SED

Student Experiment Documentation

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Mission: BEXUS 25

Team Name: IRIS

Experiment Title: InfraRed albedo measurements In the Stratosphere

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Version	Date	Changed chapters	Remarks
0.0	2017-01-01	New Version	Blank Document
1.0	2017-01-27	All	PDR
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3.0			IPR
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5.0			Final Report

Abstract: Student Experiment Documentation of InfraRed albedo measurements In the Stratosphere for BEXUS from Luleå University of Technology.
Keywords: BEXUS, infrared, albedo, IRIS, SED - Student Experiment Documentation, LTU - Luleå University of Technology

Contents

Preface

This document is a part of the preliminary design review (PDR) for the IRIS experiment. Its main purpose is to provide the reader with information on all basic knowledge about how the mission is designed and planned to perform albedo measurements from a high altitude balloon (HAB). The Student Experiment Documentation (SED) consists of the following chapters, analysed below:

- Chapter 1 - Introduction:
  This chapter explains briefly the scientific material on which this mission was based. The mission's objectives and concept is displayed. Information about the team and the team members can be found here.
- Chapter 2 - The Experiment Requirements and Constraints:
  Here, the technical functionalities are defined. This is needed to be met according to the specific requirement standards to ensure the reliability of the experiment.
- Chapter 3 - Project Planning:
  This chapter describes the schedule, the distribution of work, the available resources, the risks that have been taken into consideration and the outreach approach of the experiment.
- Chapter 4 - Experiment Description:
  This chapter clarifies the setup of the experiment, the interfaces and components, the design of the various subsystems, and the ground support equipment in need for the robustness of the experiment.
- Chapter 5 - Experiment Verification and Testing:
  This chapter displays the verification matrix and the several types of tests that will be performed in order to assure the correct operation of the experiment.
- Chapter 6 - Launch Campaign Preparation:
  In this chapter, information about the Input for the Campaign, Flight Requirement Plans, Preparation, and Test Activities at Esrange, Timeline and Countdown for the Flight, are explained along with the Post-Flight Activities
- Chapter 7 - Data Analysis:
  This chapter presents the data analysis plan, the launch campaign, results obtained, and most importantly the lessons learned from this experiment.
- Chapter 8 - Abbreviations and References:
  Contains all the abbreviations found in the document.

Information about the Experiment Review, Outreach, Additional Technology Information and Checklists are found in the Appendices in the end of the document.
The scientific terms that have been studied are emphasised in *italics*, and they are used to further comprehend the necessary scientific background for the conduction of the mission's scientific research.

This is the first release of IRIS mission Design Document.

The REXUS/BEXUS programme is performed under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Board (SNSB). The Swedish share of the payload has been made available to students from other European countries through a collaboration with the European Space Agency (ESA) [1].

EuroLaunch, a cooperation between the Esrange Space Center of SSC and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operations of the launch vehicles. Experts from DLR, SSC, ZARM and ESA provide technical support to the student teams throughout the project [2].

Suggested journals and books that have been an inspiration and give insight into the scientific background of IRIS, apart from the ones used as references in the current documentation:

- International Journal of Climatology. [3]
- International Journal of Atmospheric Sciences. [4]
- The Arctic Climate System, By Mark C. Serreze, Roger G. Barry. [5]
- The Cryosphere, An interactive open-access journal of the European Geoscience Union.[6]
- Polar meteorology, World Meteorological Organisation. [7]

Acknowledgements

This work has been generously supported by REXUS/BEXUS organisers, SNSB, DLR, ESA, SSC, ZARM, ESRANGE, IRF Kiruna, our university LTU, Thomas Khun, Olle Persson and our endorsing professor Mathias Milz . Our team has received support and advice from an immense number of individuals and organisations, so many in fact, that it would be impossible to mention them all without forgetting someone. Though the extents of the contributions vary greatly, they are all important for the success of our mission, and the entire team is and will be eternally grateful for everything that has been done for us. It is our sincere hope, however, that everyone who has been involved will feel a sense of pride when reading this document.

Without your support this project would not have been possible, and we will do everything in our power to make the most of this unique opportunity.

Thank you!
IRIS Team

Abstract

IRIS consists of an apparatus which aims to measure the incoming radiation from the Sun and Earth's reflection, in order to determine local albedo variations, throughout the troposphere and the stratosphere. Terms such as the red edge, Solar Zenith Angle (SZA), atmospheric extinction and clouds' microphysical properties, will be examined and are taken into consideration. The measurements will be performed by photodiodes pointing upwards and downwards, which cover the visible (VIS) the near-infrared (NIR) and infrared (IR) spectrum. A camera facing downwards will define the surface that lies directly beneath. Sensors, pointing upwards and downwards, will allow the differentiation between the intensity from these two directions, and how it varies depending on the altitude. A HAB traversing through the troposphere and the stratosphere is required for the distinguishment of the albedo variations, as other remote sensing methods are not as effective. The experiment, specially planned and designed for this mission, is taking into consideration all the requirements, constrains and risks needed to be taken into consideration. Thus, effectiveness of measurements is securely provided. Measuring the radiation balance of the Arctic region will aid in the development of future numerical models describing the radiative balance and the climate all over planet Earth. The supreme aim is to reduce error accumulated from remote satellite measurements.

1 Introduction

1.1 Scientific/Technical Background

The *albedo* is a non-dimensional, unit-less quantity, which indicates the quality of reflectance a surface can return. The *bond albedo* specifically, is a measure of the ratio of incident and reflected radiation. Albedo is connected directly to the heat energy budget of the planet, since the solar radiation that is not absorbed from the Earth's surface and the clouds in the atmosphere, is directly reflected into space. Thus, the long-term trend of albedo is that of cooling.
Variety and quality of the *local vegetation*, *atmospheric compositions*, type of *clouds* found throughout the troposphere and stratosphere, the *Solar Zenith Angle (SZA)* and the *wavelength* of incoming light from the Sun[8] are all factors that influence deterministically the albedo. Therefore, it is of great interest to further investigate thoroughly into how they influence the temperature equilibrium of our planet.

For the ground albedo measurements, surface type, colour and moisture and the SZA, are the most important variables to be taken into consideration.[9]
The variety and quality of vegetation is, for this reason, directly connected to the albedo. The type and healthiness of vegetation contributes to its reflectance. The *"red edge"*, consisting of wavelengths between 680-750 nm, is the spectral signature characteristic of terrestrial vegetation. This is due to the strong absorption by chlorophyll in the red region, in contrast to a strong reflectance in the near-infrared. Measurements of the red edge can provide valuable information about the chlorophyll concentration of the observed vegetation. Thereon, these measurements can be used to distinguish between living and dead plants, in order to detect and describe the anomalies of the terrestrial albedo. Previous studies have showed that the finest indicator of the level of chlorophyll contained in vegetation, is the edge of the *red edge peak*. The area of the red edge peak is useful for estimating the leaf area index. To conclude, the red edge measurements are useful, not only for the determination of the nutritional status of vegetation, but also for that of its health. [10]

Moreover, the different *types of clouds* [11] and *atmospheric compositions* influence radiation scattering through atmospheric extinction.
Clouds have a prodigious impact on the albedo, since depending on their height, temperature, thickness and composition, they play a major role to radiation scattering. This is because they consist of various droplet formations, whose size of effective radius has different scattering properties. Along with the anthropogenic aerosol particles and their absorption properties, these characteristics greatly affect the albedo and radiation scattering.

Another factor that affects the albedo is the SZA. The SZA is an indicator of radiance. It is the angle between the local zenith point and the midpoint (line of sight) of the sun. For this reason it is calculated as a function of time, day and latitude. The albedo of most surfaces depends highly on the SZA, with a general trend of increase in albedo for increasing SZA. Consequently, SZA is an essential parameter to be defined in order to correctly calculate the local albedo of an area. Snow is an exception to this case; showing almost no variation and in some cases even a decreasing albedo for larger SZA [12]. Usually, the larger the SZA is, the weaker becomes the exposure in sun's rays, because the same amount of light is spread to a larger area.

A study conducted by Steven A. Lloyd, published in 1990[13], concluded that the radiation field in the polar atmosphere is vastly different than that of lower latitudes due to several factors. The atmospheric scattering is increased for wavelengths below 340nm because of ozone depletion: ozone holes significantly affect wavelengths in the region between 280-310 nm. For smaller values of SZA, particularly below 60 degrees, surface albedo is important to consider. When this angle increases, less direct sunlight reaches the surface, but a large value of surface albedo still has some effect. All of these effects are important for estimating the rate of ozone destruction, though the most important one appears to be cloud cover.

For satellite remote sensing radiative transfer is a necessary tool. It models the sinks and sources of radiation, in other words how the intensity changes throughout the atmosphere. It specifically has terms for the absorption (transmittance), emission and scattering. It is however an empirical formula that requires assumptions, such as the local thermodynamic equilibrium (LTE). The full radiative transfer equation (RTE) in differential form is stated below:

$$\frac{dI}{ds} = -(\beta_a + \beta_s)I + \beta_a B(T) + \beta_s \int_{4\pi} P(\Omega',\Omega) I(\Omega') d\Omega'$$

Here I is the intensity, s the path through the atmosphere, β_a and β_s are the absorption and scattering coefficients, Ω is the angle, B(T) the Planck function and P the scattering probability.[14] This equation is used by RTE models such as Futbolin.[15]

It is important to consider that the polar regions, such as Lappland, are extremely important for the global climate, but they have not yet been studied enough. Their unstudied properties related to the modelling and parameterization of climate change are needed to analytically define in detail the parameters that influence the radiation budget. In terms of Albedo measurements, polar arctic regions have not been studied as intensely as other areas in lower latitudes. A small number of ground measurements have been performed in the past. Mostly polar orbit (PO) weather and PO imagining satellites are used to monitor the albedo and other important factors that aid the creation of climate prediction models. NOAA and CERES, NASA are two of the main researchers that assist in albedo monitoring. Hence, BEXUS provides a unique opportunity to study this otherwise remote place, since the balloon will be launched from Esrange Space Center in northern Sweden.

1.2 Mission Statement

The overall purpose of IRIS is to contribute to error elimination in remote sensing satellite measurements, by measuring the albedo (ratio of intensity between incoming and reflected outgoing radiation) and its change throughout the troposphere and the stratosphere. Specifically, in contrast to all remote sensing satellite measurements, IRIS will gather data from much thinner atmospheric layers, by the use of light sensors and a High Altitude Balloon (HAB). This process will increase the possibility of error estimation accumulated from remote sensing measurements.

1.3 Experiment Objectives

Obj.1 IRIS mission is based on the following primary scientific objectives:

- 1.1 Effective measurement of ground albedo.
- 1.2 Ratio variation of incoming radiation to outgoing reflectance throughout the troposphere and the stratosphere.
- 1.3 Estimation and elimination of accumulated error from satellite remote sensing measurements.
- 1.4 Build a simple but yet reliable experiment.

Obj.2 IRIS wishes to investigate the following secondary objectives, if conditions are met:

- 2.1 Relation of chlorophyll levels to albedo variations.
- 2.2 Comparison with PO satellite remote sensing measurements.
- 2.3 Record of variations and distinguishment between snow and/or cold cloud albedo.

1.4 Experiment Concept

IRIS will investigate the albedo for VIS, NIR and IR wavelengths and at various altitudes, above the polar circle. The mission will be carried out by an apparatus utilising light sensors and cameras mounted on a HAB.

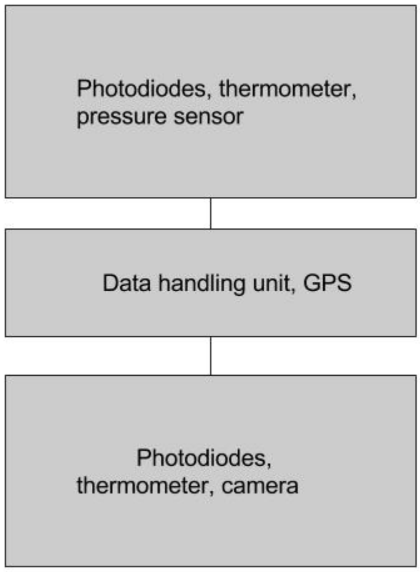


Figure 1: IRIS experiment setup

IRIS mainly consists of two sensor arrays, connected to a data storage unit. There are two separate sensor arrays, one located on the top of the gondola and the other one located at the bottom. Each array contains a number of photodiodes, which will measure the intensity of the specific wavelenghth bands required to conduct the scientific research. On the bottom one there is also mounted a colour camera. The basic functional blocks are demonstrated in fig. 1.

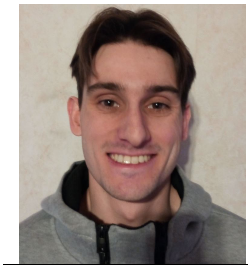
1.5 Team Details

1.5.1 Contact Point

Contact	Contact Information
Project Manager	Gustaf Ljungné Tarfalavägen 5A 98144 Kiruna, Sweden gustaf.ljungne@gmail.com +46709610679
The team	iris.bexus@gmail.com (Team email)
Contact at LTU	Associate Professor Thomas Kuhn thomas.kuhn@ltu.se Associate Professor Mathias Milz mathias.milz@ltu.se

1.5.2 Team Members

Everyone in IRIS is rewarded 15 ECTS points for the course Space Engineering Project II, P7001R by participating in BEXUS.[16]

Name and Role	Information
Gustaf Ljungné **Project Manager** 	Electrical engineering fourth year, currently working on a master in instrumentation and spacecraft design. Interests include, but are not limited to: technology, electronics, weight lifting, people skills. My role in IRIS is as the project manager. I coordinate the team and its departments.
Guillermo Ledo López **Head of Mechanical Department** 	Aerospace engineer, studying a master's degree on spacecraft design at LTU. Interested in space, physics, engineering, nature and science fiction, among others. As the head of the Mechanics department, my roles include the design of the structures and thermal control used in IRIS and the coordination of my department. I expect the heaviest workload to begin once a final configuration for the experiment has been selected and manufacturing starts.
François Piette **Mechanical Department and Head of Economics Department** 	I am an Aerospace Engineer student from the University of Liège (ULg), and I am currently completing my degree at Luleå University of Technology as an exchange student. I have high interest in aircraft and space launchers in Europe. In the mechanical department I am mainly in charge of CAD drafts with CATIA. In the Economics department we are actively looking for grants to secure the necessary funding. Also we are trying to establish partnerships with scientific institutes in the Arctic region. I am expecting a constant increase of the workload in each step of the design.

Lisa Jonsson
Head of Electronics Department

Currently studying the fourth year of MSc in space engineering with focus on instrumentation and control systems of spacecrafts and satellites. My tasks are to manage the electronic department, divide the workload between the members of the electronics team, choosing sensors and instruments according to the science department's specification and designing the electronics needed for the experiment.

Hampus König
Electronics Department

Currently in the fourth year of M.Sc in space engineering focused on instrumentation and spacecraft design. My tasks include choosing sensors according to the science department's specification and designing the electronics that are needed for the experiment.

Arttu Tiainen
Electronics Department

Currently on the second and thus last year of the MSc in spacecraft design and I did my thesis on inter-satellite link antennas. Additionally I have several years of work experience in embedded electronics design and a small consultation company. My tasks include building and programming a prototype for the measurement system and supportive and advisory tasks of the electronics design.

August Svensson
Electronics Department

Currently in the third year of a MSc in space engineering with a specialisation in spacecraft and instrumentation. My tasks involve the verification and testing of the electronics and sensors, as well as electronic design.

Edgar Martín **Head of Software Department** 	Aerospace engineering graduate, currently undertaking a master's program in spacecraft design. Among my interests are programming, electronics and entrepreneurship. As member and head of the software department, my tasks include system architecture design, programming and maintenance of the code, as well as internal management of the department. The expected workload is to be concentrated at the final stages, when the components from the hardware team are available.
Andreas Wallgren **Software Department** 	Currently thesis/final project remaining on a MSc in space engineering, with a focus on atmospheric and space physics. Relevant interests include a general fascination of mathematics; in particular information manipulation in e.g. signal processing. As a member of the software department, the task is to contribute to stable and reliable software to ensure correct data and error -handling to aid a successful mission. The bulk of the work will begin with the integration of the hardware-to-be-used. Because no system ever co-operates, the workload will be heavy and hopefully rewarding.
Eleni Athanasiou **Head of Science Department** 	I am an Electrical Engineer, currently studying Spacecraft Design (MSc) at LTU. I have work experience on Industrial Engineering automation control systems, and on the development and test of hardware parts for accelerator and non accelerator experiments for High Energy Physics (HEP). My general interests include: particle physics , superconductivity, cryogenics, cutting edge technology, biomedical engineering, sociology, photography and painting. For the IRIS experiment I am the Head of Science Department, and my duties consists of the following: • Develop and analyse the scientific background and objectives of IRIS. • Post-experiment data analysis. • Distribution of tasks within the Science department, manage and conduct communication with the other departments, as well as with the Project manager.

Ingo Wagner **Science Department** 	BSc in Earth and Space Science, currently enrolled at LTU in a master's program in Atmospheric and Space Science. My interests in science range from oceans to space and stars with a focus on the physics. In the science department my role is the development of the scientific goal as well as the application of data analysis models. As it is the nature of these roles the workload will be focused on the beginning and end of the project.
Oriol Peláez Mercadal **Science Department** 	Energy and Mining resource engineering graduate, studying a master's degree on Earth's atmosphere and Solar System at LTU. I like all kind of sports and technology, as well as science and everything related with space, specially the research for new horizons, either in exoplanets or close to us, like Mars or in some of our Solar System moons. I am also very interested in space mining, which I think is a discipline that will be very important in the near future, so harvesting resources from planets and asteroids will be very significant for the next generations in order to perform interplanetary travels. My role include development of science background and data analysis.
Alexander Korsfeldt Larsén **Public Relations** 	After a year in the telemarketing sector I enrolled at Luleå University of Technology, and I am now doing my fourth year in the Space Engineering Master Programme. Though my education is specialised towards electronics and instrumentation, my main task in this project is to handle most of the team's external communication. I am also responsible for our web page and our social media presence.

2 Experiment Requirements and Constraints

2.1 Functional Requirements

F.1 The experiment shall measure the intensity of visible light outside the gondola, looking towards the zenith.

F.2 The experiment shall measure the intensity of visible light outside the gondola, looking towards the nadir.

F.3 The experiment shall measure the intensity of infrared light outside the gondola, looking towards the zenith.

F.4 The experiment shall measure the intensity of infrared light outside the gondola, looking towards the nadir.

F.5 The experiment shall correlate the pressure at which the measurements were taken.

F.6 The experiment shall correlate the temperature at which the measurements were taken.

F.7 The experiment shall correlate the position at which the measurements were taken.

F.8 The experiment shall measure the position on the three axis of space with respect to the launching point.

2.2 Performance Requirements

P.1 The experiment shall be able to distinguish between incoming and outgoing from Earth radiation.

P.2 The experiment shall measure the electromagnetic spectrum from 0.3 μm to 2.5 μm with a minimum sensitivity of 200 $mW \cdot m^{-2}$.

P.3 The experiment shall measure the 0.43 μm to 0.45 μm with a precision of $\pm$0.005 μm.

P.4 The experiment shall measure the 0.45 μm to 0.51 μm with a precision of $\pm$0.005 μm.

P.5 The experiment shall measure the 0.53 μm to 0.59μm with a precision of $\pm$0.005 μm.

P.6 The experiment shall measure the 0.63 μm to 0.67 μm with a precision of $\pm$0.005 μm.

P.7 The experiment shall measure the 0.85 μm to 0.88 μm with a precision of $\pm$0.005 μm.

P.8 The experiment shall measure the 1.36 μm to 1.38 μm with a precision of $\pm$0.005 μm.

P.9 The experiment shall measure the 1.56 μm to 1.65 μm with a precision of ±0.005 μm.

P.10 The experiment shall measure the 2.00 μm to 2.50 μm with a precision of ±0.005 μm.

P.11 The sampling rate of the experiment shall be between 5 and 10 seconds.

P.12 The sampling delay shall not exceed 30 seconds.

P.13 The experiment shall measure the pressure from 5 to 1100 $mbar$.

P.14 The experiment shall measure the pressure with a minimum accuracy of ± 10 $mbar$.

P.15 The experiment shall measure the temperature from -90 to 30 $°C$.

P.16 The experiment shall measure the temperature with a minimum accuracy

of ± 0.5 $°C$.

P.17 The experiment shall measure the position with a minimum accuracy of ± 10 m.

2.3 Design Requirements

D.1 The experiment shall not include components that could prove to be dangerous for people.

D.2 The experiment shall not include components that disturb or harm the launch vehicle.

D.3 The experiment shall not include components that disturb or harm other experiments.

D.4 The experiment shall not weight more than 8 kg upon launch.

D.5 The experiment shall withstand vertical accelerations within the BEXUS launch and flight profile.

D.6 The experiment shall withstand horizontal accelerations within the BEXUS launch and flight profile.

D.7 The experiment's data storage unit should withstand shocks of up to 35 g during landing.

D.8 The experiment shall withstand vibrations related to handling and transportation before and after flight.

D.9 The experiment shall withstand pressures within the BEXUS flight profile.

D.10 The experiment shall withstand temperatures within the BEXUS flight profile.

D.11 The experiment shall not be at risk of falling from the gondola during flight and launch.

D.12 The experiment shall not slide or translate inside the gondola during flight and launch.

D.13 The experiment should be attached to the gondola rails if possible.

D.14 The fastening to the gondola rails shall be carried out with M6 bolts with 23 mm thread length.

D.15 The experiment shall use a sufficient number of brackets on bottom plates in order to facilitate mounting of experiments.

D.16 The experiment shall operate at temperatures within the BEXUS vehicle flight and launch profile.

D.17 All experiment critical components shall be accessible within 2 minutes.

D.18 The replacement time of the critical experiment components shall be within 5 minutes.

D.19 The experiment shall use a maximum electrical energy of 275 Wh.

D.20 The experiment shall use Ethernet 10/100 Base-T with RJ45 connectors for interfacing with the provided E-link.

D.21 The experiment shall use Ethernet 10/100 Base-T with RJ45 connectors for interfacing with the ground station.

D.22 The experiment shall use a 4 pin, male, box mount receptacle MIL-C-26482P series 1 connector with an 8-4 insert arrangement as power interface.

D.23 The data storage unit shall withstand any post-landing environment within the mission profile without corruption or loss of data for at least 3 days.

D.24 The experiment shall be able to handle two aborted launches.

D.25 The experiment shall not use a downlink rate greater than 200 kbit/s.

D.26 The experiment may include sacrificial joints or other contingency plans to avoid being damaged upon landing if it protrudes from the gondola.

D.27 The position of the experiment should be selected in order to reduce "noise" interference from other experiments.

2.4 Operational Requirements

O.1 The experiment sensors shall be clean from dust before launch.

O.2 The experiment shall accept commands from the ground station at any time.

O.3 The procedures to turn the experiment on and off should be kept simple.

O.4 The experiment shall perform autonomously in the event of loss of communication with the ground station.

O.5 The experiment shall be able to correctly handle aborted launch attempts during any point leading up to, including pre-flight tests, the launch.

2.5 Constraints

C.1 The E-Link data transfer rates are limited by coverage and quality of reception, imposing restrains on the uplink/downlink available rate.

C.2 Protrusion of parts outside the gondola is restricted by the flight operators.

C.3 The position of the experiment is not fixed at this stage.

C.4 The budget for the experiment is limited by external sponsorship.

C.5 The weather conditions are to affect the experiment and its outcomes if the sky is overcast for secondary mission objectives.

C.6 Time of delivery of components is limited on the team's location, affecting manufacturing times.

3 Project Planning

This following section will explain the work distribution and expected workload for each member. It is based on when the different reviews have deadlines and what main tasks exist within the different departments.

3.1 Work Breakdown Structure (WBS)

IRIS's WBS can be seen in fig. 2. The WBS is divided into the seven departments that the team consists of, and the work packages are the main tasks in each department.

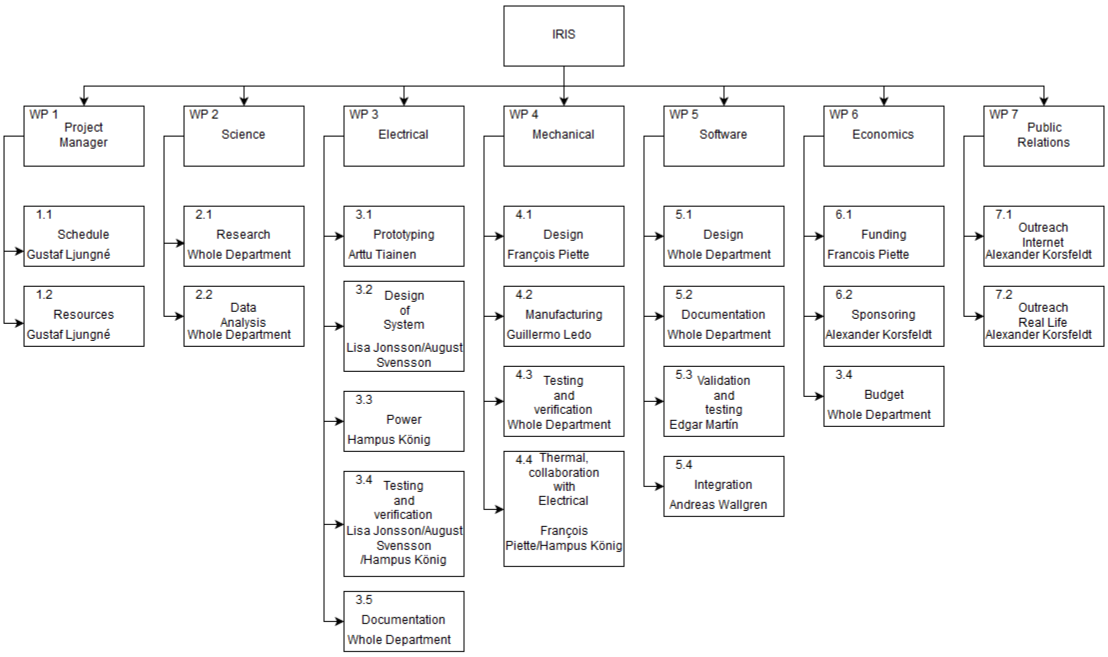


Figure 2: The WBS for IRIS

3.2 Schedule

Fig. 3 and 4 is the estimated time and tasks distruption within the IRIS team. Included are all reviews, launch, student traning week and exam periods.

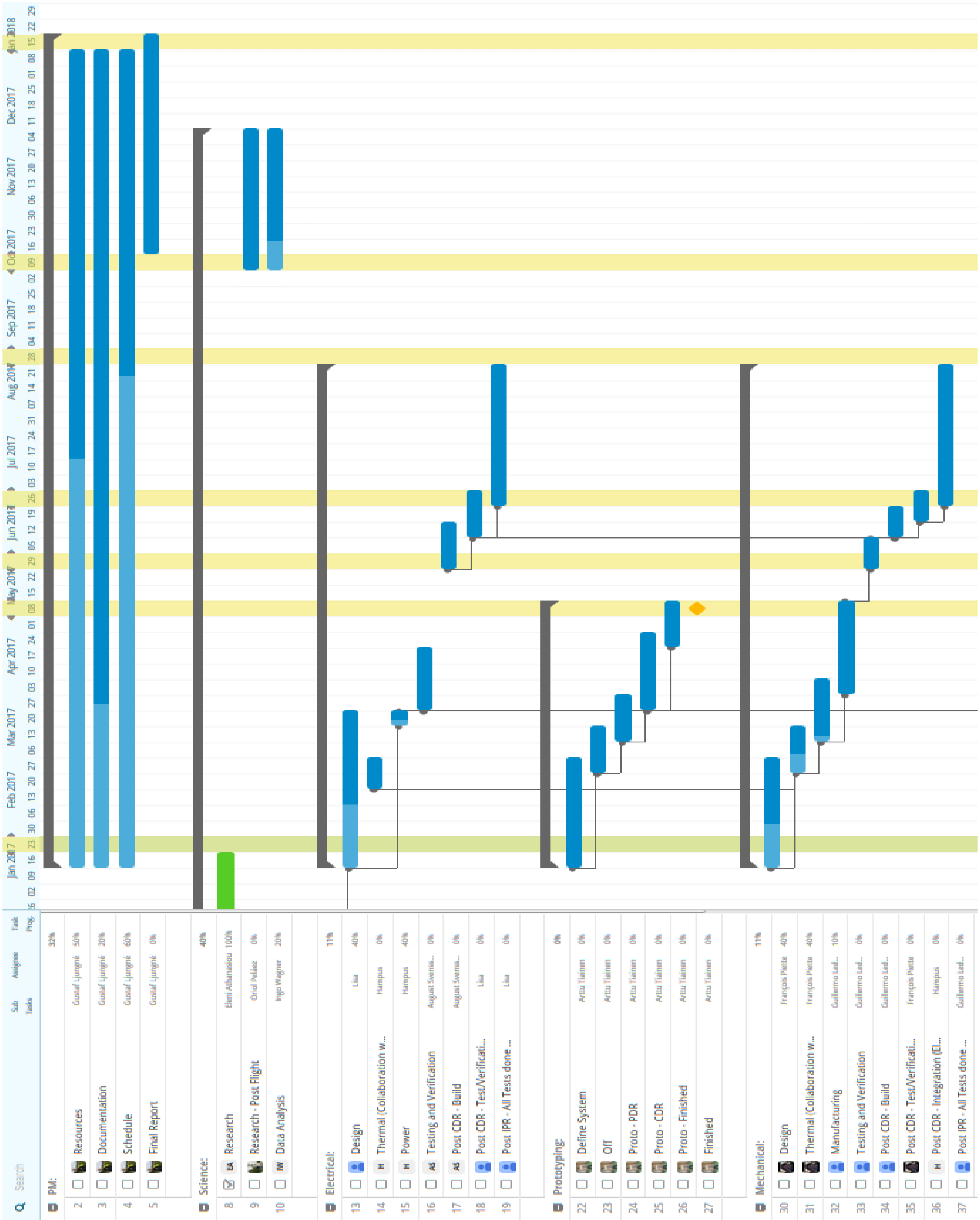


Figure 3: Gantt chart, part 1

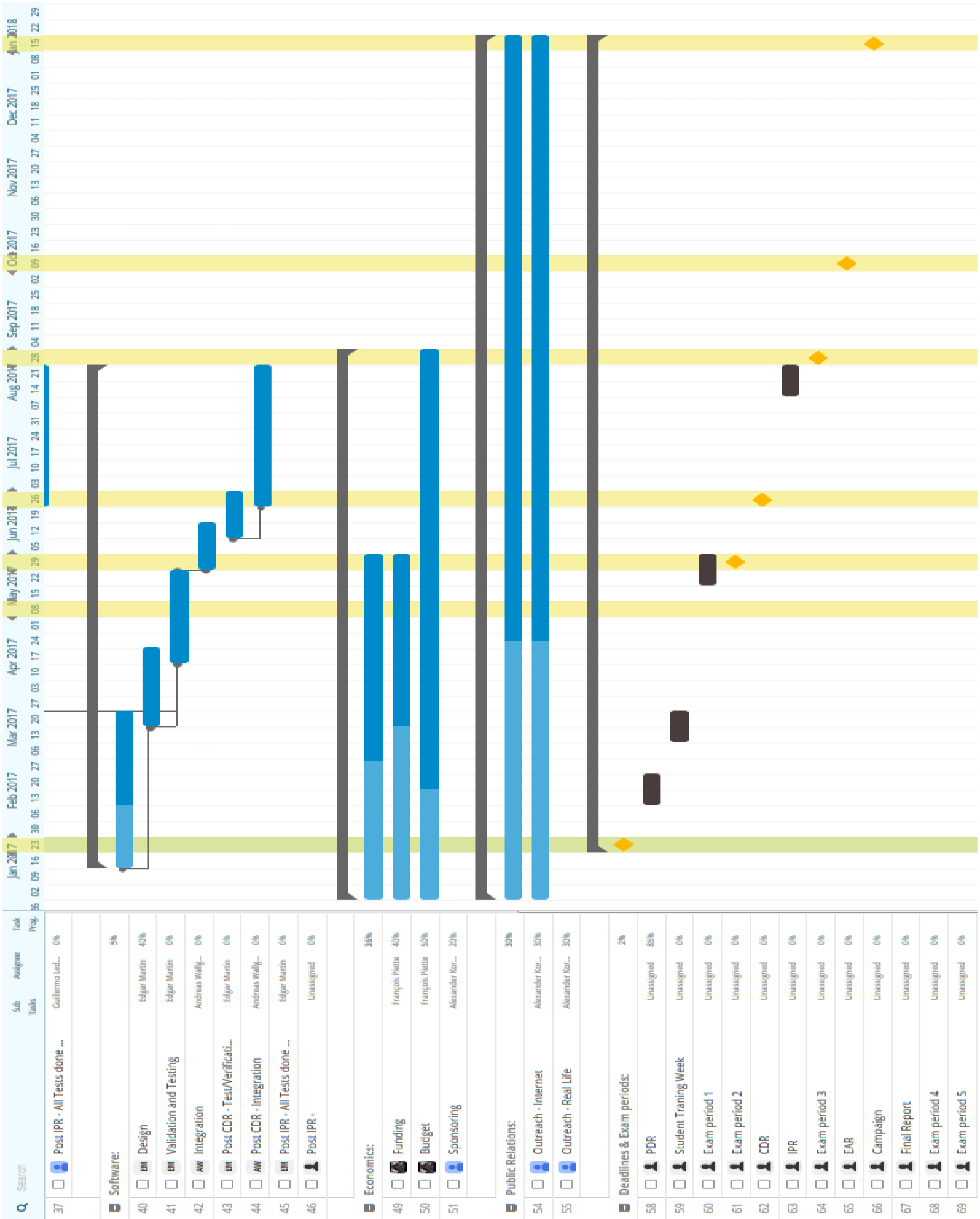


Figure 4: Gantt chart, part 2

3.3 Resources

3.3.1 Manpower

Tab. 2 and 3 show that the work hours are estimated to be distributed among the team members.

Table 2: Colour code for the work distrubution

Colour Code	Amount of time (100 % is 20h)
Red	More than 80 %
Yellow	60 to 80 %
Blue	40 to 60 %
White	Less than 40 %
Black	Not present

Table 3: Work load in hours for each team member

Month Member	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Gustaf	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Yellow
Eleni	Red	Blue	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red
Lisa	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Yellow
Edgar	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Yellow
Guillermo	Red	Yellow	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Yellow	Yellow
François	Red	Yellow	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Yellow	Yellow
Alexander	Red	Red	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red
Arttu	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Red	Red	Yellow	Yellow
Ingo	Red	Blue	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red
Oriol	Red	Blue	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red
Hampus	Blue	Blue	Blue	Blue	Red	Red	Red	Red	Red	Red	Red	Yellow	Yellow
August	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Yellow
Andreas	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Yellow

3.3.2 Budget

The current budget estimation is shown below in tab. 4. These calculations are rough, and will be updated as the design phase progresses, but they show that the total expenditures are well below the estimated income. Costs for the Outreach Programme are not determined at this point; they will depend on the final hardware costs. The team is currently working on applications for various research grants, which will help cover travel costs and allow more outreach activities to be performed. More information about the individual components can be found in section 4.3.

Table 4: Budget estimations

Incoming/outgoing	Amount	Were the money comes from/goes to
Outgoing	€600	Electrical components
Outgoing	€2,500	Sensor filters
Outgoing	€200	Mechanical parts
Outgoing	€750	Manufacturing, mechanical (materials+labour)
Outgoing	TBD	Outreach costs
Incoming	€3,000	LTU Project Course
Incoming	€3,000	SNSB
Incoming	TBD	ÅForsk Foundation
Incoming	TBD	LKAB Academy
Incoming	TBD	Sveriges Ingenjörer - Miljöfonden
Total	€1,950+	(Does not include outreach costs or income from uncertain grants)

3.3.3 External Support

Table 5: External Support

Support to	Information
Whole Team	**Name:** Mathias Milz **Title:** Associate Professor **Research Area:** Atmospheric science **Relation to the Team:** Endorsing Professor **Department:** LTU, Department of Computer Science, Electrical and Space Engineering **Email:** mathias.milz@ltu.se **Phone:** +46(0)980 67541
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Mechanical/Electrical	**Name:** Joakim Öman **Company:** SSC **Location:** Esrange Space Center **Division:** Science Services: Instrumentation **Email:** Joakim.Oman@sscspace.com
Mechanical/Electrical	**Name:** Kent Andersson **Company:** SSC **Location:** Esrange Space Center **Division:** Science Services: Instrumentation **Email:** Kent.Andersson@sscspace.com

3.4 Outreach Approach

The main idea of the IRIS Outreach Program is to focus on reaching a younger audience, e.g. university and high school students. This will be achieved through social media, the IRIS website, and by holding presentations at universities, high schools, and various events. Articles in local and national newspapers, as well as on university websites, are also part of our outreach plan.

The team's website can be found at ltuiris.wixsite.com/iris. The URL will be changed to a more convenient one in the near future. The website contains all essential information about the project and the team members behind it, as well as a short description of the REXUS/BEXUS programme. Articles written by the various departments will be regularly published, so the website also acts as a blog or development diary. All important documents produced by the IRIS team will be uploaded to this site, and made available to the public. The idea is that future students participating in this programme, or a similar one, can use our site as a resource.

IRIS has a Facebook page, located at facebook.com/bexusiris/. News and photos are shared here in a format easily accessible. Whenever an article is posted on our website, a link to the article, as well as a short summary, will be posted here. The team also has an Instagram account that will be used to upload pictures on a regular basis. It can be found at @bexus_iris.

3.5 Risk Register

- TC – Technical/implementation
- MS – Mission (operational performance)
- SF – Safety
- VE – Vehicle
- PE – Personnel
- EN – Environmental
- OR - Outreach
- BG - Budget

Table 6: The rankings of probability (**P**) and severity (**S**)

Probability P	**Severity S**
A. Minimum – Almost impossible to occur	1. Negligible – Minimal or no impact
B. Low – Small chance to occur	2. Significant – Leads to reduced experiment performance
C. Medium – Reasonable chance to occur	3. Major – Leads to failure of subsystem or loss of flight data
D. High – Quite likely to occur	4. Critical – Leads to experiment failure or creates minor health hazards
E. Maximum – Certain to occur, maybe more than once	5. Catastrophic – Leads to termination of the REXUS and/or BEXUS programme, damage to the vehicle or injury to personnel

Table 7: Risk Register

ID	**Risk (and consequence if not obvious)**	**P**	**S**	**P × S**	**Action**
MS10	Hercules impact if the experiment protrude from the gondola.	B	4	Low	Prepare spare parts of the experiment.
MS20	Failure of several sensors.	C	2	Low	Thermal test to approve the functionality of the experiment.

MS30	The balloon rotation will influence results on each sensors.	E	2	Medium	Including sensors (electronic gyro/accelerometer) to estimate rotation rate might help data analysis.
MS40	Temperature sensitive components that are essential to fulfil the mission objective might be below their operating temperature.	C	3	Low	Safe mode to prevent the components to operate out of its operating temperature range.
MS50	The MCU/Central computer unit might fail, it will prevent any further collect of data.	B	3	Low	Requires several tests of the robustness of the system. If it cannot be assessed, a redundant system will be required.
SF10	Mechanical failure of bolts.	B	5	Medium	Stress calculation and testing is required.
SF20	Self-loosening of bolts and nuts.	B	5	Medium	Redundancy to prevent the experiment to fall off.
TC10	Failure of the experiment during testing.	C	3	Low	Prepare spare parts of the experiment.
EN10	Full coverage of low and dense clouds will lead to one type of measurements.	C	2	Low	The mission objective need to be prepare to this case.
EN20	No snow covered ground during the flight.	D	2	Low	The mission objective need to be prepare to this case.
EN30	Low Sun zenith angle.	D	2	Low	The orientation of the experiment must be easily adaptable to the different position of the Sun. E.g. Consider using a dome,pyramid or tetrahedron.
EN40	The post-landing environment conditions might corrupt or destruct the data.	C	4	Medium	Testing of the data storage robustness against post-landing environmental conditions during several days.

EN50	Accumulation of dust particles on sensitive equipment, e.g. lenses or filters.	C	2	Low	Accurately estimate the risk, limit unnecessary expose of sensitive equipment to environment.
EN60	Formation of waterdroplets on sensitive equipment, e.g. lenses.	A	2	Low	Accurately estimate the risk, limit unnecessary expose of sensitive equipment to enviroment.
BG10	The expected budget is not met.	B	5	Medium	By assuring sufficient funding before critical phase or by reducing the number of costly components.
OR10	One flight might not be enough to achieve the scientific goals.	D	2	Low	Prepare eventually for other flights with other balloons to increase data sample.

4 Experiment Description

4.1 Experiment Setup

The IRIS experiment consists of two sensor arrays - one at the bottom of the gondola, pointing downwards, and the other one at the top, pointing upwards - and a data storage unit. The main sensors needed for the experiment are light sensors in the infrared and visible wavelength spectrum, namely photodiodes. These have fisheye lenses mounted on them to expand their field of view. A camera is also going to be included on the sensor array pointing downwards. Interior temperature sensors are included, to check whether the equipment is working inside their safe temperature ranges. An atmospheric pressure sensor and a GPS will also be included.

Data is managed by microcontrollers and is sent both to the data storage unit and to the ground station, while another microcontroller uses the internal temperature measurements to manage an active thermal control system, composed of electrical heaters.

A detailed view of the subsystems that are going to form the experiment can be found in fig. 5.

4.2 Experiment Interfaces

4.2.1 Mechanical

The experiment is composed of three main units, namely the upper box, the bottom box and the floor mounted unit. The upper box, which contains the upper sensor array and the data storage unit, is attached to the upper gondola frame by four (4) clamps, next to the telemetry boxes as shown on fig. 8. The bottom box, which contains the electronics for the floor mounted unit, is attached to the provided gondola rails, as shown on fig. 9 using four (4) M6 bolts with 23 mm thread length, as specified on the REXUS/BEXUS User Manual.

An aluminium plate is fitted to the bottom of the gondola on the outer side, using two (2) M6x23mm bolts, two (2) M6 nuts and two (2) M6 washers. The floor mounted unit, containing the bottom sensor array and the camera, is attached to this plate. This design has been selected for the large field of view it allows for the sensors, without the need for a protruded design. A view of the mounting of the floor mounted unit is shown on fig. 6 and 7.

Static load and shock tests will be conducted to check whether the chosen nuts and bolts meet the requirements stated in section 2.3.

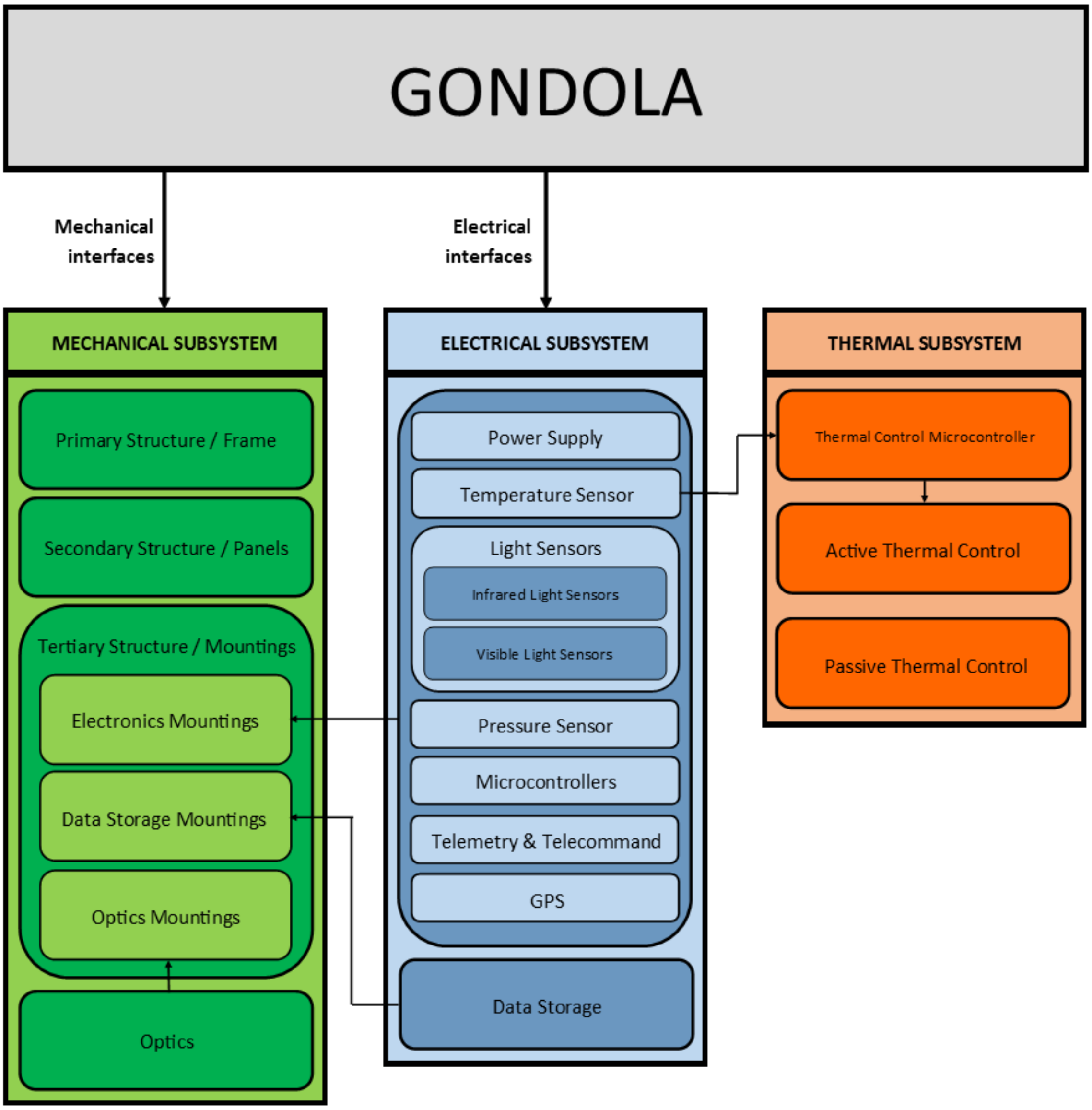

Figure 5: Subsystem diagram of the IRIS experiment

	Bolts	**Nuts**	**Washers**
Upper Box	8 M3×70	8 M3	16 M3
Bottom Box	4 M6×23	4 M6	4 M6
Lower Floor Box	2 M6×23	2 M3	2 M6

Table 8: Bolts, nuts and washers used to mount the bottom, upper and lower floor box on the gondola.

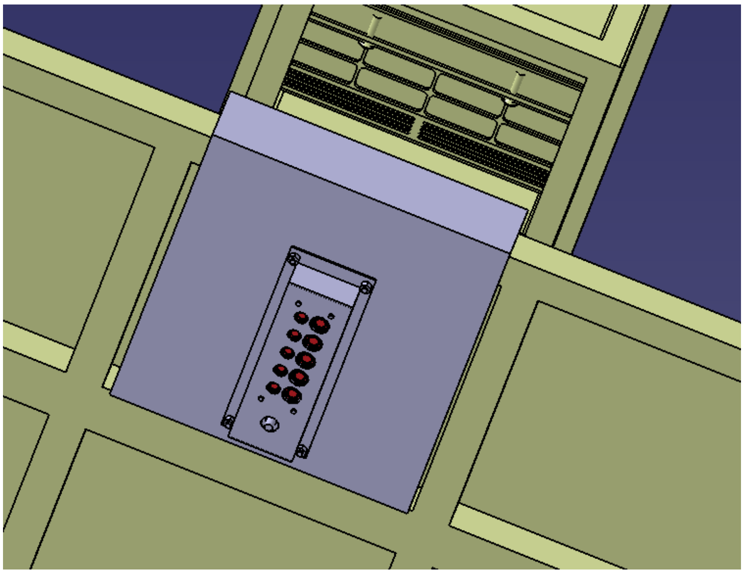

Figure 6: Bottom view of the floor mounted unit attached to the gondola

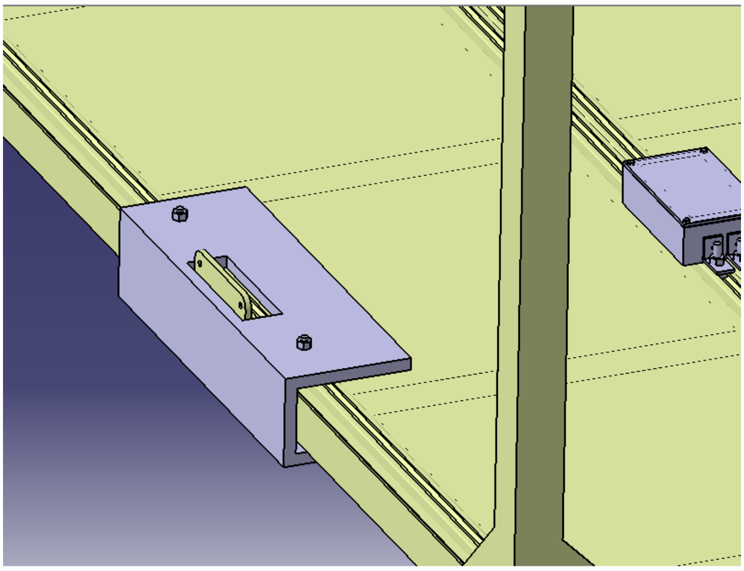

Figure 7: Top view of the floor mounted unit and bottom box attached to the gondola

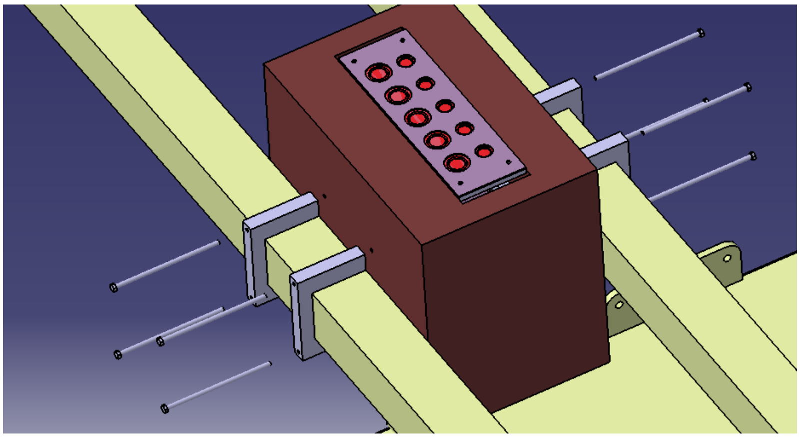

Figure 8: Top view of the upper box attached to the gondola

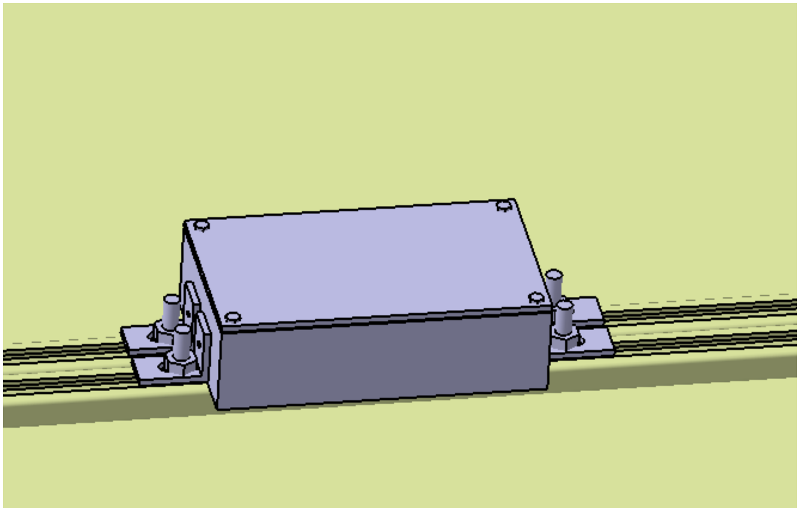

Figure 9: Top view of the bottom box attached to the gondola.

4.2.2 Electrical

According to the BEXUS User Manual, an Ethernet protocol shall be used in this experiment, and the connector shall be an Amphenol RJF21B with a standard RJ45 connector.

The transfer rates are expected to be 200 kbps nominal and 800 kbps peak downlink. The expected uplink rates will just be command strings, not greater than 256 bytes per request. For more information about transfer rates, please refer to section 4.8.2.3.

The experiment uses the provided 28.8 V/1 mA (13 Ah) battery pack consisting of eight SAFT LSH20 batteries in series, where each battery has got a built-in 5 A fuse (not changeable) for protection, and the combined recommended continuous maximum current draw is 1.8 A. The expected max current is 1.43 A. The connector to the battery which will provide power to the IRIS experiment shall be a 4" male, box mount receptacle MIL – C-26482P series 1 connector with an 8-4 insert arrangement (MS3112E8-4P) as specified in the BEXUS User Manual.

4.2.3 Radio Frequencies (Optional)

Will not be used.

4.2.4 Thermal (Optional)

Will not be used.

4.3 Experiment Components

Component	Supplier	Mass	Dimensions	Amount	Cost	Notes	Status
Serial Camera Module 4D Systems	Mouser Electronics	6 g	32x32x21 mm (varies with focus)	1	€50	Low weight, cheap	Not ordered
Garmin GPS Receiver 18x-LVC	Elfa	160 g	diameter: 85 mm, height: 50 mm	1	€110	Compact, cheap	Not ordered
Barometric Pressure Sensor MS5607-02BA03	Digikey	TBD (1-2 g ?)	5.0x3.0x1.0 mm	1	€28	High resolution, large measuring range	Not ordered
Photo diode G12183-030K Longwave	Hamamatsu	TBD	9.4x22.4mm	5	€100 (total)	Large measuring range	Not ordered
Photodiode S1336-8BK	Hamamatsu	TBD	14.1x20.2mm	5	€100 (total)	Large measuring range	Not ordered
Raspberry Pi Model B+	Elfa	42 g	85x56x1.4 mm (without considering USB ports, etc.)	1	€25	Easy to use, cheap	Not ordered
Arduino Nano	Elfa	7 g	18x45 mm	3	€25	Easy to use, cheap	Not ordered

DC/DC Converter 15W 18-36Vin 5Vout 300-3000mA	Mouser Electronics	15 g	25x25x10 mm	2	€30	Low consumption of supply current	Not ordered
Diode Relay	Farnell	TBD	20.5x10.1x15	TBD	€3	...	Not ordered
Diode Circuit Transistor BSS138	Elfa	TBD	TBD	TBD	€1	...	Not ordered
Data Storage Unit	TBD	TBD	TBD	TBD	€100	...	Not ordered
Optical Filter 440BP20**	Omega Optical	TBD	TBD	TBD	$98.80	**WR**:430-450 nm, **AR**:430-450 nm, **CW**:440 ± 5 nm **FWHM**:20 ± 5 nm	Not ordered
Optical Filter	Edmund Optics	TBD	TBD	TBD	$125.00	**WR**:450-510***** nm, **AR**:450-500 nm, **CW**:475 ± 5 nm, **FWHM**:50 ± 5 nm	Not ordered
Optical Filter 560BP60 RAPID-BAND	Omega Optical	TBD	TBD	TBD	$175.00	**WR**:530-590 nm, **AR**:530-590 nm, **CW**:560 ± 2 nm, **FWHM**:60 ± 4 nm	Not ordered

Optical Filter 650BP40 RAPID-BAND	Omega Optical	TBD	TBD	TBD	$175.00	**WR**:630-670 nm, **AR**:630-670 nm, **CW**:650 ± 2 nm, **FWHM**:40 ± 4 nm	Not ordered
Optical FIl-ter	Edmund Optics	TBD	TBD	TBD	$125.00	**WR**:850-880***** nm, **AR**:850-900 nm, **CW**:875 ± 5 nm, **FWHM**:50 ± 5 nm	Not ordered
Optical FIl-ter	Edmund Optics	TBD	TBD	TBD	$149.00	**WR**:1360-1380***** nm, **AR**:1350-1400 nm, **CW**:1375 ± 5 nm, **FWHM**:50 ± 5 nm	Not ordered
Optical Filter	Edmund Optics	TBD	TBD	TBD	$149.00	**WR**:1560-1660***** nm, **AR**:1575-1625 nm, **CW**:1600 ± 5 nm, **FWHM**:50 ± 5 nm	Not ordered
Optical Filter FB2250-500	Thorlabs	TBD	TBD	TBD	2,808.00 SEK	**WR**:2000-2500 nm, **AR**:2000-2500 nm, **CW**:2250 ± 50 nm, **FWHM**:500 ± 100 nm	Not ordered
Aluminium rough-cast plate	Alfer/Elfa	TBD	200x250x0.8 mm	TBD	77.20 SEK	...	Not ordered

Aluminium perforated plate (roundholes)	Alfer/Elfa	Mass	200x250x1.5 mm	TBD	204 SEK	...	Not ordered
Mounting plate Aluminium	Pentair Schroff/Elfa	Mass	84x220x2 mm	TBD	179 SEK	...	Not ordered
Mounting plate Aluminium	Pentair Schroff/Elfa	Mass	84x280x2 mm	TBD	193 SEK	...	Not ordered
Mounting plate Aluminium	Pentair Schroff/Elfa	Mass	84x460x2 mm	TBD	256 SEK	...	Not ordered
Mounting plate Aluminium	Pentair Schroff/Elfa	Mass	84x400x2 mm	TBD	187 SEK	...	Not ordered
Mounting plate Aluminium	Pentair Schroff/Elfa	Mass	84x340x2 mm	TBD	218 SEK	...	Not ordered
Sheet aluminium, blank	Alfer/Elfa	Mass	500x250x0.3 mm	TBD	33.10 SEK	High Priority	Not ordered
Sheet aluminium, blank	Alfer/Elfa	Mass	500x250x0.5 mm	TBD	50.60 SEK	High Priority	Not ordered
Sheet aluminium, blank	Alfer/Elfa	Mass	500x250x0.8 mm	TBD	57.60 SEK	High Priority	Not ordered

Explanations: **WR** = Wanted Range, **AR** = Actual Range, **CW** = Center Wavelength,
***** = Exact range not found

Table 10: Upper Box mass and volume

Experiment mass (in kg):	2,046
Experiment dimensions (in m):	0,2×0,17×0,13
Experiment footprint area (in m2):	0,026
Experiment volume (in m3):	0,003
Experiment expected COG position:	x = 0,385 [m]; y = 0,488 [m]; z = 0,004 [m]

Table 11: Bottom Box mass and volume

Experiment mass (in kg):	0,503
Experiment dimensions (in m):	0,12×0,07×0,035
Experiment footprint area (in m2):	0,008
Experiment volume (in m3):	0,0003
Experiment expected COG position:	x = 0,107 [m]; y = -0,289 [m]; z = -0,009 [m]

Table 12: Lower Floor Sensor mass and volume

Experiment mass (in kg):	5,12
Experiment dimensions (in m):	0,36×0,33×0,076
Experiment footprint area (in m2):	0,121
Experiment volume (in m3):	0,002
Experiment expected COG position:	x = 0,366 [m]; y = -0,359 [m]; z = 0 [m]

4.4 Mechanical Design

The floor mounted unit is composed of a sensor array and a camera. Each of these components is mounted on a box attached to the floor of the gondola on its outer side. By attaching an specially designed plate around the beams of the gondola frame and then fastening this box to this plate, the number of holes on the gondola plates is minimised. A description of the mounting of these components in the box is shown on fig. 10.

The bottom box, attached to the provided gondola rails, is composed of an Arduino microcontroller and other necessary electronic components that control the bottom sensor array, which is located on the floor mounted unit. The inside of the aluminium panel box is covered by a layer of thermal insulating material, namely polyurethane, where the electronic unit is sealed. The mounting of the components of the bottom box is shown on fig. 15.

The upper box, attached to the gondola upper frame, is composed of a sensor array, an Arduino microcontroller, a Raspberry Pi board, a GPS receiver and other electronic components. Different cutaway of the structure are represented on fig. 11, 12, 13 and 14. The frame bar structure of this box is encircled by a layer of thermally insulating material to keep the thermal sensitive components within their thermal survivability range.

Heaters and an active thermal control device are also inside this box to allow for active thermal control of this box. To further ensure the survivability of this box -as it will contain the data collected during the experiment- it will be constructed to be water-proof.

Beams and plates used on the experiment are created in aluminium alloys (Al). Additional nuts and bolts for attaching some of these elements together -as well as the equipment to the structure- are made of steel.

It should be noted that despite the presence of crash pads on the bottom of the gondola, there is a risk of the lower sensor array being crushed if the gondola lands on a hard protrusion on the ground, such as a rock. Using sacrificial joints to prevent the failure of the instruments is still under investigation.

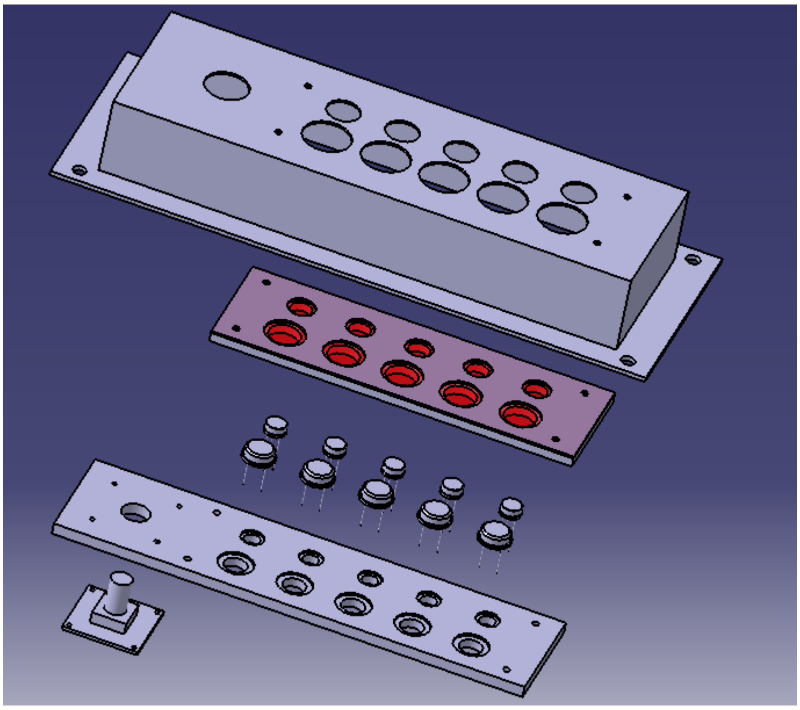

Figure 10: View of the components forming the sensor box.

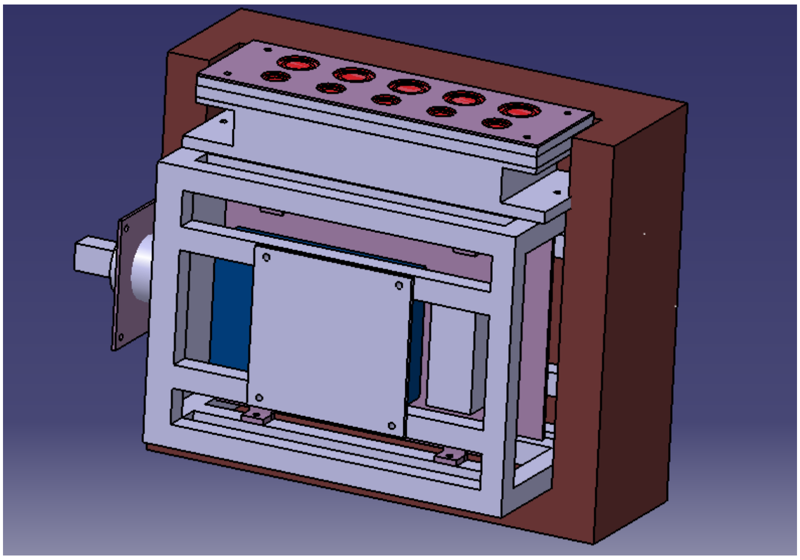

Figure 11: Cutaway view of the upper box.

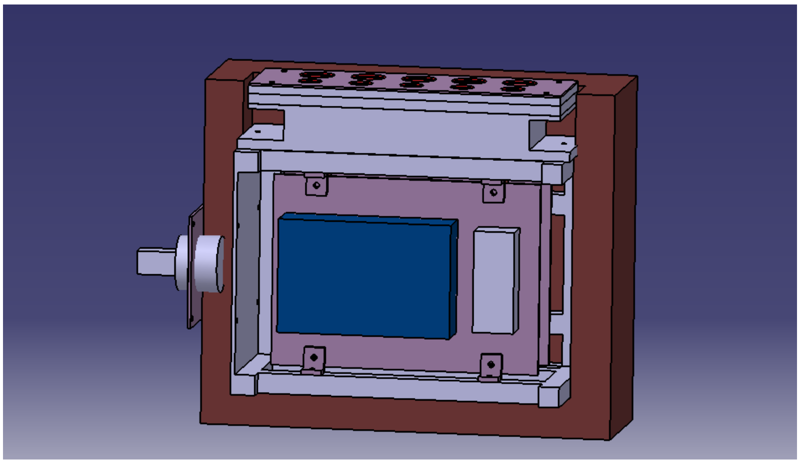

Figure 12: Cutaway view of the upper box. Raspberry and data storage unit are shown.

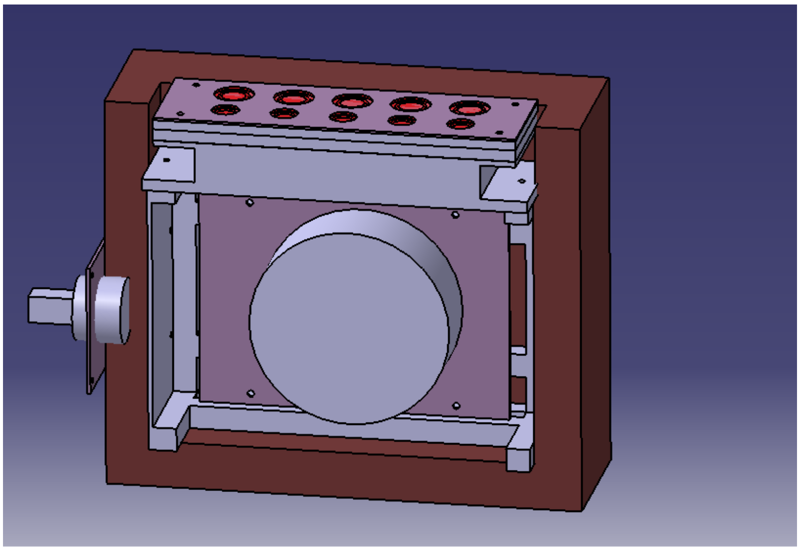

Figure 13: Cutaway view of the upper box. GPS sensor is shown.

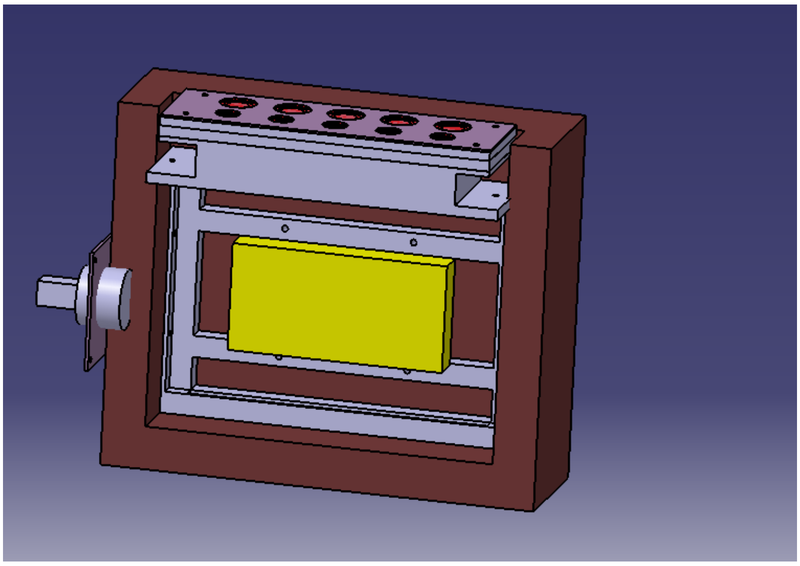

Figure 14: Cutaway view of the upper box. Arduino and electronic components unit are shown.

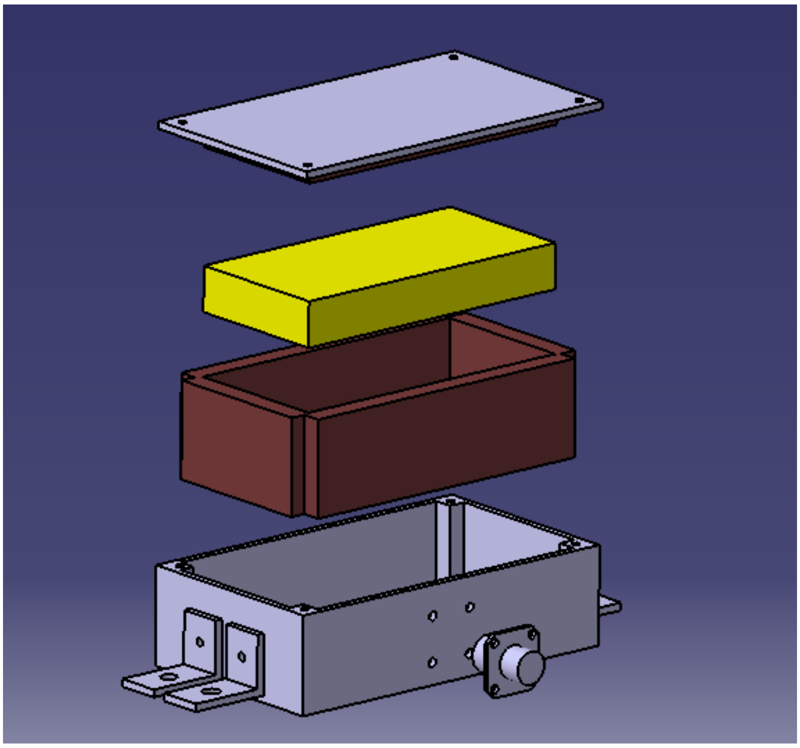

Figure 15: View of the components forming the data storage unit.

4.5 Electronics Design

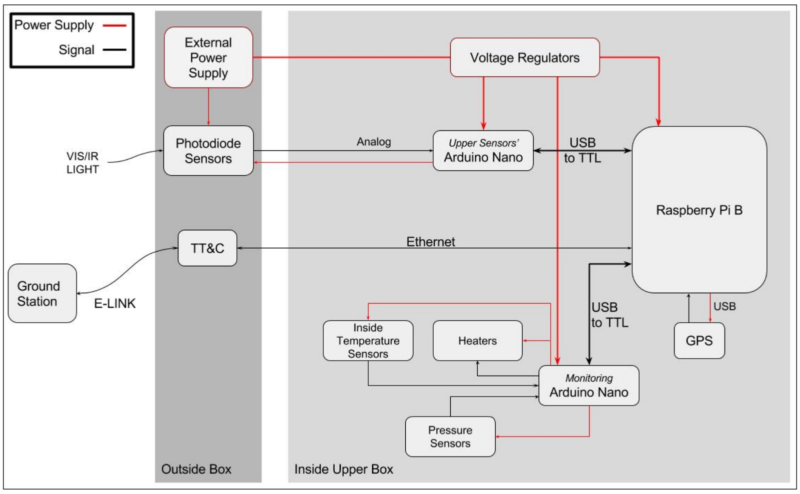

Figure 16: A block diagram of the electronics and interfaces that will be planted in the upper box.

Fig. 16 shows the design and interfaces of the electronics that will be placed in the upper box. Fig. 17 shows the design and interfaces of the electronics that will be placed in the lower box.

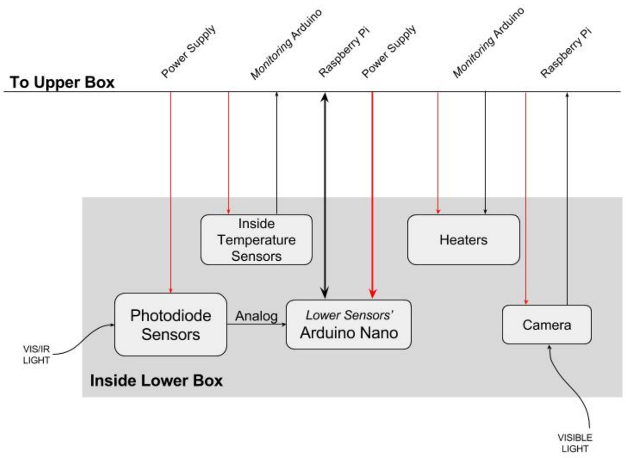

Figure 17: A block diagram of the electronics and interfaces that will be planted in the lower box.

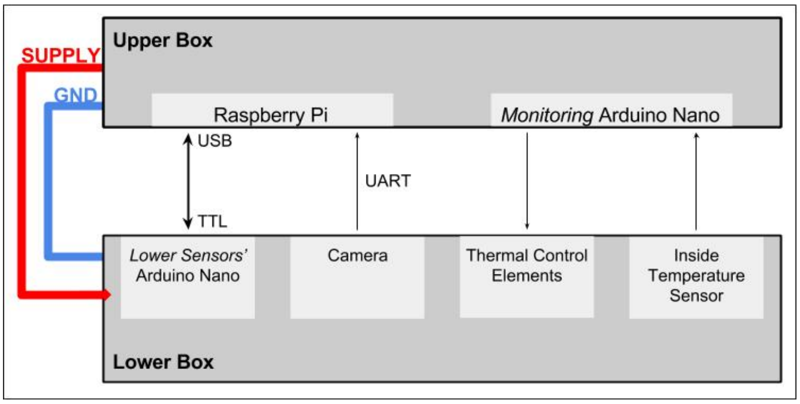

Figure 18: An overview of the interaction between the upper and lower box.

Fig. 18 shows how the upper and lower box will be connected.

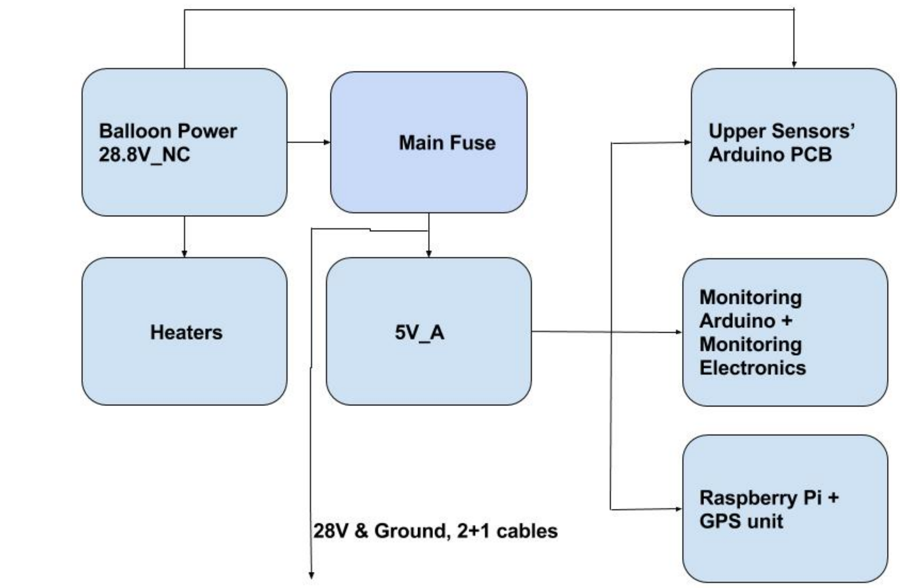

Figure 19: A block diagram of the power supply of the upper box

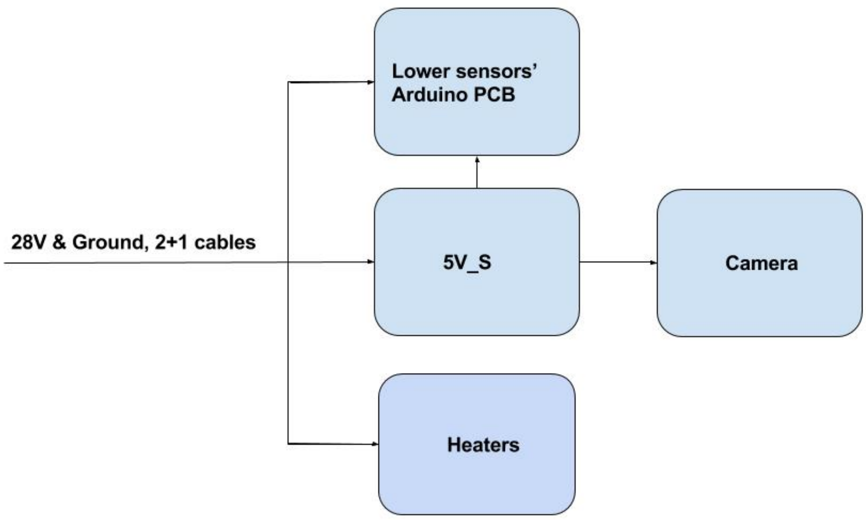

Figure 20: A block diagram of the power supply of the lower box.

Fig. 19 is showing the power supply setup in the upper box. 28.8 V from the gondola is distributed to the heaters, the upper sensors' Arduino and a fuse. From the fuse, 28.8 V are converted to 5 V in a DC/DC converter and then fed to the upper sensors' Arduino PCB, the monitoring Arduino plus the monitoring electronics (which consists of a temperature and a pressure sensor). The GPS device is powered by the Raspberry Pi via USB and the photo diodes are powered by the Arduino. From the fuse, three cables, 28 V and ground, go into the lower box.

Fig. 20 is showing the power supply setup in the lower box. 28 V controlled by the fuse are fed to the lower sensors' Arduino PCB, the heaters and a DC/DC converter which provides 5 V to the camera. The temperature sensor in the lower box will be powered by the monitoring Arduino located in the upper box.

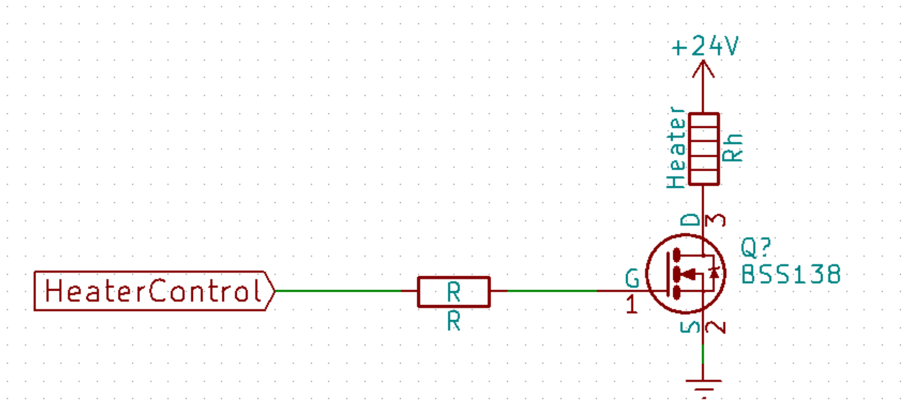

Figure 21: Simple heater circuit

Fig. 21 is showing a simple circuit for heating. The heater is controlled by a PWM signal *HeaterControl* from the Arduino using a transistor. The heater resistance R_h shall be chosen to be high enough so the power dissipated will not exceed the power budget in case of software failure.

Fig. 22 is showing the circuit for measuring light with different wavelengths using photo diodes. On one sensor board, the 10 photo diodes are connected to five analog inputs on the Arduino board. This is realised by including switches in between the diode output and the board, letting it switch between sampling the first five readings and the other five readings, continually. During the period that the controller is reading the first five photo diodes' voltage, the other five are effectively disconnected, and vice versa for the next period. The Arduino controls the diodes' voltage supply, using its digital output pin and a FET transistor to trigger the relays by drawing current from the supply battery.

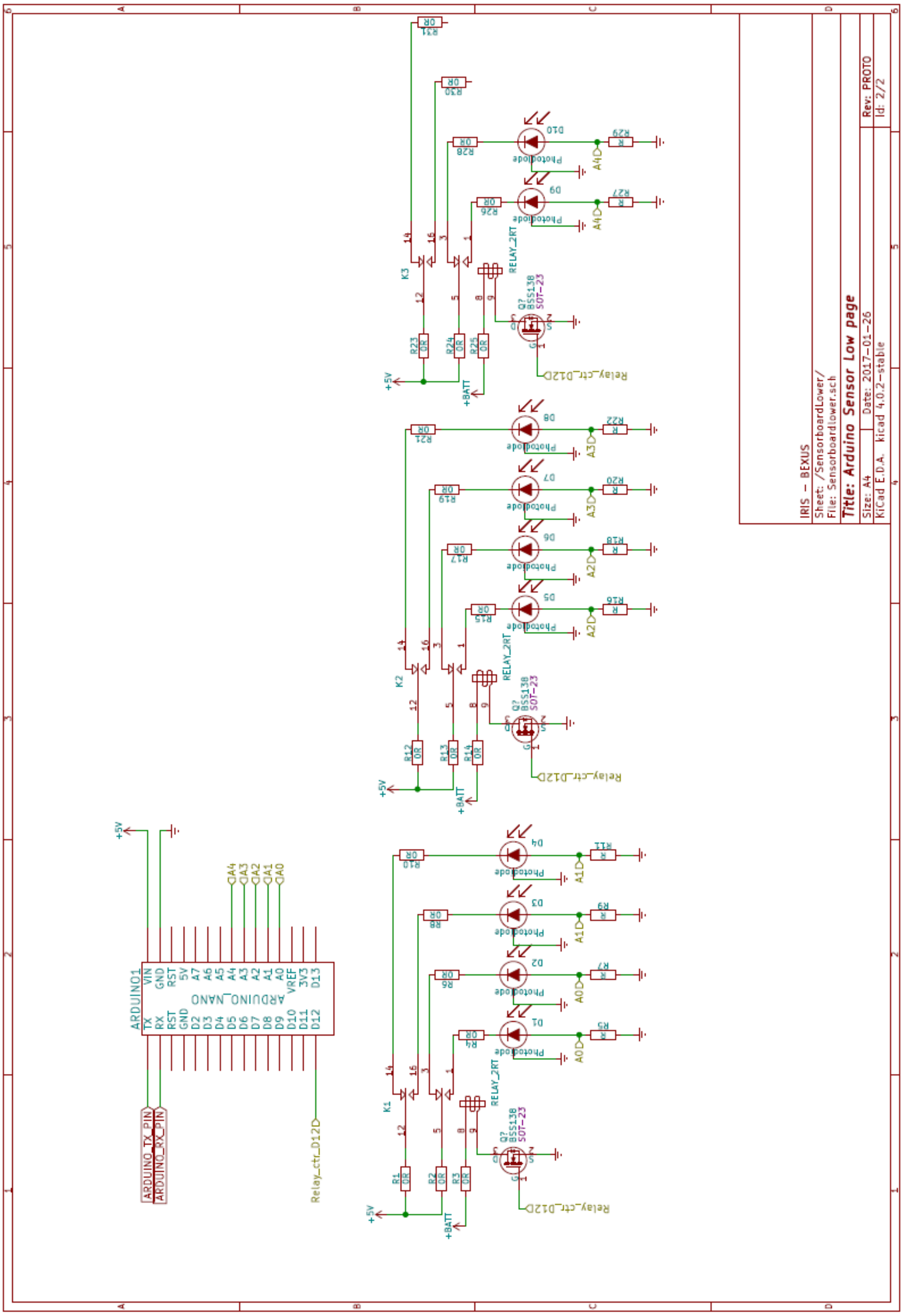

Figure 22: Photodiode circuit

4.6 Thermal Design

The lowest temperature ever recorded on the altitude range of HAB flights is -90 ºC [2], which allows to set this temperature as the lowest possible minimum temperature the experiment might encounter.

Tab. 13 shows the expected operating maximum and minimum temperature of each component, as well as their longevity temperature range.

Table 13: Component thermal range table

ID	Component	Operating T(°C)		Survivable (°C)		Comments
		Min	Max	Min	Max	
1	Serial Camera Module	-30	85	-40	105	
2	GPS Reciever	-30	80	-40	90	
3	Barometer	-40	85	-40	125	
4	Photodiode G12183-030K Longwave	-40	85	-55	125	
5	Photodiode S1336-8BK	-40	100	-55	125	
6	Raspberry Pi Model B+	0	70	-20	85	
7	Arduino Nano	-40	85	-40	85	
8	DC/DC Converter	0	70	-65	150	
9	Diode Relay	-25	65	-25	65	
10	Diode Circuit Transistor	-55	150	-55	150	

The thermal control subsystem is divided into passive and active thermal control. The former is carried out by thermal insulation located on the inner side of the boxes containing the equipment. Active thermal control is accomplished by the use of heaters, which is controlled by a dedicated microcontroller (MCU). The MCU is using the temperature measurements from the interior thermometers to ensure the components are going to be working under their operational temperature ranges, as shown in fig. 5.

In order to design the thermal control system, a first approximation analysis of thermal power balance was conducted. It is intended to represent a worst-case scenario, where thermal losses are the highest possible. For this model, the following assumptions were made:

- Exterior temperature is -90 ºC.
- Interior temperature of each of the three boxes is 0 ºC.
- Each box shows three of its sides to the Sun, which are assumed to be perpendicular to it.
- No thermal insulation is present in any of the boxes.

- Only heat generated by the electronics contained in the boxes and incoming solar radiation are considered to contribute to power input. The former is obtained from tab. 14 as the power consumed by each component.

- Only convective and radiative thermal losses are considered. Thermal losses towards the gondola structure due to conduction were not considered due to lack of data about the thermal power generation of the gondola.

This analysis provides the following results for thermal power balance on each box, using the Stefan-Boltzmann Law and Newton's Law of Cooling for calculating radiative and convective losses respectively:

- Upper box: $-79.8\ W$

- Lower box that contains the bottom sensor array: $-23.7\ W$

- Lower box that contains the electronics for the bottom sensor array: $-66.3\ W$

These results are intended to provide an upper limit for the requirements of the thermal control system, and as such should not be considered as the normal working values.

4.7 Power System

To fulfil the power needs for the project, a battery pack is available for use. The pack is stated to be able to provide 28.8 V/1 mA and has 13 Ah. One other constraint that must be considered is the 1.8 A continuous use of current as stated in the BEXUS user manual. With these constraints well defined, the list of components can be added, and determined in case additional power will be required. The first estimate of the power for the experiment seems to fit within these margins as stated below in tab. 14. The power budget will also be able to support a possible number of heaters, which will be placed at strategic locations, if they are considered necessary after the problem areas have been identified.

Table 14: Power consumption estimation

ID	Component	Voltage [V]	Current [mA]	Power [W]	Total [Wh]
1	Serial Camera Module	5	90	0.45	12.5
2	GPS Receiver	5	110	0.55	5.5
3	Pressure sensor	3.3	1.4	0.00462	0.0462
4	Photodiode G12183-030K Longwave	5	N/A	N/A	N/A
5	Photodiode S1336-8BK	5	N/A	N/A	N/A
6	Raspberry Pi Model B+	5	1000	5	50
7	Arduino Nano	5	2×19	0.19	1.9
8	Diode Relay	5	100	0.5	5
9	Diode Circuit Transistor	N/A	N/A	N/A	N/A
10	**Total**	N/A	1240.4	6.26962	62.6962

All DC/DC converters have heat loss when reducing the voltage, usually the efficiency is between 88 to 90 % so it's reasonable to increase the consumption with approximately 15 % from what is shown in tab. 14.

4.8 Software Design

4.8.1 Purpose

The software will be responsible for monitoring, housekeeping and data handling of the experiment IRIS. A monitoring and housekeeping subsystem will be designed, and environmental experiment data shall be stored and a portion transmitted to a ground station to aid a successful mission.

4.8.2 Design

4.8.2.1 Process overview

The system has been designed to fulfil three main functions: handling measured data, telemetry for sending back data to ground, and monitoring and housekeeping internal systems.

Most of the measured data is to be stored on an internal memory in the form of a SD-card. Some data from the camera uses the downlink during the early parts of the mission, specifically the ascent, to utilise the larger downlink rates and ease constraints on the memory budget and reduce the risk of experiment result returning NULL. The central hub and coordinator will be a SOC, in particular a Raspberry Pi (RPi). The RPi shall be responsible for data handling, data storage, telemetry and talking to the MCU:s (Arduino) that relay data from the sensors to the RPi.

There will be a total of three MCU's. Two MCU's will be interfaced with the sensors in a nominal mission capacity, while the third MCU will be used as a system monitor for error handling and control of thermal systems.

The process, including interfaces, is described graphically in fig. 23, where the brackets encapsulate the software role for each component with respect to the three main functions listed.

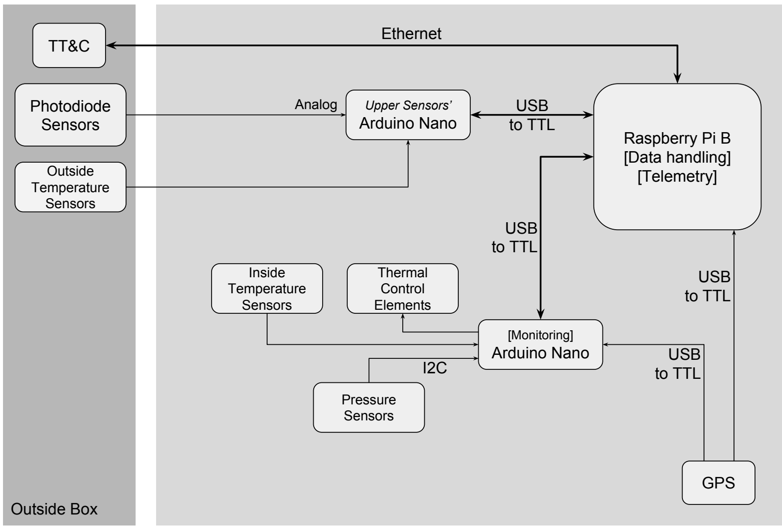

Figure 23: Process Overview Diagram

4.8.2.2 General safety related concepts

The experiment features a monitoring system independent from the main data handling system, which is in charge of handling errors, restarting the system in case of major malfunction and controlling environmental factors (operating temperature for sensors). Some of the possible failure modes are described in tab. 15.

4.8.2.3 Interfaces

The platform uses mainly two interfaces: Serial communication among the components, and Ethernet Base 10/100 for communicating with the E-Link. The module shall be able to transmit part of the data gathered and stored, operate autonomously in the event of loss of communication with ground station, and ensure a correct transmission from the sensors to the storage unit.

The telemetry sent via the E-link has a TBD size, and every packet will feature a header and terminator. Tab. 16 depicts the packet design for the telemetry data.

Table 15: General safety concerns

Topic	Possible errors and safety concerns	Mitigation measures
Initialization	- Any of the connected devices through UART does not initialize. ADC or storage fails to start.	- If the monitor is initialized but none of the other interfaces are, the monitor will try to reboot the system. - If the Ethernet interface with the E-link is initialized but no other interface is, a critical failure message will be sent. One restart attempt will happen after that. - If all the system initializes but the monitor interface, a warning will be sent through the downlink.
Data storage	- Possible corruption or loss of data	- Shut down the system before touchdown, disconnect power from the storage unit to avoid damage.
Heaters	- Temperature inside the experiment boxes is under/over the thresholds before lift-off.	- Monitor temperature on the experiment before lift-off will be monitored and action will be taken.
Sensors performance	- Any malfunction in sensors is detected.	- Readings will continue to be taken, but a flag/message indicating faulty measurements will be added.
E-link connection	- Connection is lost or not working.	- The system will continue to work with pre-stored conditions for loss of communications. - Data transmission will be halted until connection is recovered.
Test	- The system has rebooted, or dedicated command has been received.	- During test mode little data will be stored and testing telemetry will be sent through the command link for troubleshooting. It will be determined by the number of tasks to be performed.

Table 16: Telemetry and telecommand messages

Name	SYNC	MID	DATA	STAT	CHK
Description	Synchronization	Message ID	Transmitted message	Status	Checksum
Size	2 bytes	2 bytes	1-16 bytes	1 byte	2 bytes
Use	Initialization of reception and syncing	States the nature of the message and its length	The data transmitted	Gives telemetry data or mode of operation	Checks errors of the message

The telecommand functionality will follow the same packet distribution as the telemetry design, but featuring a fixed 1 byte transmitted data section for the command.

The minimum expected bandwidth is 100 kbps, the nominal 200 kbps and the maximum 800 kbps for downlink. The uplink of commands is expected to be sporadic messages for command, minimum of 0 kbps, nominal of 20 bytes and peak of 50 bytes.

Regarding the internal communication system, the interfaces will be serial communication and the reception of the data from the sensors is done in analog fashion. Some sensors already feature a serial I2C interface, and the actuation on the thermal control system will be done using PWM signals.

The communication protocol with the off-the-shelf components using serial such as the GPS and camera is TBD. However, for the communication between the Arduino MCUs and RPi the communication will be as follows on tab. 17.

Table 17: Inner communication packet design

Name	SYNC	MID	VAL	STAT	PAR
Description	Synchronization	Message ID	Transmitted value	Status	Parity bit
Size	2 bits	8 bits	8-12 bits	1 bit	1 bit
Use	Initialization of reception and syncing	States procedence of the message and the sensor generating the value	The value transmitted	States the calibration of the sensor	Checks errors of the message

To avoid corrupt data on transmission, a checksum in larger and a parity bit in short messages is included. Critical messages (such as commanded shut down from ground) will be sent twice for the experiment not to be blocked by these.

Please refer to section 4.5 for more information on the analog interfaces.

4.8.2.4 Data acquisition and storage

The RPi used in the experiment has an inbuilt microSD card slot. This is used to store the boot information for the board's software and the data gathered by the sensors. The estimated amount of data from the sensors is two bytes from each of the photodiodes, and between 400 and 800 kB for the single camera reading. Position, temperature and pressure readings are also considered a total amount of 1 kB.

The experiment shall take measurements with a delay of between 5 and 10 seconds, and the approximate flight time is around six hours. Therefore, the expected amount of data generated is 4 GB, which can be solved with one 8 GB microSD card.

Part or the complete of the data will be sent back to the ground station. The station features a fully capable computer that integrates enough storage capacity for the data that has been sent.

The data files to be used for this purpose are txt files generated as a CSV file to store the sensor data, and JPEG format to store the information about the images.

4.8.2.5 Process Flow

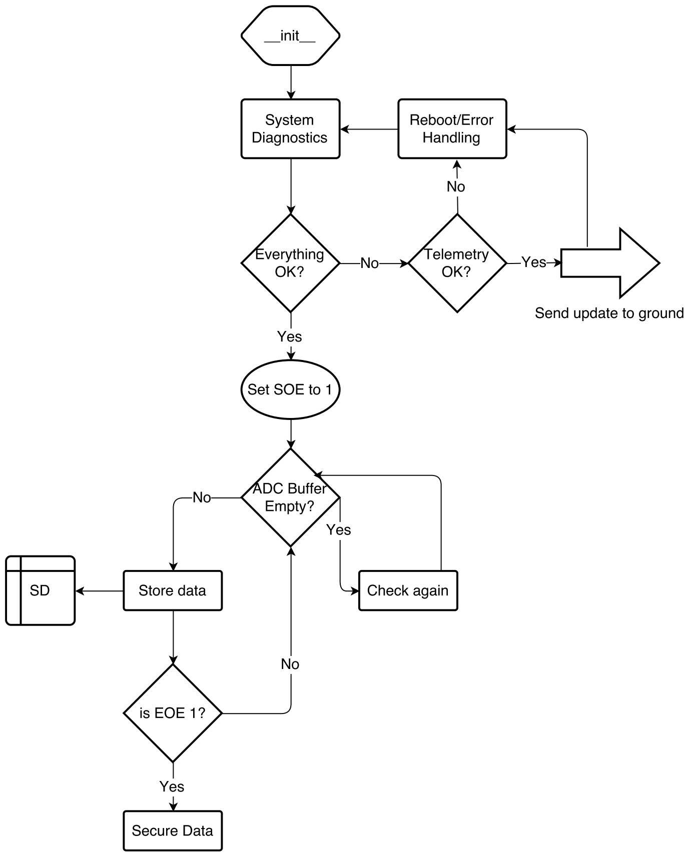

Figure 24: RPi Process Flow

The SOC is initialized according to its boot procedure by applying power, which then initializes all objects. The monitoring object is initialized on one of the Arduino MCU's and is responsible for the "System Diagnostics" block, by receiving initialization data, performing checks, and verifying integrity of system initialization. If everything checks out, SOE will be set to 1 and data collection can start. The sensor object will start generating data, which will fill the buffer of the MCU's interfaced with the external sensors. The ADC will be continuously measured by the MCU, and the SOC will ask the MCU's for available data.

4.8.2.6 Modularization and pseudo code

The system software architecture can be divided into three different modules with different functions. This functions are data acquisition, system monitoring and housekeeping and data handling and storage.

The data acquisition module will be in charge of reading the sensors. It will be programmed in Arduino IDE. The main objects included in this module will be:

- **Data gathering:** Will provide the functions to other objects to make a readout of the sensors.
- **Serial Interface:** Will be in charge of handling the requests from the serial interface and send the relevant information.
- **Calibration:** Will provide a function to calibrate the sensors, and will return the values associated with them.
- **Mode:** Will store the information about the mode of operation and will decide which actions are taken by the rest of the module.
- **Initialization:** Will be the first object to take action, initializing all the other objects and checking that they are functioning correctly.

The second module will be in charge of monitoring all the other modules, ensuring that they work correctly and taking action when they do not perform as intended. It will also be in charge of controlling the environment and will relay the information of internal housekeeping to the main unit. The main objects of the module will be:

- **Data gathering:** Will provide the functions to other objects to make a readout of the sensors.
- **Serial Interface:** Will be in charge of handling the requests from the serial interface and send the relevant information.
- **Actuator:** Will be in charge or providing the control mechanism for the thermal resistance to heat the module in case temperature runs out of limits.
- **Monitoring:** Will check all the subsystems and will set the modes of operation of them.
- **Error control:** Will set the modes of operation of the subsystems in function of the errors reported. Will also shut down the main computer when the flight is about to end.
- **Initialization:** Will initialize all the objects and will check that all the other modules have started correctly.

Finally, the third module is the main system data handling and storage. It will also provide the interface to the E-Link, allowing to communicate with the ground station. It will run an operating system based on Linux, and the code will be programmed in Python. The main objects of this module are:

- **Data collection:** Will communicate with other modules to ask for the values of the sensors.
- **Mode:** Will hold the mode of operation for the actions that have to be taken. Will also execute the shutdown command when commanded by the monitoring module.

- **Data storing:** Will handle the files to store the values and will provide the function to other objects.
- **System inialization:** Will initialize all the interfaces and objects.
- **Ethernet interface:** Will provide the functions necessary to communicate through the E-link and will generate the package to be sent.
- **Serial interface:** Will provide the functions to handle communications through the Serial interfaces.

It is still to be determined which of the modules should include an I2C connection object to provide the handling of the interfaces to the sensors.

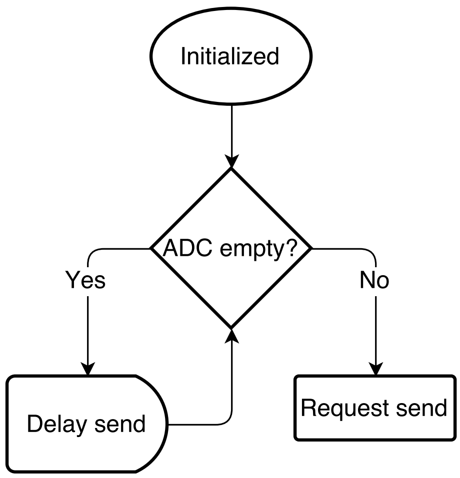

Figure 25: Sensor MCU Process Flow

The initialization signal from the SOC lets the MCU know it's OK to start collecting analogue data, which will be fed from the sensors, converted to digital and sent to the SOC.

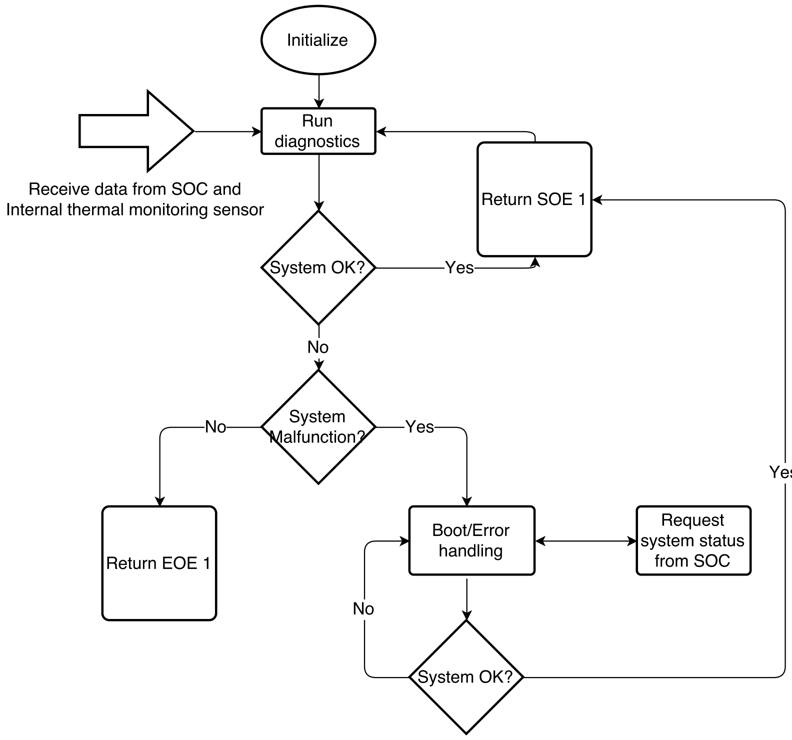

Figure 26: Monitor MCU Process Flow

4.8.3 Implementation

The languages to implement the code are Arduino and Python. Arduino is an IDE based on C++ with custom built functions, that verifies, compiles and uploads the code to the Arduino-compatible boards (based on Atmel controllers). However, it can be programmed outside this environment with Atmel studio and the output runfile uploaded to the controllers without using the environment.

Regarding Python, it is included as part of Anaconda IDE. It is an interpreted language that allows for handling and representing high amounts of data. It is as well integrated with the RPi environment. The possible libraries to be included would be Ethernet handling libraries, as well as for creating and storing text files and images.

4.9 Ground Support Equipment

The ground support equipment will consist of a computer with an Ethernet interface connected to the ground station to receive the data. It is still TBD if the ground station will use Python or Matlab to provide a GUI to evaluate images in real time.

5 Experiment Verification and Testing

5.1 Verification Matrix

- I - Verification by inspection
- R - Verification by review-of-design
- A - Verification by analysis or similarity
- T - Verification by test

Table 18: Verification Matrix

ID	Requirement text	Verification	Test number	Status
P.1	The experiment shall be able to distinguish between incoming and outgoing from Earth radiation.	R	-	To be done
P.2	The experiment shall measure the electromagnetic spectrum from 0.3 μm to 2.5 μm with a minimum sensitivity of 200 $mW \cdot m^{-2}$	I, T	Test 1	To be done, see test plan
P.3 to P.10	The experiment shall measure the 0.43 μm to 0.45 μm, 0.45 μm to 0.51 μm, 0.53 μm to 0.59 μm, 0.63 μm to 0.67 μm, 0.85 μm to 0.88 μm, 1.36 μm to 1.38 μm, 1.56 μm to 1.65 μm, 2.00 μm to 2.50 μm with a precision of $\pm$0.005 μm.	I, T	Test 1	To be done, see test plan
P.11	The sampling rate of the experiment shall be between 5 and 10 seconds.	A, T	Test 2	To be done, see test plan
P.12	The sampling delay shall not exceed 30 seconds.	A, T	Test 2	To be done, see test plan

P.13	The experiment shall measure the pressure from 5 to 1100 $mbar$.	I, T	Test 3	To be done, see test plan
P.14	The experiment shall measure the pressure with a minimum accuracy of 10 $mbar$.	I, T	Test 3	To be done, see test plan
P.15	The experiment shall measure the temperature from -90 to 30 $°C$.	I, T	Test 4	To be done, see test plan
P.16	The experiment shall measure the temperature with a minimum accuracy of ± 0.5 $°C$.	I, T	Test 4	To be done, see test plan
P.17	The experiment shall measure the position with a minimum accuracy of ± 10 m.	I, T	Test 5	To be done, see test plan
D.1	The experiment shall not include components that could prove to be dangerous for people.	R	-	To be done
D.2	The experiment shall not include components that disturb or harm the launch vehicle.	R	-	To be done
D.3	The experiment shall not include components that disturb or harm other experiments.	R	-	To be done
D.4	The experiment shall not weigh more than 8 kg upon launch.	R, T	Test 6	To be done, see test plan
D.5	The experiment shall withstand vertical accelerations within the BEXUS flight and launch profile.	A, T	Test 7	To be done, see test plan

D.6	The experiment shall withstand horizontal accelerations within the BEXUS launch and flight profile.	A, T	Test 7	To be done, see test plan
D.7	The experiment's data storage unit should withstand shocks of up to 35 g during landing.	A, T	Test 7	To be done, see test plan
D.8	The experiment shall withstand vibrations related to handling and transportation before and after flight.	A, T	Test 13	To be done, see test plan
D.9	The experiment shall withstand pressures within the BEXUS flight profile.	R, T	Test 3	To be done, see test plan
D.10	The experiment shall withstand temperatures within the BEXUS flight profile.	R, T	Test 4	To be done, see test plan
D.11	The experiment shall not be at risk of falling from the gondola during flight and launch.	R, T	Tests 7, 11	To be done, see test plan
D.12	The experiment shall not slide or translate inside the during flight and launch.	R, A	-	To be done
D.13	The experiment should be attached to the gondola rails if possible.	R	-	To be done
D.14	The fastening to the gondola rails shall be carried out with M6 bolts with 23 mm thread length.	R	-	To be done
D.15	The experiment shall use a sufficient number of brackets on bottom plates in order to facilitate mounting of experiments.	R	-	To be done

D.16	The experiment shall operate at temperatures within the BEXUS vehicle flight and launch profile.	R, T	Test 4	To be done, see test plan
D.17	All experiment critical components shall be accessible within 2 minutes.	R, T	Test 8	To be done, see test plan
D.18	The replacement time of the critical components shall be within 5 minutes.	R, T	Test 8	To be done, see test plan
D.19	The experiment shall use a maximum electrical energy of 275 Wh.	R, A, T	Test 9	To be done, see test plan
D.20	The experiment shall use Ethernet 10/100 Base-T with RJ45 connectors for interfacing with the provided E-link.	R	-	To be done
D.21	The experiment shall use Ethernet 10/100 Base-T with RJ45 connectors for interfacing with the ground station.	R	-	To be done
D.22	The experiment shall use a 4 pin, male, box mount receptacle MIL-C-26482P series 1 connector with an 8-4 insert arrangement as power interface.	R	-	To be done
D.23	The data storage unit shall withstand any post-landing environment within the mission profile without corruption or loss of data for at least 3 days.	R, A, T	Test 10	To be done, see test plan

D.24	The experiment shall be able to handle two aborted launches.	R	-	To be done
D.25	The experiment shall not use a downlink rate greater than 200 kbit/s.	R, A	-	To be done
D.26	The experiment may include sacrificial joints or other contingency plans to avoid being damaged upon landing if it protrudes from the gondola.	R	-	To be done
D.27	The position of the experiment should be selected in order to reduce "noise" interference from other experiments.	R	-	To be done
O.1	The experiment sensors shall be clean from dust before launch.	I, T	Test 1	To be done, see test plan
O.2	The experiment shall accept commands from the ground station at any time.	A, T	Test 11	To be done, see test plan
O.3	The procedures to turn the experiment on and off should be kept simple.	A	-	To be done
O.4	The experiment shall perform autonomously in the event of loss of communication with the ground station.	R, T	Tests 11, 12	To be done, see test plan
O.5	The experiment shall be able to correctly handle aborted launch attempts during any point leading up to, including pre-flight tests, the launch.	R, T	Test 12	To be done, see test plan

5.2 Test Plan

- Test 1: Photodiodes Calibration Test
- Test 2: Data Collection Test
- Test 3: Low Pressure Test
- Test 4: Thermal Test
- Test 5: GPS Calibration Test
- Test 6: Weight Verification
- Test 7: Shock Test
- Test 8: Experiment Assembly and Disassembly Test
- Test 9: Power Test
- Test 10: Data Storage Unit Robustness Test
- Test 11: E-link Test
- Test 12: Autonomy Test
- Test 13: Vibration Test

Table 19: Test 1: Photodiodes Calibration test description

Test number	1
Test Type	Calibration and Verification
Test facility	Kiruna Space Campus laboratory
Tested item	Photodiodes, lenses and filters
Test level/procedure and duration	Test procedure: TBD (A given object, with well-known electromagnetic spectrum response, is used to examine the accuracy of the photodiodes, the functionality of the lenses and filters, determine the influence of dusts on the sensors). Test duration: TBD (~10 minutes)
Test campaign duration	Recurrent test until and during the launch campaign.
Test campaign date	April
Test completed	NO

Table 20: Test 2: Data Collection test description

Test number	2
Test Type	Software
Test facility	Kiruna Space Campus laboratory
Tested item	Micro-controller Unit and Experiment sensors
Test level/procedure and duration	Test procedure: TBD Test duration: 5 hours. Based on previous BEXUS flight durations.
Test campaign duration	2 days (1 day build-up, 1 day testing)
Test campaign date	June
Test completed	NO

Table 21: Test 3: Low pressure test description

Test number	3
Test Type	Low Pressure
Test facility	TBD (Esrange Space Center TBC)
Tested item	The whole experiment
Test level/procedure and duration	Test procedure: TBD (reproduce pressure similar to stratospheric pressure at 30 km. Verify that all subsystems are operational and reliable) Test duration: 5 hours.
Test campaign duration	3 days (1 day build-up, 1 day verification, 1 day testing)
Test campaign date	July-August
Test completed	NO

Table 22: Test 4: Thermal test description

Test number	4
Test Type	Thermal
Test facility	Esrange Space Center
Tested item	The whole experiment
Test level/procedure and duration	Test procedure: TBD (reproduce temperature of -80°C to verify that all subsystems are operational and reliable. Test of the active/passive thermal control unit). Test duration: 5 hours.
Test campaign duration	3 days (1 day build-up, 1 day verification, 1 day testing)
Test campaign date	July-August
Test completed	NO

Table 23: Test 5: GPS test description

Test number	5
Test Type	Calibration and Verification
Test facility	Kiruna Space Campus laboratory
Tested item	GPS unit
Test level/procedure and duration	Test procedure: TBD (Drive a car or climb a building to verify the GPS accuracy) Test duration: TBD (30 min).
Test campaign duration	1 day
Test campaign date	April
Test completed	NO

Table 24: Test 6: Weight verification test description

Test number	6
Test Type	Weight Verification
Test facility	Kiruna Space Campus laboratory
Tested item	The whole experiment
Test level/procedure and duration	Test procedure: TBD Test duration: TBD (1 min).
Test campaign duration	1 day
Test campaign date	July-August
Test completed	NO

Table 25: Test 7: Shock test description

Test number	7
Test Type	Shock
Test facility	Kiruna Space Campus laboratory
Tested item	The mechanical structure alone first and secondly the whole experiment.
Test level/procedure and duration	Test procedure: TBD. Test duration: TBD .
Test campaign duration	4 days
Test campaign date	July-August
Test completed	NO

Table 26: Test 8: Assembly Disassembly test description

Test number	8
Test Type	Assembly and Disassembly
Test facility	Kiruna Space Campus
Tested item	The whole experiment.
Test level/procedure and duration	Test procedure: TBD (All components are placed on a table, a chronometer is used to determine the time necessary to assemble the experiment. After assembly, the chronometer is restarted to calculate the time necessary to disassemble and replace components). Test duration: TBD (1 hour).
Test campaign duration	2 days
Test campaign date	July-August
Test completed	NO

Table 27: Test 9: Power test description

Test number	9
Test Type	Power
Test facility	5 Kiruna Space Campus
Tested item	All the components using electronic power.
Test level/procedure and duration	Test procedure: TBD Test duration: TBD (7hours, to reproduce pre-flight and flight conditions).
Test campaign duration	2 days (1day build-up, 1 day testing).
Test campaign date	July-August
Test completed	NO

Table 28: Test 10: Data storage unit robustness test description

Test number	10
Test Type	Robustness
Test facility	Kiruna Space Campus laboratory
Tested item	Data Storage Unit
Test level/procedure and duration	Test procedure: TBD (The data storage unit will be tested in various conditions to assure its resistance for post-landing environmental conditions. Example: put data storage in water, soil, snow,etc. Verify mechanical resistance of the data storage. Determine if sacrificial joints might be needed.) Test duration: TBD (2-3 days).
Test campaign duration	1 month
Test campaign date	April
Test completed	NO

Table 29: Test 11: E-link test description

Test number	11
Test Type	E-link
Test facility	TBD (Kiruna Space Campus or Esrange Space Center)
Tested item	TBD
Test level/procedure and duration	Test procedure: TBD Test duration: TBD
Test campaign duration	TBD
Test campaign date	TBD
Test completed	NO

Table 30: Test 12: Autonomy test description

Test number	12
Test Type	E-link
Test facility	TBD (Kiruna Space Campus or Esrange Space Center)
Tested item	TBD
Test level/procedure and duration	Test procedure: TBD Test duration: TBD.
Test campaign duration	TBD
Test campaign date	TBD
Test completed	NO

Table 31: Test 13: Vibration test description

Test number	13
Test Type	Vibration
Test facility	Kiruna Space Campus
Tested item	TBD
Test level/procedure and duration	Test procedure: TBD Test duration: TBD.
Test campaign duration	TBD
Test campaign date	TBD
Test completed	NO

5.3 Test Results

No tests has been conducted yet.

6 Launch Campaign Preparation

6.1 Input for the Campaign/Flight Requirements Plans

6.1.1 Dimensions and Mass

Table 32: Upper Box mass and volume

Experiment mass (in kg):	2,046
Experiment dimensions (in m):	0,2×0,17×0,13
Experiment footprint area (in m2):	0,026
Experiment volume (in m3):	0,003
Experiment expected COG position:	x = 0,385 [m]; y = 0,488 [m]; z = 0,004 [m]

Table 33: Bottom Box mass and volume

Experiment mass (in kg):	0,503
Experiment dimensions (in m):	0,12×0,07×0,035
Experiment footprint area (in m2):	0,008
Experiment volume (in m3):	0,0003
Experiment expected COG position:	x = 0,107 [m]; y = -0,289 [m]; z = -0,009 [m]

Table 34: Lower Floor Sensor mass and volume

Experiment mass (in kg):	5,12
Experiment dimensions (in m):	0,36×0,33×0,076
Experiment footprint area (in m2):	0,121
Experiment volume (in m3):	0,002
Experiment expected COG position:	x = 0,366 [m]; y = -0,359 [m]; z = 0 [m]

6.1.2 Safety Risks

There are no apparent safety concerns with the experiment regarding launch campaign preparation.

6.1.3 Electrical Interfaces

Please refer to tab. 35 for information on the electrical interfaces with the gondola.

6.1.4 Launch Site Requirements

The IRIS team will require a working space to mount the three boxes of the experiment on the gondola, and connect them together and to the gondola electrical interfaces (refer to section 4.2.2), as well as to dismount the experiment from the gondola after the flight. For this to be achieved, the following items will be required:

Table 35: Electrical interfaces applicable to BEXUS.

BEXUS Electrical Interfaces		
E-Link Interface: E-Link required? Yes		
	Number of E-Link interfaces:	1
	Data rate - downlink:	200 kbit/s
	Data rate – uplink:	1 kbit/s
	Interface type (RS-232, Ethernet):	Ethernet
Power system: Gondola power required? Yes		
	Peak power (or current) consumption:	6.79 W
	Average power (or current) consumption:	4.93 W
Power system: Experiment includes batteries? No		
	Type of batteries:	
	Number of batteries:	
	Capacity (1 battery):	Ah
	Voltage (1 battery):	V

- Thirteen (13) chairs
- At least one (1) table
- One (1) toolbox
- One (1) power outlet

6.1.5 Flight Requirements

There is no minimum float time for the experiment as measurements will be taken during the whole flight. Therefore, float time should be as long as possible.

In case of cloud-cover the IRIS experiment needs to be able to take measurements from above the clouds. Thus, float altitude should be at least high enough for the gondola to raise above the clouds that may be present at the day of launch. Most clouds, like cirrus clouds, are located in the troposphere, below the expected floating altitude of the HAB [11].

IRIS requires daylight in order to obtain the intended scientific data. As a result, launch should take place between sunrise and noon, to maximise the amount of daylight present during the flight. The minimum daylight time required should be during the ascend and 1 hour during the float time. If the flight is during the night we cannot guarantee to collect any meaningful data.

6.1.6 Accommodation Requirements

Sensor blocks shall be placed on top and beneath the gondola respectively. They shall also be located next to the gondola sides, as they can only be mounted on these locations due to the mechanical design of the experiment. Refer to section 4.4 for a sketch of the correct placement of the sensor boxes.

Gondola crash pads shall be mounted on the gondola before attempting to mount the experiment. This way the bottom sensor box can be attached while the gondola is resting on a surface, and accidental crushing of this particular sensor block under the weight of the gondola can be avoided.

Both sensor blocks have sensors pointing perpendicularly to the upper and lower surfaces of the gondola, which have a field of view close to 360º x 180º. Any other objects protruding from the upper or lower surfaces of the gondola should be placed as far away from the sensor blocks as possible to minimise interference.

Both sensor blocks shall remain uncovered during the whole flight, but they may be covered before and after flight if it is deemed necessary for handling the gondola by the launch and recovery crews.

6.2 Preparation and Test Activities at Esrange

TBD

6.3 Timeline for Countdown and Flight

The experiment will start measuring data at the time of launch. This will be activated by a command send through the link. It will stop recording data when it is at 10000 ft from ground prior to touchdown, to avoid data loss. The experiment, however, will be switched on prior to the restriction of access, or will be active at any time if power is correctly provided.

When the balloon reaches cruise altitude the experiment may need to switch the frequency at which the data is either gathered or sent to ground. For this, a command will be sent from the ground station. The experiment will however shut down automatically at the specified altitude, or by command prior to that point if considered necessary by the science team or due to low battery readings.

Tab. 36 summarizes the most important moments on countdown and during flight. Note that this is only a first guess and may suffer changes in the future.

6.4 Post-Flight Activities

The SD Memory card needs to be retrieved to save the full data collected during the flight. As our team is based in Kiruna, receiving the data from Esrange should not pose

Table 36: Experiment timeline during countdown and flight

Time	Action
T-4H	Experiment check-outs, ground
T-2H30	Experiment check-outs, mounted
T-1H00	Experiment check-outs, through E-Link
T+0	E-Link command to start recording, receiving data
T+∼83	Command to reduce acquisition rate
T+∼4H	Check reception of shutdown

any difficulties.

Afterwards the science team will start analysing the data, providing preliminary results for the post-flight meeting and later a full analysis for the final report. Scientific publications are also planed as well as possible presentations at conferences such as EGU - general assembly.

7 Data Analysis and Results

7.1 Data Analysis Plan

The data from the sensors will be used to compute the irradiances that comes in from the sun and that is reflected from the surface and lower part of the atmosphere. By comparing the two values the bond albedo can be calculated.
The measurements during the ascend phase will give the change of the albedo along the (increasing) height.

A model for radiative transfer (RT) in the atmosphere shall be used. A model like e.g.'FUTBOLIN' [15] will be used to model the different radiative components that are coming in onto the surface as well as the outgoing reflected flux, at the according radiation conditions. These RT models are important for satellite measurements as they are used for the retrieval. By comparing the measured values with the model results, both this model and our measurements can be evaluated. If our measurements and the modelled values are in disagreement, further data analysis could reveal where the error is located and eventually improve the model. An improved radiative transfer model will help to improve the accuracy of satellite measurement evaluation.

For the error analysis many factors have to be taken into account, from the movement of the gondola, the position of the sun in the sky to the potential shadows cast by cables and possibly other experiments.

It is possible that the sun in October, in northern Sweden, is very low on the horizon and therefore it will not directly contribute to the sensors mounted on the top array. Nevertheless, this should not be a problem as a lot of radiation is scattered in the atmosphere. The measurement should reflect the true flux coming from the top and the flux from the bottom.

7.2 Launch Campaign

TBD

7.3 Results

There will be three measurement periods during the flight: the ascent, the float phase and the descent.
During ascent the albedo is expected to vary significantly, because some radiation is absorbed by water vapour in the troposphere. This absorption does not apply for the VIS wavelength spectrum. In the case of clouds or haze much light in the VIS spectrum will be scattered. Therefore, the incident radiation at the top is expected to increase with altitude. In the case of cloud coverage the albedo is expected to increase, as clouds have a high reflectance.
While the balloon is floating the albedo is expected to stabilise, only varying when passing over possible water bodies, such as lakes and rivers or when passing over single clouds.

The measurements during the descent phase should resemble those during the ascent phase.

One expected outcome of the subsequent analysis should be to find a better relation with the albedo throughout changing altitude, contributing to the correction of the errors in the satellite measurements.

This can be achieved by comparing and contrasting the data from both methodologies and calculating the error made from the remote sensing satellites, which measurements are less accurate than the HAB used in this project, as the data in the HAB case is gathered in-situ.

7.4 Lessons Learned

TBD

8 Abbreviations and References

8.1 Abbreviations

ADC	Analog-to-digital converter
BEXUS	Balloon Experiment for University Students
CATIA	Computer Aided Three-dimensional Interactive Application
CERES	Clouds and the Earth's Radiant Energy System
ECTS	Europeant Credit Transfer System
EM	Electromagnetic
EOE	End of Experiment
EGU	European Geosciences Union
ESRANGE	European Space and Sounding Rocket Range
EXIST	Examination of Infrasound in the Stratosphere and Troposphere
FUTBOLIN	Full Transfer by Ordinary LINe-by-line methods
GPS	Global Positioning System
HAB	High Altitude Balloon
HEP	High Energy Physics
I2C	Inter-Integrated Circuit
IDE	Integrated Software Environment
IR	Infrared part of the EM spectrum
IRIS	InfraRed albedo measurements In the Stratosphere
LTE	Local Thermodynamic Equilibrium
LTU	Luleå University of Technology
MCU	Micro Controller Unit
MSc	Master of Science
NASA	National Aeronautics and Space Administration
NIR	Near-Infrared part of the EM spectrum
NOAA	National Oceanographic and Atmospheric Administration
PO	Polar Orbit
PWM	Pulse-Width Modulation
PDR	Preliminary Desing Review
REXUS	Rocket Experiment for University Students
RJ45	Registered Jack 45
RPi	Raspberry Pi
RT	Radiative Transfer

RTE	Radiative Transfer Equation
SD	Secure Digital (Storage)
SED	Student Experiment Documentation
SOC	System On Chip
SOE	Start of experiment
EOE	End of experiment
SZA	Solar Zenith Angle
TBC	To Be Confirmed
TBD	To Be Determined
UART	Universal Asynchronous Receiver Transmitter
ULg	University of Liège
VIS	Visible part of the EM spectrum
WBS	Work Breakdown Structure

8.2 References

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A Experiment Reviews

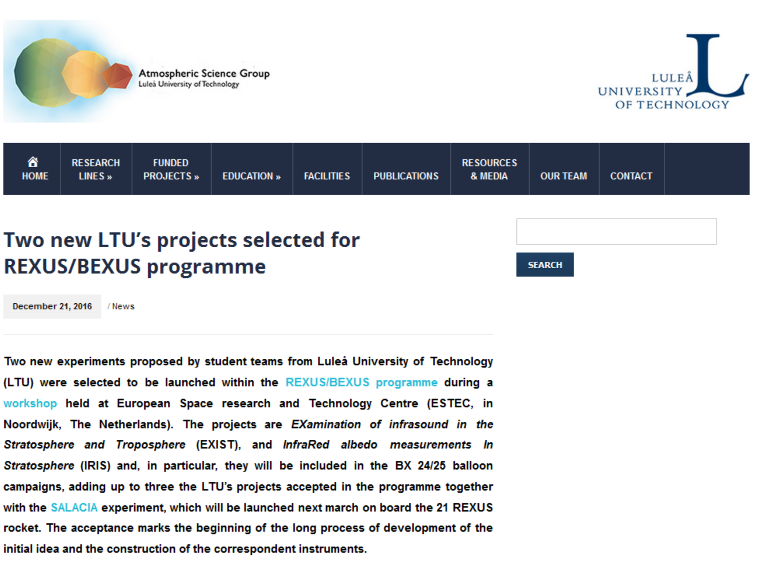
B Outreach and Media Coverage

The team's website can be found at: ltuiris.wixsite.com/iris.

IRIS has a Facebook page, located at: facebook.com/bexusiris/.

Our Instagram account is found at: @bexus_iris.

An article about IRIS, as well as our sister project EXIST, has been published by the Atmospheric Science Group at Luleå University of Technology. It can be found here: atmospheres.research.ltu.se



Two new LTU's projects selected for REXUS/BEXUS programme

December 21, 2016 / News

Two new experiments proposed by student teams from Luleå University of Technology (LTU) were selected to be launched within the REXUS/BEXUS programme during a workshop held at European Space research and Technology Centre (ESTEC, in Noordwijk, The Netherlands). The projects are *EXamination of infrasound in the Stratosphere and Troposphere* (EXIST), and *InfraRed albedo measurements In Stratosphere* (IRIS) and, in particular, they will be included in the BX 24/25 balloon campaigns, adding up to three the LTU's projects accepted in the programme together with the SALACIA experiment, which will be launched next march on board the 21 REXUS rocket. The acceptance marks the beginning of the long process of development of the initial idea and the construction of the correspondent instruments.

Figure 27: Article about IRIS and EXIST

Another article, based on an interview of members from both IRIS and EXIST, is currently being written by LTU's Communicator Linda Alfredsson. It will be published shortly.

A 20 minute presentation, with an additional 10 minutes for questions, was held for participants of the Space Instruments R7013R course at Luleå University of Technology. The presentation took place on December 16, 2016. Information about the course can be found at this link.

The IRIS logo, fig. 28, was created with the aid of Martin Tomasson, a student at Chalmers University of Technology, Göteborg. In addition to a balloon the logo shows incoming light, with the colours of the EU flag, being reflected as the flags of every nation represented in the IRIS project. These countries are Sweden, Belgium, Finland, Spain, Greece, Bulgaria, and Germany.

Figure 28: The IRIS Project logo

On January 28, 2017, IRIS will take part in the Space Day 2017, an event organised at Folkets Hus in central Kiruna. Here we will present our project to the general public of Kiruna, sharing a booth with EXIST and the REXUS team SALACIA.

We are investigating the possibility of purchasing clothes with our team logo printed on the back. Inquiries have been sent to multiple companies, and right now we are negotiating a sponsorship deal with T&S Reklam tsreklam.se.

C Additional Technical Information

TBD

D Checklists

TBD