# SED

## Student Experiment Documentation

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**Mission: BEXUS 28**

## Team Name: IRISC

Experiment Title: InfraRed Imaging of astronomical targets with a Stabilized Camera


| **Team** | **Name** |
|---|---|
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**Abstract:**

**Keywords:**

# Contents

# PREFACE

The Rocket and Balloon Experiments for University Students (REXUS/BEXUS) programme is realized 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).

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.

The Student Experiment Documentation (SED) is a continuously updating document regarding the BEXUS student experiment IRISC - InfraRed Imaging of astronomical targets with a Stabilized Camera and will undergo reviews during the preliminary design review, the critical design review, the integration progress review, and final experiment report.

# Acknowledgements

# 1 Introduction

## 1.1 Scientific Background

## 1.2 Mission Statement

## 1.3 Experiment Objectives

## 1.4 Experiment Concept

## 1.5 Team Details

**Diego Octavio Talavera Maya - Management**

*Current Education*:

*Previous Education*:

*Responsibilities*:

**Anja Möslinger - Science/Electrical/Mechanical/Thermal**

*Current Education*:

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**Eligius Franciscus Maria Weterings - Electrical**

*Current Education*: MSc in Space Sciences and Technology (Spacemaster).

*Previous Education*: BSc in electrical engineering at the University of Rotterdam (HR) with a specialization in computer sciences and mathematics at the University Utrecht (UU).

*Responsibilities*: Embedded systems, electrical engineering

**Kimberly Tuija Steele - Science/Electrical/Mechanical/Thermal**

*Current Education*:

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*Responsibilities*:

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*Current Education*:

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*Responsibilities*:

**Ajith Kumar Baskar - Science/Electrical/Mechanical/Thermal**

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**Sabina Björk - Science/Electrical/Mechanical/Thermal**

*Current Education*:

*Previous Education*:

*Responsibilities*:

**William Eriksson - Science/Electrical/Mechanical/Thermal**

*Current Education*:

*Previous Education*:

*Responsibilities*:

# 2 Experiment Requirements and Constraints

A list of requirements and constraints are listed below. The requirements are separated in functional, performance, design and operational requirements.

## 2.1 Functional Requirements

F.1 The telescope shall successfully track the celestial bodies of interest.

F.2 The camera shall take images in the near infrared (NIR) spectrum.

## 2.2 Performance Requirements

P.1 The gimbal stabilization system shall point the telescope towards the celestial body with an accuracy of at least 1 arc seconds.

P.2 The optics shall be cable of making pictures of 0.5-1.5 x 0.3-1 degrees.

P.3 The NIR camera shall make images in the range of 720-850 to 1200 nm.

P.4 The NIR camera shall have a resolution of at least 16 MP.

P.5 The NIR camera shall be able to make images with exposure times between 0.5 and 150 seconds.

P.6 The experiment shall measure the location and orientation of the gondola.

## 2.3 Design Requirements

D.01 The experiment shall be able to operate in the temperature profile of the BEXUS environment.

D.02 The experiment shall be able to operate in the pressure profile of the BEXUS environment.

D.03 The experiment shall be able to operate in the vibration profile of the BEXUS environment.

D.04 The absolute position of the telescope relative to the gondola shall be known with a accuracy of 0.1 degrees.

D.05 The supporting structure shall not twist by more than 0.1 degrees.

D.06 The experiment shall never be pointed directly at the sun.

D.07 The experiment shall be able to fly during the entire day.

D.08 The temperature of the NIR camera shall be held at $0 \pm 5\,^{\circ}$C.

D.09 The images obtained shall be send to a ground station by the E-link system with a maximum data rate of 1000 kilo bits per second.

D.10 The experiment shall be mounted at the side of the gondola.

D.11 The experiment shall not consume more power than 250 Wh.

D.12 The volume of the experiment shall not exceed 65 x 40 x 40 cm.

D.13 The mass of the experiment shall not exceed 20 kg.

D.14 The experiment shall be able to run for at least 3 hours.

D.15 The experiment shall be able to function autonomously.

## 2.4 Operational Requirements

O.1 The experiment shall be able to be controlled by the ground station when requested.

O.2 The experiment shall rotate to a 'safe' location while descending.

## 2.5 Constraints

C.1 The shared E-link data transfer rates are limited by coverage and quality of reception.

C.2 There shall be no direct internet connection on the ground station.

C.3 The mass and volume should fit inside the gondola together with the other experiments.

C.4 The budget for the experiment is limited by the generous companies and organizations that sponsor IRISC.

# 3 Project Planning

## 3.1 Work Breakdown Structure

## 3.2 Schedule

## 3.3 Resources

### 3.3.1 Manpower

### 3.3.2 Budget

| **Category** | **Total Mass [g]** | **Total Price [EUR]** |
|---|---|---|
| Structure | 0.00 | 00.0 |
| Electronics Box | 000.0 | 0.00 |
| Cables and Sensors | | |
| CAC | | |
| AAC | | |
| Tools | – | |
| Travel | – | |
| Contingency | – | |
| **Total without Error Margin** | | |
| Shipping Costs and Error Margin | | |
| **Total with Error Margin** | | |

Table 3: Mass and Cost Budget.

### 3.3.3 External Support

## 3.4 Outreach Approach

## 3.5 Risk Register

**Risk ID**

TC – Technical/Implementation

MS – Mission (operational performance)

SF – Safety

VE – Vehicle

PE – Personnel

EN – Environmental

OR - Outreach

BG - Budget

Adapt these to the experiment and add other categories. Consider risks to the experiment, to the vehicle and to personnel.

**Probability (P)**

A Minimum – Almost impossible to occur

B Low – Small chance to occur

C Medium – Reasonable chance to occur

D High – Quite likely to occur

E Maximum – Certain to occur, maybe more than once

**Severity (S)**

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

The rankings for probability (P) and severity (S) are combined to assess the overall risk classification, ranging from very low to very high and being coloured green, yellow, orange or red according to the SED guidelines.

Whether a risk is acceptable or unacceptable has been assigned according to the SED guidelines. Where mitigation is written for acceptable risks this details the mitigation undertaken in order to reduce the risk to an acceptable level.

| ID | Risk (& consequence if) | P | S | P * S | Action |
|---|---|---|---|---|---|
| TC10 | Software fails to store data | B | 2 | Very Low | Acceptable Risk: Extensive testing will be done. Using telemetry, all data gathered from sensors will be sent to ground station. |
| TC20 | Failure of several sensors | B | 2 | Very Low | Acceptable Risk: Thermal test (Test Number 5) to approve the functionality of the experiment. |
| TC30 | Critical component is destroyed in testing | B | 1 | Very Low | Acceptable Risk: Spare components can be ordered but for expensive ones, they will be ordered and tested early in the project in case we need to order more. |
| TC40 | Electrical connections dislodges or short circuits because of vibration or shock | B | 4 | Low | Acceptable Risk. D-sub connections will be screwed in place. It will be ensured that there are no loose connections and zip ties will be used to help keep wires in place. Careful soldering and extensive testing will be applied. |

Table 4: Risk Register.

# 4 Experiment Design

## 4.1 Experiment Setup

## 4.2 Experiment Interfaces

### 4.2.1 Mechanical Interfaces

### 4.2.2 Thermal Interfaces

### 4.2.3 Electrical Interfaces

### 4.2.4 Radio Frequencies (Optional)

### 4.2.5 Thermal (Optional)

## 4.3 Experiment Components

### 4.3.1 Electrical Components

### 4.3.2 Mechanical Components

#### 4.3.3 Other Components

## 4.4 Mechanical Design

### 4.4.1 Structure

### 4.4.2 Inside

### 4.4.3 etc

## 4.5 Electrical Design

### 4.5.1 Block Diagram

### 4.5.2 Critical Component/Part A

### 4.5.3 Critical Component/Part B

### 4.5.4 Critical Component/Part C

### 4.5.5 Schematic

### 4.5.6 PCB Layout

## 4.6 Thermal Design

### 4.6.1 Thermal Environment

### 4.6.2 The Critical Stages

### 4.6.3 Overall Design

### 4.6.4 Internal Temperature

### 4.6.5 Calculations and Simulation Reports

## 4.7 Power System

## 4.8 Software Design

### 4.8.1 Purpose

### 4.8.2 Design

### 4.8.3 Implementation

## 4.9 Ground Support Equipment

# 5 Experiment Verification and Testing

## 5.1 Verification Matrix

The verification matrix is made following the standard of *ECSS-E-10-02A*. [**?** ].

*There are four established verification methods:*
*A - Verification by analysis or similarity*
*I - Verification by inspection*
*R - Verification by review-of-design*
*T - Verification by testing*

| **ID** | **Written requirement** | **Verification** | **Test number** | **Status** |
|---|---|---|---|---|
| F.1 | The telescope shall successfully track the celestial bodies of interest. | | | |
| F.2 | The camera shall take images in the near infrared (NIR) spectrum. | | | |
| P.1 | The gimbal stabilization system shall point the telescope towards the celestial body with an accuracy of at least 1 arc seconds. | | | |
| P.2 | The optics shall be cable of making pictures of 0.5-1.5 x 0.3-1 degrees. | | | |
| P.3 | The NIR camera shall make images in the range of 720-850 to 1200 nm. | | | |
| P.4 | The NIR camera shall have a resolution of at least 16 MP. | | | |
| P.5 | The NIR camera shall be able to make images with exposure times between 0.5 and 150 seconds. | | | |
| P.6 | The experiment shall measure the location and orientation of the gondola. | | | |
| D.01 | The experiment shall be able to operate in the temperature profile of the BEXUS environment. | | | |
| D.02 | The experiment shall be able to operate in the pressure profile of the BEXUS environment. | | | |
| D.03 | The experiment shall be able to operate in the vibration profile of the BEXUS environment. | | | |
| D.04 | The absolute position of the telescope relative to the gondola shall be known with a accuracy of 0.1 degrees. | | | |
| D.05 | The supporting structure shall not twist by more than 0.1 degrees. | | | |
| D.06 | The experiment shall never be pointed directly at the sun. | | | |

| | | | | |
|---|---|---|---|---|
| D.07 | The experiment shall be able to fly during the entire day. | | | |
| D.08 | The temperature of the NIR camera shall be held at $0 \pm 5\,^{\circ}$C. | | | |
| D.09 | The images obtained shall be send to a ground station by the E-link system with a maximum data rate of 1000 kilo bits per second. | | | |
| D.10 | The experiment shall be mounted at the side of the gondola. | | | |
| D.11 | The experiment shall not consume more power than 250 Wh. | | | |
| D.12 | The volume of the experiment shall not exceed 65 x 40 x 40 cm. | | | |
| D.13 | The mass of the experiment shall not exceed 20 kg. | | | |
| D.14 | The experiment shall be able to run for at least 3 hours. | | | |
| D.15 | The experiment shall be able to function autonomously. | | | |
| O.1 | The experiment shall be able to be controlled by the ground station when requested. | | | |
| O.2 | The experiment shall rotate to a 'safe' location while descending. | | | |

Table 5: Verification Matrix.

## 5.2 Test Plan

### 5.2.1 Planned Tests

The planned tests are as follows:

1. Test 1
2. Test n

### 5.2.2 Test Descriptions

| | |
|---|---|
| **Test Number** | 4 |
| **Test Type** | Vacuum |
| **Test Facility** | IRF, Kiruna |
| **Tested Item** | Sampling System |
| **Test Level/ Procedure and Duration** | Test procedure: Take sampling system down to 5 hPa and verify all systems work. If the size of the vacuum chamber is restrictive testing just the pump with the airflow and pressure sensors, one valve and one bag will suffice. Ensure valves and pump still perform as expected by checking the flow rate with the airflow sensor and visually observing the bag inflating. In addition the insulating foam will be checked to ensure it does not deform when exposed to low pressures.<br>Test duration: 5 hours |
| **Test Campaign Duration** | 1 week |
| **Test Campaign Date** | 18th July, 20th July and August [1] |
| **Test Completed** | YES |

Table 6: Test 4: Low Pressure Test Description.

[1] Testing date dependent on valve arrival. A problem arose with the order which we are in contact with the company about.

| | |
|---|---|
| **Test Number** | 5 |
| **Test Type** | Thermal |
| **Test Facility** | FMI, Finland, Esrange, Kiruna |
| **Tested Item** | The entire experiment |
| **Test Level/ Procedure and Duration** | Test procedure: Place experiment in thermal chamber and take the temperature down to at least $-40°C$ but preferably $-80°C$ and verify all systems still work. Make sure that the Brain stays between $-10°C$ and 25°$C$.<br>Test duration: 5 hours |
| **Test Campaign Duration** | 1 week |
| **Test Campaign Date** | 3rd-7th September, 29th September, 5th October |
| **Test Completed** | YES |

Table 7: Test 5: Thermal Test Description.

## 5.3 Test Results

The results shown here provide the key information obtained from testing. A full report for each test can be found in Appendix **??**.

# 6 Launch Campaign Preparations

## 6.1 Input for the Campaign / Flight Requirements Plans

### 6.1.1 Dimensions and Mass

The data shown in Table 8 below is based on the design presented in Section 4.4.

| | xxx | xxx | TOTAL |
|---|---|---|---|
| Experiment mass [kg] | | | |
| Experiment dimensions [m] | | | |
| Experiment footprint area [$m^2$] | | | |
| Experiment volume [$m^3$] | | | |
| Experiment expected COG position | $X = cm$<br>$Y = cm$<br>$Z = cm$ | $X = cm$<br>$Y = cm$<br>$Z = cm$ | $X = cm$<br>$Y = cm$<br>$Z = cm$ |

Table 8: Experiment Summary Table.

### 6.1.2 Safety Risks

### 6.1.3 Electrical Interfaces

Please refer to Table 9 for details on the electrical interfaces with the gondola.

| **BEXUS Electrical Interfaces** | | |
|---|---|---|
| **E-link Interface:** | | |
| | Number of E-link interfaces | |
| | Data rate - Downlink | |
| | Data rate - Uplink | |
| | Interface type (RS232, Ethernet) | |
| **Power system: Gondola power required?** | | |
| | Peak power (or current) consumption: | |
| | Average power (or current consumption) | |
| **Power system: Experiment includes batteries?** | | |

Table 9: Electrical Interface Table.

### 6.1.4 Launch Site Requirements

### 6.1.5 Flight Requirements

### 6.1.6 Accommodation Requirements

## 6.2 Preparation and Test Activities at Esrange

## 6.3 Timeline for Countdown and Flight

Table 10 is the estimated timeline during countdown and flight.

| Time | Altitude | Events |
|---|---|---|
| T- | 0 | |
| T- | 0 | |
| T-3H | 0 | Experiment is switched on external power |
| T-3H | 0 | Experiment goes to Standby mode |
| T-1H | 0 | Experiment switches to internal power |
| T=0 | 0 | Lift-off |
| T+1s | ∼5 meter | Experiment goes to Normal - Ascent mode |
| T+ | km | |
| T+ | km | |
| T+∼1.5H | ∼25 km | Float Phase |
| T+∼2.5H | ∼25 km | Cut-off |
| T+∼2.6H | ∼25 km | Experiment goes to Normal - Descent mode |
| T+∼2.75H | ∼20 km | Parachute is deployed |
| T+ | km | |
| T+ | km | |

Table 10: Countdown and Flight Estimated Timeline.

## 6.4 Post Flight Activities

### 6.4.1 Recovery Checklist

### 6.4.2 Analysis Preparation

# 7 Data Analysis and Results

## 7.1 Data Analysis Plan

### 7.1.1 Analysis Strategy

## 7.2 Launch Campaign

### 7.2.1 Flight preparation activities during launch campaign

The flight preparations can be found in Section 6.2.

### 7.2.2 Flight performance

### 7.2.3 Recovery

### 7.2.4 Post flight activities

## 7.3 Results

No results for now. More will come after the launch campaign in an updated version of the SED.

### 7.3.1 Expected Results

## 7.4 Lessons Learned

### 7.4.1 Management

- Friendship
- Sleep deprivation

### 7.4.2 Scientific

- Friendship
- Sleep deprivation

### 7.4.3 Electrical

- Friendship
- Sleep deprivation

### 7.4.4 Software

- Friendship
- Sleep deprivation

### 7.4.5 Mechanical

- Friendship
- Sleep deprivation

### 7.4.6 Thermal

- Friendship
- Sleep deprivation

# 8 Abbreviations and References

## 8.1 Abbreviations

## 8.2 References

# Appendix A Experiment Reviews

# Appendix B Outreach

# Appendix C Additional Technical Information

# Appendix D Checklists