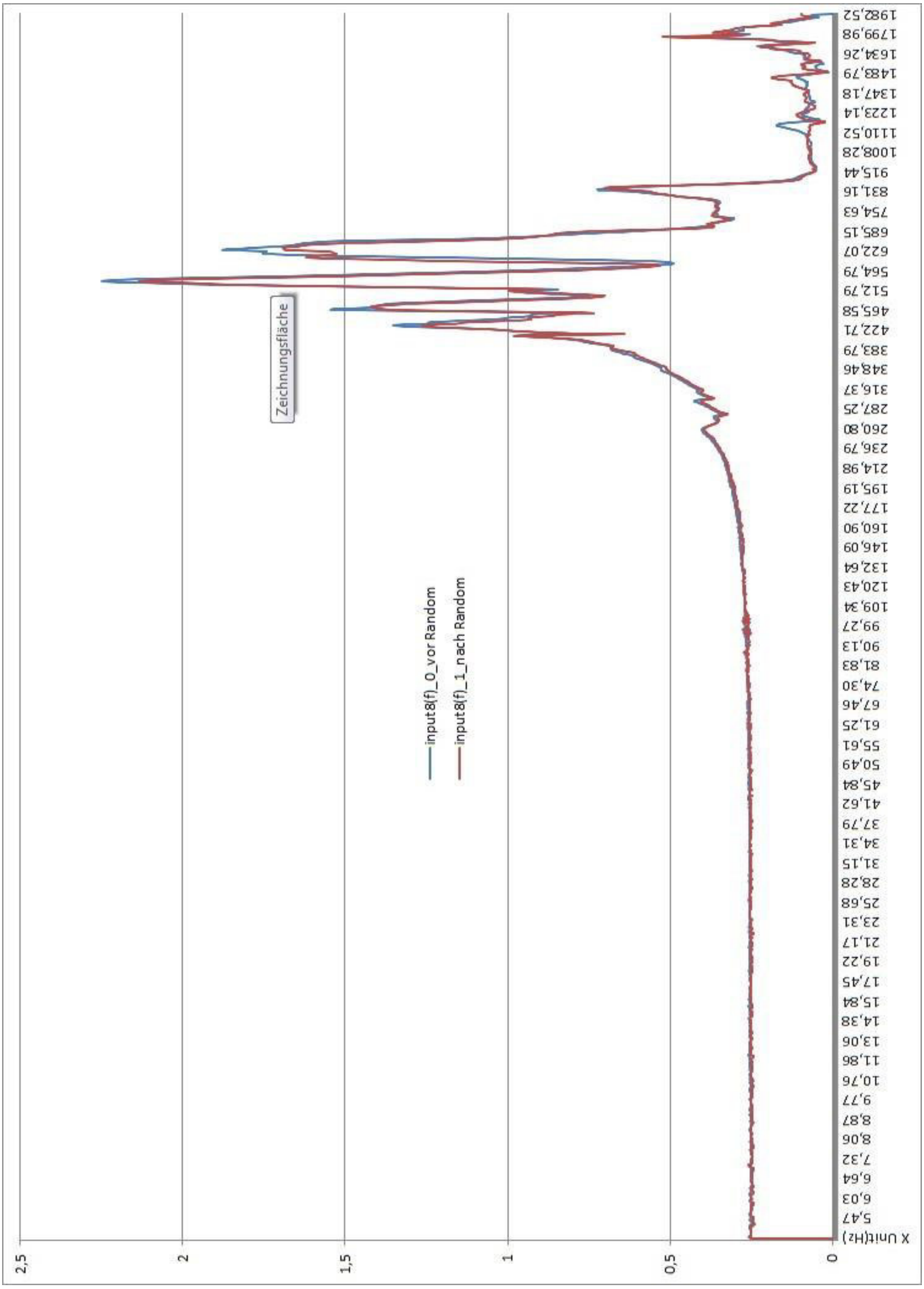

Nach Random x Achse 08.01.14
Vor Random x Achse 08.01.14
Diagrammbereich
X Unit(Hz)

## Y-Axis

The search of the eigen frequency using 0.25g in the range of 5–2000 Hz in direction of the y-axis leads to the following results:

| Time | Eigen frequency before Random | Eigen frequency after Random |
|---|---|---|
| 00:00:02 | Start at 5,00 Hz | Start at 5,00 Hz |
| 00:03:16 | 414,14 Hz | 414,14 Hz |
| 00:03:21 | 435,17 Hz | 435,27Hz |
| 00:03:24 | 471,06 Hz | 469,69 Hz |
| 00:03:29 | 538,95 Hz | 540,53 Hz |
| 00:03:33 | 605,90 Hz | 609,45 Hz |
| 00:03:36 | 629,39 Hz | 627,55 Hz |
| 00:03:48 | 843,41 Hz | 850,85 Hz |
| 00:04:02 | 1146,86 Hz | - |
| 00:04:04 | 1230,32 Hz | - |
| 00:04:07 | 1312,15 Hz | - |

Also in this case the eigen frequency is quite high. The comparison of the eigen frequency shows good match with the eigen frequencies gained under strain.

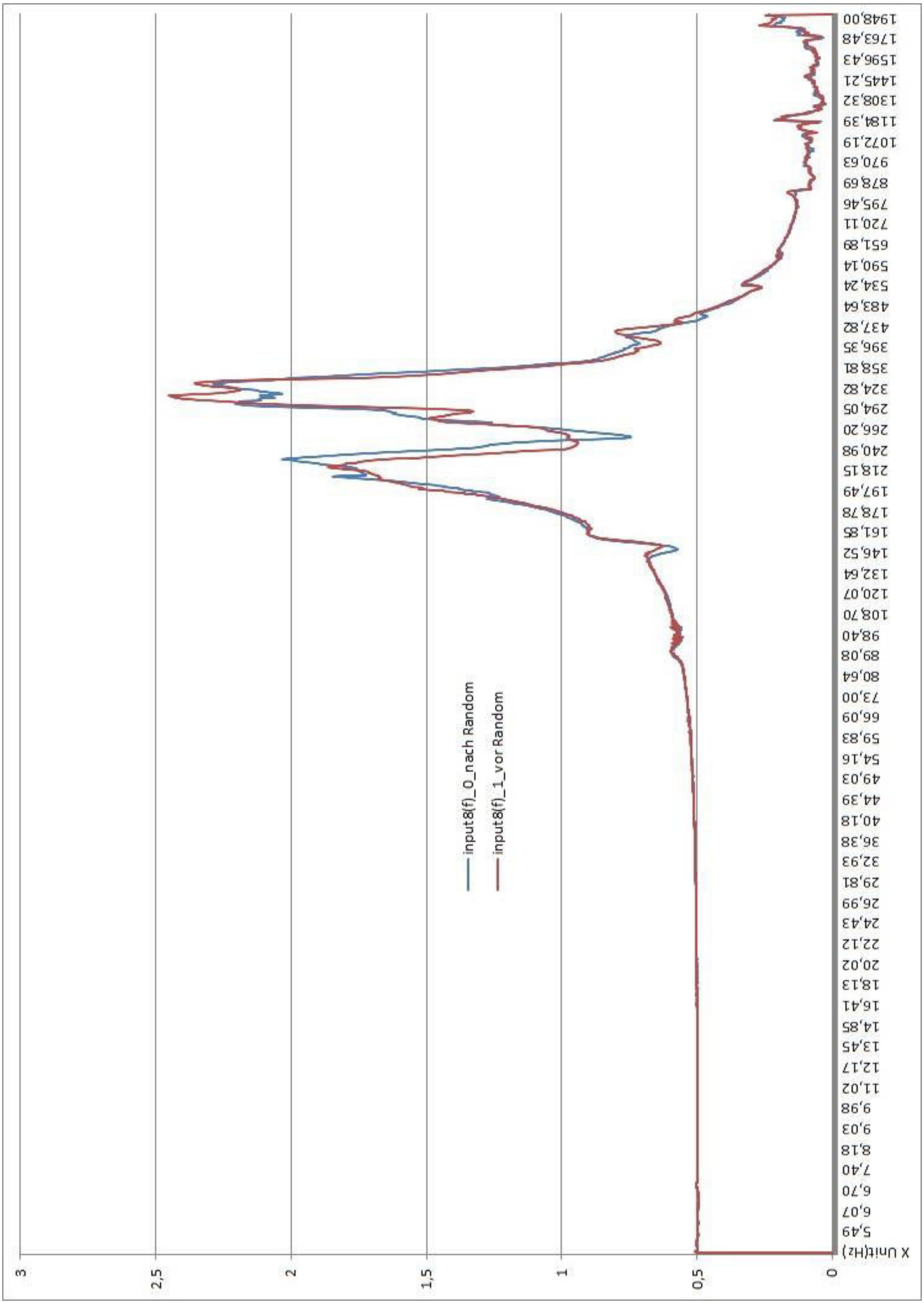

2,5
2
1,5
1
0,5
0
X Unit(Hz)
5,47
6,03
6,64
7,32
8,06
8,87
9,77
10,76
11,86
13,06
14,38
15,84
17,45
19,22
21,17
23,31
25,68
28,28
31,15
34,31
37,79
41,62
45,84
50,49
55,61
61,25
67,46
74,30
81,83
90,13
99,27
109,34
120,43
132,64
146,09
160,90
177,22
195,19
214,98
236,79
260,80
287,25
316,37
348,46
383,79
422,71
465,58
512,79
564,79
622,07
685,15
754,63
831,16
915,44
1008,28
1110,52
1223,14
1347,18
1483,79
1634,26
1799,98
1982,52
Zeichnungsfläche
input8(f)_0_vor Random
input8(f)_1_nach Random

## Z-Axis

After the conversion of the shaker for the tests in direction of the Z-axis, eigen frequency test runs were conducted. Due to the fact the first test runs couldn't be executed over the hole frequency spectrum (section 8.1), the strain was changed from 0.25 to 0.5g, still also in this case the test was conducted from 5 to 2000 Hz. The following eigen frequencies were found:

| Time | Eigen frequency Before | Eigen frequency After |
|---|---|---|
| 00:00:02 | Start at 5,00 Hz | Start at 5,00 Hz |
| 00:02:35 | 223,32 Hz | 231,98 Hz |
| 00:03:09 | 314,53 Hz | 331,54 Hz |
| 00:03:56 | 1156,97 Hz | - |
| 00:04:00 | 1198,33 Hz | - |
| 00:04:02 | 1278,04 Hz | - |
| 00:04:03 | 1304,49 Hz | - |
| 00:04:06 | 1483,79 Hz | - |
| 00:04:14 | 1753,19 Hz | - |
| 00:04:15 | 1886,28 Hz | - |

During comparison of the eigen frequency curves before and after the randomtest we noticed that the graves are similar but they are shifts in the values of the eigen frequencies. These values are within the range of ±5% and details are shown in section 8.2.


input8(f)_0_nach Random
input8(f)_1_vor Random
X Unit(Hz)
5,49
6,07
6,70
7,40
8,18
9,03
9,98
11,02
12,17
13,45
14,85
16,41
18,13
20,02
22,12
24,43
26,99
29,81
32,93
36,38
40,18
44,39
49,03
54,16
59,83
66,09
73,00
80,64
89,08
98,40
108,70
120,07
132,64
146,52
161,85
178,78
197,49
218,15
240,98
266,20
294,05
324,82
358,81
396,35
437,82
483,64
534,24
590,14
651,89
720,11
795,46
878,69
970,63
1072,19
1184,39
1308,32
1445,21
1596,43
1763,48
1948,00
0
0,5
1
1,5
2
2,5
3

# Evaluation on the test measurements and discussion

## Z-Axis – Finding the eigen frequency using 0,25g

As mentioned in Section 7.3, during the test measurement, which should determine the eigen frequency in the direction of the Z-axis, a measurement error occurred. The shaker did start the search for the eigen frequency but stopped the measurement to early at 1500 Hz.

After an intense searching for errors and multiple restarts of the measurement using different measurement parameters, it was obvious that the problem in not solvable in easy manner. The only possibility to enable the measurement of the frequency response of the device to 2000 Hz is to increase the strain level. Alternatively we wouldn't gain any information in the frequency range of 1500 to 2000 Hz. The fact that all axis had been investigated in the range of 5 to 2000 Hz and no problems for the other measurements were found, the decision was made to increase the strain level to 0,5 gramm.

## Comparison of eigen frequencies

Due to the fact that the shifts of the eigen frequency of the X and Y-axis had been very small it can be assumed that no measurement errors concerning the stiffness occurred. The visual control and the check during demounting showed no measurement errors. The visual control after the test of the z-axis measurement showed no signs of stability problems. The only thing which was suspicious was a rattling noise occurring during the last tests. During the following demounting we noticed that the screws of the cap of the electronic box became loose and these screws are responsible for the irregular noise and for the displacement of the graphs.

But this isn't a problem for the experiment, because all screws are secured before the final mounting with screw locking. Furthermore the screws of the electronic box were already strained by many tests in X- and Y-direction before and due to this fact loosening occurred.

An unwanted loosening of the screw connection during the flight can be excluded if the mounting with done properly and screw locking is used. Therefore the necessary safety concerning the stability of our module is given.

## Opening of the Hatch

The independent opening of the Hatch during the Randomtest illustrates the problem which is multiple appeared. For this the interlocking system was optimized between the tests. We can conclude that this leads to an extension of the time which it takes to until it opens by itself. This does not lead to a solution of the problem.

If the Hatch is opened to early, the sensors can get contaminated or damaged due to particle from the rocket or air turbulences. The Randomtest was executed without a power enhancement but with maximal vibration power of 0,018 $g^2/Hz$ and with duration of 30 seconds to analyze the behavior of the module during the flight. The tests show that the hatchway opens itself around 3-5 seconds after start.
But the rotation of the rocket knits against this effect. The centrifugal force which results of this effect knits in the same axis like the bolt of the electromagnet of the closing device. Due to differences in storage life no defined vibration profile was found and therefore also the turn-on behavior of each motor is different. The position of the MOXA experiment on the rocket also decreases the impact of a to early opened hatch. Only the experiment of the team HORACE is positioned along the axis of height above the MOXA module. Furthermore no additional experiments are conducted by the team HORACE outside of the module. Therefore we don't expect any problems.
Even thought we can't determine the exact point in time when the hatch opens, we can be sure that in any case no problems should occur.

# Facit

The results of the vibration test shows that the module and the experimental set-up have a very rigid behavior and that only the interlocking system reacts sensitive of the vibration.

Searching for the eigen frequencies with different arrangement of damper on the fixture of the Pirani-sensor results for the team intern interests information about the damper behavior at this component.

It should be realized that the interlocking system using a brad and an electromagnet doesn’t demonstrate an optimal solution.

The reliability of the experiment could be warranted for the allowed vibration load.

Nathanael Warth, Responsible person

Alexander Mager, Team leader

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# APPENDIX F – PREPARATION AND TEST ACTIVITIES AT ESRANGE