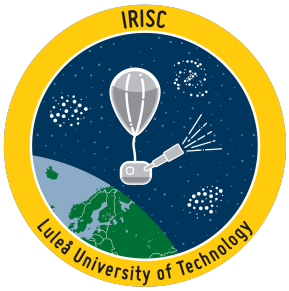
SED

Student Experiment Documentation



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Mission: BEXUS 28

Team Name: IRISC

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

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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:

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Responsibilities:

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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 $\pm$ 27 degrees.

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 2.5 hours.

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

D.16 The data stored in the experiment shall be able to survive the landing.

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*. [1].

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	Requirement text	Method	Reference	Status	Verification result
F.1	The telescope shall successfully track the celestial bodies of interest.	A, T	Tests: 4, 5, 9, 10	A: to be done T: to be done	Not verified
F.2	The camera shall take images in the near infrared (NIR) spectrum.	R	Test: 1	R: to be done	Not verified
P.1	The gimbal stabilization system shall point the telescope towards the celestial body with an accuracy of at least 1 arc seconds.	A, T	Tests: 3, 4, 5, 9, 10	A: to be done T: to be done	Not verified
P.2	The optics shall be cable of making pictures of 0.5-1.5 x 0.3-1 degrees.	R, T	Test: 1	R: to be done T: to be done	Not verified
P.3	The NIR camera shall make images in the range of 720-850 to 1200 nm.	R	Test: 1	R: to be done	Not verified
P.4	The NIR camera shall have a resolution of at least 16 MP.	R, T	Test: 1	R: to be done T: to be done	Not verified
P.5	The NIR camera shall be able to make images with exposure times between 0.5 and 150 seconds.	R, T	Test: 1	R: to be done T: to be done	Not verified
P.6	The experiment shall measure the location and orientation of the gondola.	A, T	Tests: 3, 4, 5, 9, 10	T: to be done	Not verified
D.01	The experiment shall be able to operate in the temperature profile of the BEXUS environment.	T	Test: 2	T: to be done	Not verified
D.02	The experiment shall be able to operate in the pressure profile of the BEXUS environment.	T	Test: 2	T: to be done	Not verified

D.03	The experiment shall be able to operate in the vibration profile of the BEXUS environment.	T	Tests: 8, 10	T: to be done	Not verified
D.04	The absolute position of the telescope relative to the gondola shall be known with a accuracy of 0.1 degrees.	T	Tests: 3, 4, 9, 10	T: to be done	Not verified
D.05	The supporting structure shall not twist by more than 0.1 degrees.	T	Tests: 9, 10	T: to be done	Not verified
D.06	The experiment shall never be pointed directly at the sun $\pm$ 27 degrees.	T	Tests: 4, 9, 10	A: to be done T: to be done	Not verified
D.07	The experiment shall be able to fly during the entire day.	T	Tests: 9, 10	T: to be done	Not verified
D.08	The temperature of the NIR camera shall be held at $0 \pm 5\,^{\circ}$C.	T	Tests: 9, 10	T: to be done	Not verified
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.	T	Test: 6	T: to be done	Not verified
D.10	The experiment shall be mounted at the side of the gondola.	T	Tests: 9, 10	T: to be done	Not verified
D.11	The experiment shall not consume more power than 250 Wh.	T	Tests: 9, 10	T: to be done	Not verified
D.12	The volume of the experiment shall not exceed 65 x 40 x 40 cm.	I	Test: 7	I: to be done	Not verified
D.13	The mass of the experiment shall not exceed 20 kg.	I	Test: 7	I: to be done	Not verified
D.14	The experiment shall be able to run for at least 2.5 hours.	T	Tests: 9, 10	T: to be done	Not verified
D.15	The experiment shall be able to function autonomously.	T	Tests: 4, 9, 10	T: to be done	Not verified
D.16	The data stored in the experiment shall be able to survive the landing.	T	Test: 8	T: to be done	Not verified
O.1	The experiment shall be able to be controlled by the ground station when requested.	T	Tests: 4, 10	T: to be done	Not verified
O.2	The experiment shall rotate to a 'safe' location while descending.	T	Tests: 4, 9, 10	T: to be done	Not verified

Table 5: Verification Matrix.

5.2 Test Plan

5.2.1 Planned Tests

The planned tests are as follows:

Test 01: Optics & Camera;

Test 02: Thermal & pressure test;

Test 03: Electronics;

Test 04: Software with electronics;

Test 05: Control system;

Test 06: Data transfer;

Test 07: Mass & Volume;

Test 08: Drop test (without optics and camera);

Test 09: Gimbal mounted on replicated gondola;

Test 10: Gimbal mounted on a car.

5.2.2 Test Descriptions

Test Number	1
Test Type	Optics & Camera
Test Facility	LTU (outside), Kiruna
Tested Item	Optics & Camera
Test Level/ Procedure and Duration	Verify the design that pictures are only able to be made in the specified NIR spectrum range, with the specified resolution and angular size. Then put the selected optics with camera on a tripod and make picture of all the selected targets. For these tests the NIR filter may be temperately removed (if possible). But all targets should be photographed at least in the NIR spectrum. Test duration: 8 hours (at night).
Test Campaign Duration	1 day
Test Campaign Date	April
Test Completed	NO
Requirements verified	NO

Table 6: Test 1: Optics & camera ground tested.

Test Number	2
Test Type	Vacuum & freezer
Test Facility	IRF/ EISCAT, Kiruna
Tested Item	Electronics, optics and camera
Test Level/ Procedure and Duration	The electronics, optics and camera should be placed in a vacuum and freezer to test the components functionality with a simulated environment based on the one we expect to encounter. The pressure should be <5 mbar and temperature -80 °C (or atleast colder than -40 °C if not possible) The components may be tested separately, but should function during the test. Test duration: 15 minutes per test on the specified pressure and temperature.
Test Campaign Duration	1 day
Test Campaign Date	Beginning of June
Test Completed	NO
Requirements verified	NO

Table 7: Test 2: Vacuum and freezer test of atleast the electronics, optics and camera.

Test Number	3
Test Type	Electronics
Test Facility	LTU, Kiruna
Tested Item	Sensors and Actuators
Test Level/ Procedure and Duration	The sensors should first be read out one by one, without the other sensors connected. If multiple sensors or actuators are located on the same PCB, there should also be a test PCB available with each sensor and actuator separated from the prototype phase. Afterwards, the same is done for each actuator. Then, one by one, each sensor and actuator is added to the system to test the system as a whole. Test duration: 5 hours.
Test Campaign Duration	1 day
Test Campaign Date	Beginning of June
Test Completed	NO
Requirements verified	NO

Table 8: Test 3: Sensors and actuators test.

Test Number	4
Test Type	Software
Test Facility	LTU, Kiruna
Tested Item	Raspberry pi software with electronics connected.
Test Level/ Procedure and Duration	This test should be done after the functionality of the electronics is verified. Then all sensors and actuators should be tested integrated with the software. Let the gimbal be targeting 4 specific points with a separation of 90 degrees. Test if the gimbal stabilize the system when moved and switches targets based on the field of view. The targets should also be able to be switched on the groundstation. Then add a 5th target which it may never look directly at and repeat the test. Test duration: 5 hours.
Test Campaign Duration	1 day
Test Campaign Date	Beginning of June
Test Completed	NO
Requirements verified	NO

Table 9: Test 4: Software (onboard and ground) with electronics connected test.

Test Number	5
Test Type	Control system
Test Facility	LTU, Kiruna
Tested Item	Control software.
Test Level/ Procedure and Duration	This test is done in a simulation program. The program verifies that the control system is able to track moving targets realtime in the sky without looking directly at the sun. Test duration: 2.5 hours (real time, simulation might be speed up).
Test Campaign Duration	1 day
Test Campaign Date	Beginning of June
Test Completed	NO
Requirements verified	NO

Table 10: Test 5:Control system simulation.

Test Number	6
Test Type	Data transfer
Test Facility	LTU, Kiruna
Tested Item	Controller
Test Level/ Procedure and Duration	Send the pictures, made in test 1, over the telemetry channel and monitor the data packages with the program 'Wireshark' or similar. Write down the telemetry data rate including headers and footers. During the test the connection should be resetted and the buffer should make sure all data will be transferred after the connection comes online again. Test duration: 30 minutes.
Test Campaign Duration	0.5 Day
Test Campaign Date	Beginning of June
Test Completed	NO
Requirements verified	NO

Table 11: Test 6: Telemetry testing.

Test Number	7
Test Type	Mass & Volume
Test Facility	LTU, Kiruna
Tested Item	Entire system
Test Level/ Procedure and Duration	Weigh the project on a measuring scale and write down the total weight. All components that are also included on the BEXUS balloon should be added. The subsystems may be measured individuality or as a whole. Then measure the volume of the project and write down the volume. Test duration: 30 minutes.
Test Campaign Duration	1 hour
Test Campaign Date	Beginning of June
Test Completed	NO
Requirements verified	NO

Table 12: Test 7: Check mass and dimensions of entire system.

Test Number	8
Test Type	Drop test
Test Facility	LTU, Kiruna
Tested Item	Electronics and gimbal
Test Level/ Procedure and Duration	Get the electronics and gimbal and put them off. Put them on the replicated gondola in the preferred positions with the attachment material that will also be used during the BEXUS flight. Drop the experiment from 1, 2 and 3 meters high. After every test the functionality of the system should be tested. At least the data logger should survive. Test duration: 1 hour.
Test Campaign Duration	0.5 day
Test Campaign Date	Beginning of June
Test Completed	NO
Requirements verified	NO

Table 13: Test 8: Drop test of entire system except optics and camera.

Test Number	9
Test Type	Gimbal performance
Test Facility	LTU, Kiruna
Tested Item	Gimbal, software and electronics
Test Level/ Procedure and Duration	Put the entire system in the replicated gondola and montage the system as would be montaged on the BEXUS flight. Let the system in sleep mode for atleast 2 hours (waiting) plus 1.5 hours (ascending) and simulate that the floating phase is reached. Then let the system work for at least 2.5 hours. Move the system around during the floating phase. Then simulate that the descending phase has started. Monitor the power and data usage during this test. Test duration: 6 hours.
Test Campaign Duration	1 week
Test Campaign Date	End of June
Test Completed	NO
Requirements verified	NO

Table 14: Test 9: Gimbal with all subsystems mounted on a replicated gondola.

Test Number	10
Test Type	Gimbal vibration test
Test Facility	LTU (outside), Kiruna
Tested Item	Gimbal, software and electronics
Test Level/ Procedure and Duration	Then let the system make images for at least 2.5 hours while being mounted on top of a car. Drive with the slowly car around on a mostly flat survive. Test duration: 5 hours.
Test Campaign Duration	1 week
Test Campaign Date	End of June
Test Completed	NO
Requirements verified	NO

Table 15: Test 10: Gimbal mounted on a car to test entire system with vibrations.

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 **??**.

Verification Number	1
Test Type	Optics & Camera
Facility	LTU (outside), Kiruna
Verified item	Sampling System
Verification description	The camera should make pictures in the NIR spectrum with the specified resolution and angular size. This test is also used to obtain ground made pictures from the targets of interest.
Expected results	The camera makes NIR images from the targets of interest.
Obtained results	
Conclusions	Not verified.

Table 16: Results test 1: Optics & camera ground tested.

Verification Number	2
Test Type	Vacuum & freezer
Facility	IRF/ EISCAT, Kiruna
Verified item	Electronics, optics and camera
Verification description	The electronics, optics and camera withstand a pressure of $<$5 mbar and a temperature of atleast -40 °C.
Expected results	The system controls the temperature if the temperature almost gets below the minimum temperature specified. The system is also able to survive in a $<$5 mbar environment.
Obtained results	
Conclusions	Not verified.

Table 17: Results test 2: Vacuum and freezer test of atleast the electronics, optics and camera.

Verification Number	3
Test Type	Electronics
Facility	LTU, Kiruna
Verified item	Sensors and actuators
Verification description	The specified range and accuracy of each sensor and actuator are being met, even after integration. The sensors are read out by the same board that is used for the onboard control system and read out on a display.
Expected results	Each sensor and actuator works separated and integrated together within the specified accuracy.
Obtained results	
Conclusions	Not verified.

Table 18: Results test 3: Sensors and actuators test.

Verification Number	4
Test Type	Software
Facility	LTU, Kiruna
Verified item	Raspberry Pi software with electronics connected.
Verification description	Program four targets of interest and move the gimbal around. Determine if the targets are being followed. Then add a 5th point that the gimbal should never point, or around with the specified angle, and determine that this never happens. Connect the ground station and check if the system can be controlled remotely.
Expected results	The gimbal is able to chose targets and keeps it tracked and a specific target will never be looked directly at or nearby.
Obtained results	
Conclusions	Not verified.

Table 19: Results test 4: Software (onboard and ground) with electronics connected test.

Verification Number	5
Test Type	Control system
Facility	LTU, Kiruna
Verified item	Control software
Verification description	In a simulation program the control system is verified. The targets with movement are inserted in this simulation.
Expected results	The gimbal is able to chose the specified targets and keeps it tracked and a specific target (sun) will never be looked directly at or nearby.
Obtained results	
Conclusions	Not verified.

Table 20: Results test 5: Control system simulation.

Verification Number	6
Test Type	Data transfer
Facility	LTU, Kiruna
Verified item	Controller
Verification description	The data packages will be monitored by 'Wireshark' or a simular program and the data rate is below the specified data rate. The data gets buffered while being connection is lost.
Expected results	The data rate is below the specified data rate and the data gets buffered while the connection is lost.
Obtained results	
Conclusions	Not verified.

Table 21: Results test 6: Telemetry testing.

Verification Number	7
Test Type	Mass & Volume
Facility	LTU, Kiruna
Verified item	Entire system
Verification description	The mass and volume of the experiment gets measured.
Expected results	The mass and volume are below the specified values.
Obtained results	
Conclusions	Not verified.

Table 22: Results test 7: Check mass and dimensions of entire system.

Verification Number	8
Test Type	Drop test
Facility	LTU, Kiruna
Verified item	Electronics and gimbal
Verification description	The electronics and gimbal get droped, mounted on a replicated gondola, from a height of 1, 2 and 3 meters and atleast the data logger survives.
Expected results	The data logger survives but the gimbal might break depending on the impact.
Obtained results	
Conclusions	Not verified.

Table 23: Results test 8: Drop test of entire system except optics and camera.

Verification Number	9
Test Type	Gimbal performance
Facility	LTU, Kiruna
Verified item	Gimbal, software and electronics
Verification description	The test is run for atleast 6 hours. The system is slightly moved during the last 2.5 hours, while the images are made. The power and data usage is monitored during the test.
Expected results	The system is able to work for atleast 6 hours with the specified power and data usage. The images are the same as made from a static point.
Obtained results	
Conclusions	Not verified.

Table 24: Results test 9: Gimbal with all subsystems mounted on a replicated gondola.

Verification Number	10
Test Type	Gimbal vibration test
Facility	LTU (outside), Kiruna
Verified item	Gimbal, software and electronics
Verification description	The entire system including the replicated gondola is mounted on top of a car and the images takes are compared to the images taken while being static.
Expected results	The system is able to work with the vibrations and movement from the car, the images obtained are the same.
Obtained results	
Conclusions	Not verified.

Table 25: Results test 10: Gimbal mounted on a car to test entire system with vibrations.

6 Launch Campaign Preparations

6.1 Input for the Campaign / Flight Requirements Plans

6.1.1 Dimensions and Mass

The data shown in Table 26 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	$X = cm$ $Y = cm$ $Z = cm$	$X = cm$ $Y = cm$ $Z = cm$	$X = cm$ $Y = cm$ $Z = cm$

Table 26: Experiment Summary Table.

6.1.2 Safety Risks

6.1.3 Electrical Interfaces

Please refer to Table 27 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 27: 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 28 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 28: 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

[1] ECSS Secretariat. *Space Engineering: Verification*. ESA-ESTEC, Requirements & Standards Division, ESTEC, P.O. Box 299, 2200 AG Noordwijk, The Netherlands, Nov 1998.

Appendix A Experiment Reviews

Appendix B Outreach

Appendix C Additional Technical Information

Appendix D Checklists