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BEXUS User Manual

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Abstract: This document has been created to aid experimenters taking part in a BEXUS flight as part of the REXUS/BEXUS Programme. It is continually updated and developed in order to serve the experimenters and operators better. It describes important information about flights for experimenters, interface details, design guidelines, and testing.

Keywords: BEXUS, manual, interface, EuroLaunch, testing, design

This is not an ICD document.

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1 INTRODUCTION

The REXUS/BEXUS programme allows students from universities and higher education colleges across Europe to carry out scientific and technological experiments on research rockets and balloons. Each year, two rockets and two balloons are launched, carrying up to 20 experiments designed and built by student teams.

The REXUS/BEXUS programme is realised 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.

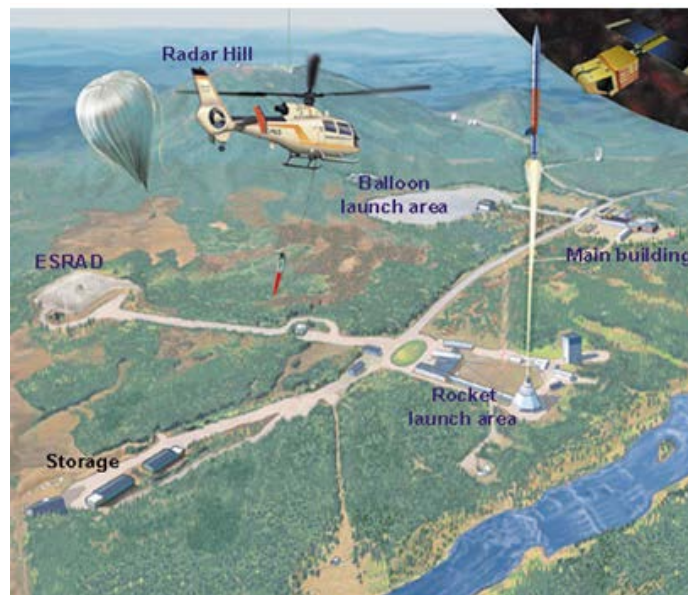


Figure 1-1: SSC, Esrange Space Center near Kiruna in northern Sweden.

BEXUS experiments are lifted by a balloon with a volume of 12 000 m³ to an altitude of 25-30 km, depending on total experiment mass (40-100 kg). The flight duration is 2-5 hours.

The BEXUS payload is modularised to provide simple interfaces, good flexibility and independence between experiments. All payload service systems necessary for telecommunication, payload control, and recovery are included in the system. High speed telemetry and up-link command control of experiments is provided.

This document describes all the necessary information for a user of the BEXUS system, including the services offered by EuroLaunch. It defines the requirements that apply to the BEXUS experiment modules and gives design recommendations. It also includes a description of the BEXUS system, the programmatic elements, the pre-flight tests and the campaign schedule and, finally, there is a chapter on quality assurance and safety.

If you require additional information on the BEXUS system, please contact the EuroLaunch project manager or the system engineer of the current project.

2 ALWAYS READ THIS

There is plenty of useful information in this manual. Make sure that you have found and understood the meaning of the following information.

Experiment safety

If there are hazardous items such as chemicals, lasers, radiation, etc. included in the experiments, there may be a need for further investigation by the Esrange Safety Board. This may take some time and should be done early in the design process.

Durability of your experiment

During the pre-flight tests and the count down, the experiments will be turned on and off several times over the course of many hours and multiple days. Make sure that there is enough battery, memory, etc. to survive these activities, in addition to that which is required for the flight.

Transceivers

All equipment that emits or receives RF must have Esrange permission to do so.

Radio Frequency interference test

After the RF test it is not permitted to make any changes to the gondola or experiments before flight. If you miss this test during the campaign preparation phase, it may be necessary to remove your experiment or fly the gondola with your experiment turned off.

If your experiment disturbs any of the flight systems, it will not be flown at all.

Weather constraints

It is not possible to guarantee a launch during any specific week, due to weather constraints. Make sure that your experiment can be operated by Esrange staff, in case the launch is postponed beyond the date when you have to leave.

Planning

It is essential to have a build-up plan and checklists for your experiment. Without these, there is a significant risk of failures and delays during the campaign week.

Safety on balloon pad

No one is allowed on the balloon pad without the permission of the Operations Officer. In the final 1 hour and 30 minutes before launch after the sweet spot tests, there is no more access to the experiments.

Campaign Requirements / Flight Requirements Plan

This is a document that is compiled by the EuroLaunch Project Management based on input and requests from all experimenters. Without good information, well before the campaign, it might be impossible to fulfil a requirement such as the provision of gases, special tools, etc.

Our goal is to have a successful and enjoyable campaign with all teams and their experiments. You are always welcome to contact us with any questions.

2.1 Definitions

The BEXUS system consists of the following components according to the EuroLaunch definition.

BEXUS	The complete integrated vehicle to perform the flight.
Ground Equipment	BEXUS supporting systems on ground.
EBASS	Balloon service system.
E-Link	Ethernet up & downlink.
Estrange Facilities	Equipment used to monitor and control the flight, and telemetry receiving equipment.
Ground Support Equipment	Equipment used to control and communicate with various modules during test and count down.
Balloon	The parts of BEXUS giving the lifting force.
Payload	Experiment modules and all subsystems.
Subsystems	All systems required for flight control, recovery, and telemetry.
Experiment Gondola	Experiment equipment and the carrier structure.

2.2 References

NOTE: All references documents can be found on the BEXUS Teamsite along with the manual. The ECSS references link directly to the documents themselves, firstly though, in order to access the documents, registration is required (this is easy and free for the user)

- [1] ECSS, *Space project management / Project planning and implementation*, ECSS-M-ST-10C (ESA Publications Division, 2008)
([http://www.ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100743/d20090306173339/No/ECSS-M-ST-10C_Rev.1\(6March2009\).pdf](http://www.ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100743/d20090306173339/No/ECSS-M-ST-10C_Rev.1(6March2009).pdf))
- [2] ECSS, *Space product assurance / Manual soldering of high-reliability electrical connections*, ECSS-Q-ST-70-08C (ESA Publications Division, 2009) ([http://ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100753/d20090306190830/No/ECSS-Q-ST-70-08C\(6March2009\).pdf](http://ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100753/d20090306190830/No/ECSS-Q-ST-70-08C(6March2009).pdf))
- [3] ECSS, *Space product assurance / Crimping of high-reliability electrical connections*, ECSS-Q-ST-70-26C (ESA Publications Division, 2008)
([http://ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100679/d20081111131154/No/ECSS-Q-ST-70-26C\(31July2008\).pdf](http://ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100679/d20081111131154/No/ECSS-Q-ST-70-26C(31July2008).pdf))
- [4] SSC, Esrange Space Center, *Esrange Safety Manual*, REA00-E60, ver 3B (23June2010) (<http://www.sscspace.com/file/esrange-safety-manual.pdf>)
- [5] SSC, Esrange Space Center, *User's Handbook*, ver 2 (11April2011)
(<http://www.sscspace.com/file/usershandbook.pdf>)
- [6] ECSS, *Space product assurance / Data for selection of space materials and processes*, ECSS-Q-70-71A rev. 1 (ESA Publications Division, 2004)
(<http://ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100362/d20040622123217/No/ECSS-Q-70-71Arev1%2818June2004%29.pdf>)
- [7] EuroLaunch, *RXBX_REF_SED Template_v4-0_06Dec12*
- [8] EuroLaunch, *RXBX_REF_SED Guidelines_v4-0_06Dec12*

2.3 Applicable documents

- [9] Montenbruck, Oliver & Gill, Eberhard: *Satellite Orbits* (Springer Verlag, 2000)
 - [10] Vallado, David A.: *Fundamentals of Astrodynamics and Applications* (McGraw-Hill Companies, Inc, 1997)
-

2.4 Abbreviations

AGT	Argos GPS and ATC Transponder
AIT	Assembly, Integration and Test
APID	Application Identifier
ASAP	As Soon As Possible
ATC	Air Traffic Control
BCR	BEXUS Campaign Report
BEXUS	Balloon-borne EXperiments for University Students
CD	Count Down
CDR	Critical Design Review
CRP	Campaign Requirement Plan
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EAR	Experiment Acceptance Review
EAT	Experiment Acceptance Test
EBASS	Balloon piloting system
ECEF	Earth Centered, Earth Fixed
EGon	Esrang balloon Gondola
EIT	Electrical Interface Test
E-Link	Ethernet up & downlink system
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESA	European Space Agency
ESD	Electrostatic Sensitive Device
ESRANGE	Esrang Space Center
FAR	Flight Acceptance Review
FRP	Flight Requirements Plan
FRR	Flight Readiness Review
FST	Flight Simulation Test
GND	Ground
GSE	Ground Support Equipment
H/W	Hardware
HCD	Hot Countdown
HERCULES	Balloon launch vehicle
HK	House Keeping
I/F	Interface
ICD	Interface control document
IFU	Interface Unit
IPR	Integration Progress Review
LOS	Line of sight
LT	Local Time
LTC	Local Tangent Coordinate System

Mbps	Mega bits per second
MFH	Mission Flight Handbook
MORABA	Mobile Raketenbasis (DLR)
NC	Not Connected
NCR	Non Conformance Report
PCM	Pulse Code Modulation
PDR	Preliminary Design Review
PFR	Post-Flight Report
PI	Principal Investigator
PST	Payload System Test
QA	Quality Assurance
RNRZ	Randomized NRZ (a signalling modulation)
RX	Receiver
S/W	Software
SED	Student Experiment Documentation
SNSB	Swedish National Space Board
STW	Student Training Week
T	Time before and after launch noted with + or -
TBC	To Be Confirmed
TBD	To Be Determined
TC	Tele-Command
TM	Telemetry
TX	Transmission
WGS84	World Geodetic System 1984
WT	Walky Talky, handheld radio
ZARM	Center of Applied Space Technology and Microgravity

3 BEXUS PROJECT OVERVIEW AND MILESTONES

3.1 Project Organisation

The technical support in the integration and testing phase, as well as the campaign management and operations, is provided by EuroLaunch. EuroLaunch is a joint venture of SSC and the Mobile Rocket Base of (MORABA) the German Aerospace Center (DLR).

The DLR service part concerning experiment integration, testing and student support is provided by ZARM in Bremen.

The scientific evaluation of the experiment proposals and the financial support of the students are the responsibility of the German Space Agency (DLR) and the Swedish National Space Board (SNSB), in the latter case through cooperation with the European Space Agency (ESA).

At EuroLaunch the following key-positions will be assigned for every flight project:

- Project manager
- Payload manager
- Mechanical design responsible
- Electrical design responsible
- Telemetry (TM) and Telecommand (TC) systems responsible
- Electric Ground Support Equipment (EGSE) responsible

One person can have dual assignments.

Additional positions will be assigned during the campaign, see chapter 9.4

The majority of the communication between EuroLaunch and the experiment teams shall pass through the Project managers.

3.2 BEXUS Flight Ticket

In the BEXUS “flight ticket”, which is offered to the international student community, the following services are included:

- General management and planning of the BEXUS project
 - Provision of launch vehicle and subsystems necessary for a flight mission of 2-5 hours with recovery.
 - Integration of participating modules into the flight configured payload and pre-flight testing of payload (TM, TC, flight simulation test).
 - Assembly of the payload into the gondola and pre-flight testing at the Esrange launch site
 - Provision of laboratory facilities at the Esrange launch site.
 - Launch and recovery of payload.
 - Data acquisition with provisions of real time, quick-look and replay data from gondola and payload subsystems.
 - Disassembly of payload and return of experiments.
 - BEXUS Campaign report.
-

3.3 Experimenter's Role

Once selected to participate in the REXUS/BEXUS programme, the teams become a part of the mission team. Their primary responsibility is to ensure the timely delivery of their portion of the scientific payload in good order. This responsibility extends to defining the investigation, providing the instrumentation, timely processing of data, and publishing of results. The experimenters must also contribute to establishing and conducting the operational programme through correspondence and fulfilment of the documentation requirements.

The successful operation of experiments is vital to the overall success of the REXUS/BEXUS missions. EuroLaunch supports the teams in order to see the good scientific returns. Information and expertise is available where required for assisting decisions relating to design, component, materials, operation, and any other mission related issues. Final decisions are normally left to the experimenters but if required (by safety or otherwise), EuroLaunch withholds the right to enforce decisions on any issue. Before flight, the experimenters must successfully convince EuroLaunch through testing, simulation, and documentation that their experiment is fit and safe for flight.

The experimenters are responsible for developing and providing the scientific payloads and support equipment provided. EuroLaunch can aide with many of these issues but the teams are responsible for ensuring that these are organized in a timely manner. They are also responsible for ensuring that the experiments conform to all required electrical and mechanical interface specifications, meets safety requirements, and survives the flight. EuroLaunch assists in all these issues where possible but the experimenters must keep in mind that ensuring the resolution of issues is their responsibility.

3.4 Project Planning

A detailed project plan and time schedule will be released by EuroLaunch as soon as possible after the selection workshop. These will be regularly updated during the project.

3.5 Experimenter Documentation Requirements

3.5.1 Student Experiment Documentation (SED)

The SED provides EuroLaunch and other stakeholders from SNSB, ESA, DLR and ZARM with all the important information on a particular experiment. During the phases of experiment development, production and flight, the SED will be the main documentation for students to describe their experiment and 5 frozen versions will be provided. All documentation relating the requirements of this document can be found at the REXUS/BEXUS Teamsite including the SED guidelines and SED template documents.

3.5.2 Campaign Requirements Plan (CRP)

Any requests for input from EuroLaunch must be fulfilled by the student teams. This document is a reference document for the many people who will be involved in the launch of experiments and care must be taken that information is correct and clear to avoid errors

are made concerning the experiments. These requirements will be made on an individual basis with each of the teams.

3.5.3 Flight Report Documentation

EuroLaunch requires a post-flight report document for inclusion in the Flight Report that must be produced following each launch. The experimenters must submit only one to two pages regarding performance of their experiment during the flight and preliminary results when possible. This must be submitted two weeks after the launch campaign (each experiment team is expected to present a preliminary performance overview whilst at the campaign following the launch).

4 BEXUS SYSTEM

4.1 BEXUS flight configuration

The typical BEXUS configuration consists of: 12.000 m³ balloon, valve, cutter, parachute, Esrange Balloon Service System (EBASS), flight train, Argos GPS and ATC Transponder (AGT), strobe light, radar reflector and the gondola. The total length of this system is up to 75 m. (Figure 4-1).

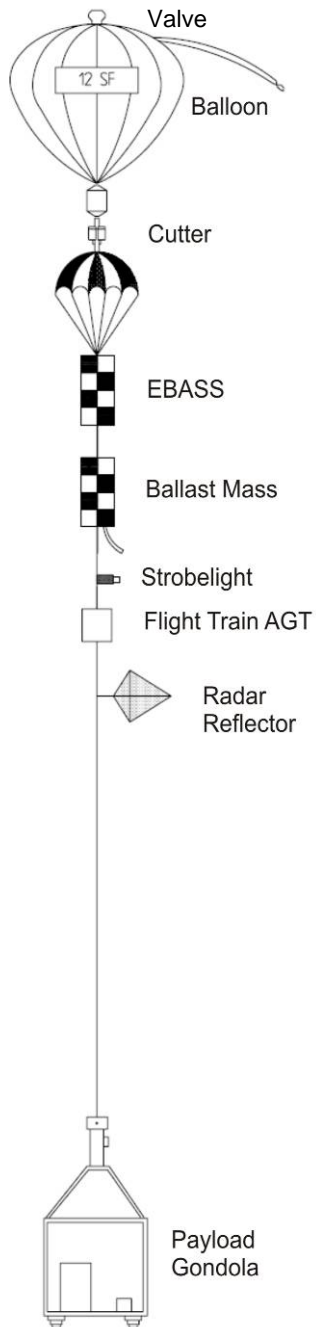


Figure 4-1: BEXUS Vehicle



Figure 4-2: BEXUS-15 Experiment Gondola (M-Egon)



Figure 4-3: Hercules Launch Vehicle with Gondola

4.2 Gondolas

There is one primary size of experiment gondola available for the BEXUS programme:

Medium Erange gondola (M-Egon) is a medium-sized gondola with dimensions of 1.16 m x 1.16 m x 0.84 m. It is designed to carry experiment loads up to 100 kg.

It is possible to cover the sides of the gondola with heavy-duty canvas material.

It is possible to cover the top of the gondola with heavy duty canvas material or aluminium sheeting.

These coverings are not nominal and should be requested to Eurolaunch.

4.3 Homing Aid

The flight train and balloon envelope are equipped with separate ARGOS/GPS-receiver/transmitters (AGT), from which the position information can be assessed by satellite both during the flight and after landing. The GPS position is also transmitted via the telemetry stream through the EBASS system. The recovery team in the helicopter can be equipped with a homing-receiver in order to acquire the GPS position for a quick and easy way to locate the payload.

Both the balloon envelope and the payload are equipped with an air traffic transponder and altitude encoder (ATC), to aid tracking.

4.4 Flight sequence

For details of previous flights, please refer to the past campaign reports and flight data. If these cannot be found on the REXUS/BEXUS webpage or teamsite, they can be made available upon request.

4.4.1 Launch

The payload is held by a launch vehicle and is released when the balloon inflation (Helium) is completed.



Figure 4-4: Dynamic Launch with Hercules Launch Vehicle

4.4.2 Ascent phase

The nominal ascent speed is 5 m/s. Depending on float altitude and variations in speed, this phase takes approx. 1.5 hours. A slight oscillating movement is experienced. Expect an initial drift above ground of 5-10 m/s

4.4.3 Float phase

When the total mass of the system and the buoyancy of the gas reaches equilibrium, the ascent phase stops. During float there are only minor changes in altitude (± 200 m). If the sun sets during flight, the balloon will begin to descend due to the cooling of the gas.

The payload mass influences the maximum altitude. The final altitude is calculated shortly before launch and may vary between 25 and 30 km. The nominal flight time is one to five hours.

4.4.4 Descent phase

To end the flight, the cutter is activated, causing the balloon to separate from the rest of the flight train and rip open. There is a parachute system that brings down everything below the cutting device.

A small period of reduced gravity will be experienced, but the gondola may tumble and it's suggested that this is not particularly suitable for microgravity experiments.

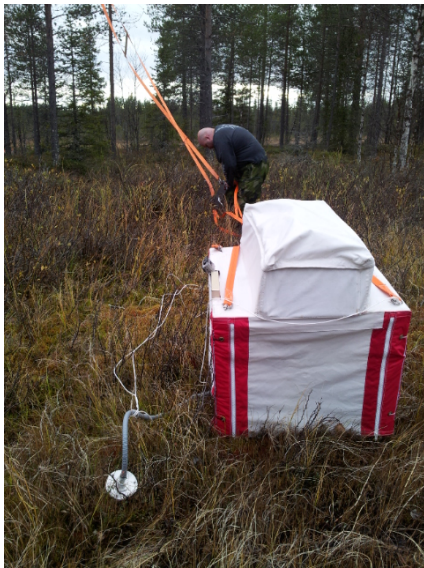
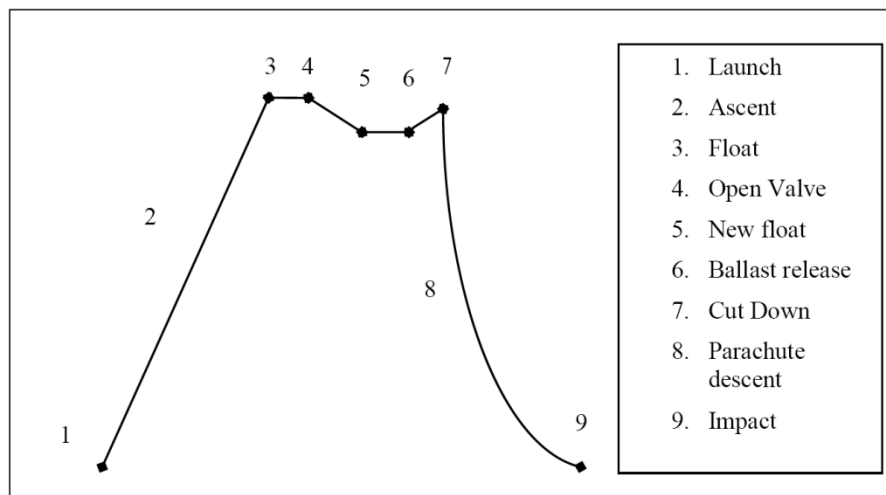
The descent speed is high from the start, due to the thin atmosphere. Closer to the ground, it will stabilize at approximately 7-8 m/s.

4.4.5 Landing

Landing is always planned to be in sparsely-populated areas, preferably without any lakes.

The landing velocity is approximately 7-8 m/s. This is equivalent to a drop from approximately 3 m. There is a shock-absorbing material at the bottom of the gondola that lowers the shock load at landing. Nominally, the landing is gentle with no damage to the experiments.

On rare occasions we have seen landing shocks up to 35 g when landing in rocky terrain. A water landing is softer but comes with another problem, since the gondola is not watertight.

**Figure 4-5: Soft landing (BX-14)****Figure 4-6: Hard landing (BX-15)****Figure 4-7: BEXUS Flight Profile**

The performance of the BEXUS balloon may be adapted to the respective mission requirements. Ballast release (6) operations are optional and not normally flown on BEXUS.

4.5 Flight trajectory

The total distance covered is different for all missions. Since all flight systems depend of Line Of Sight (LOS) between Esrange and the gondola, the maximum range is about 400 km. Flight profiles are available in numerical form upon request, and some typical examples from previous missions are given below:

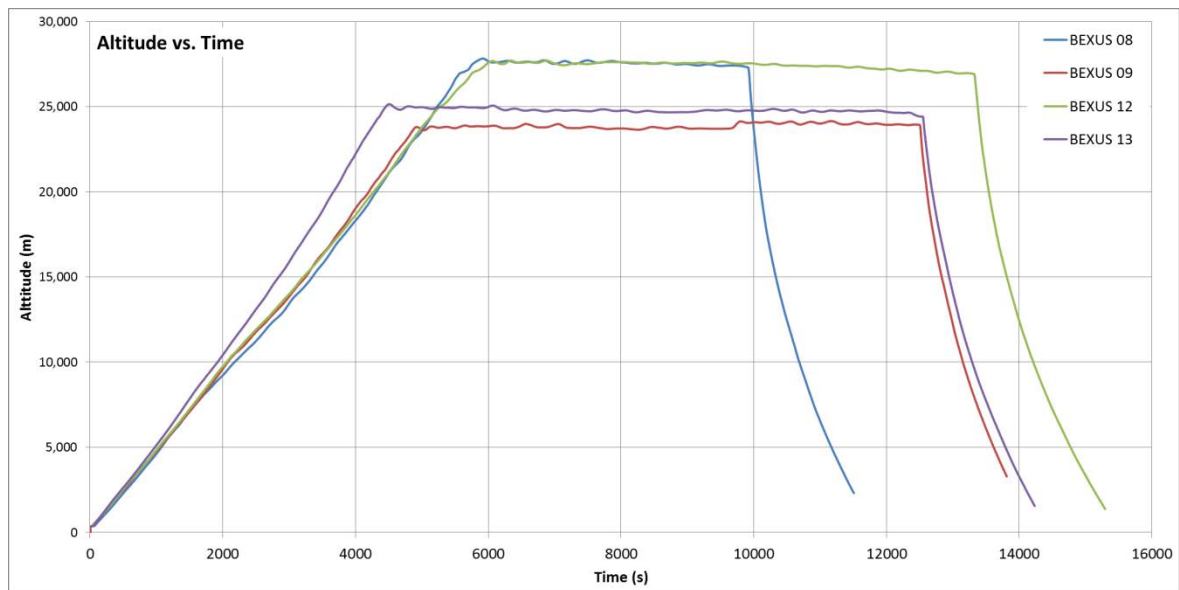


Figure 4-8: Altitude vs. Time for typical BEXUS flights

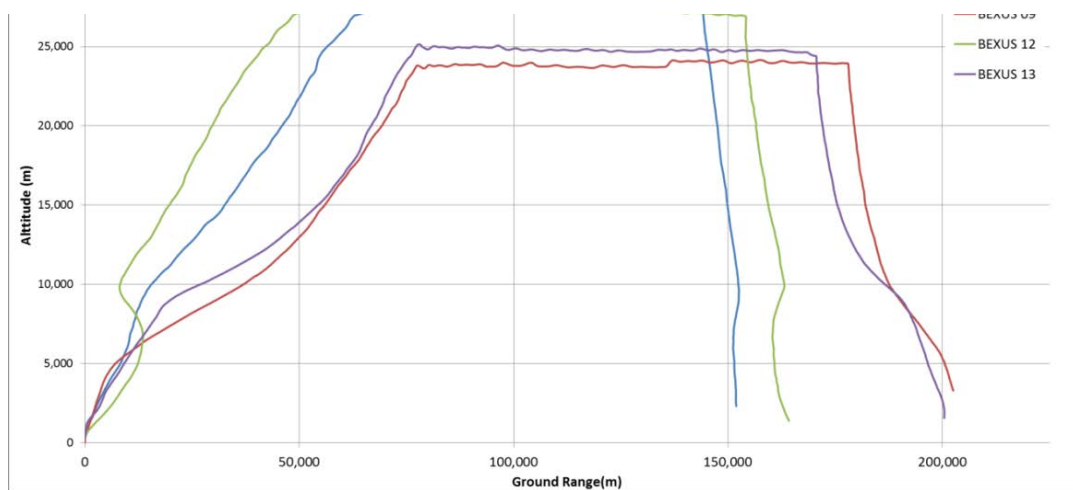


Figure 4-9: Altitude vs. Ground Range for typical BEXUS flights

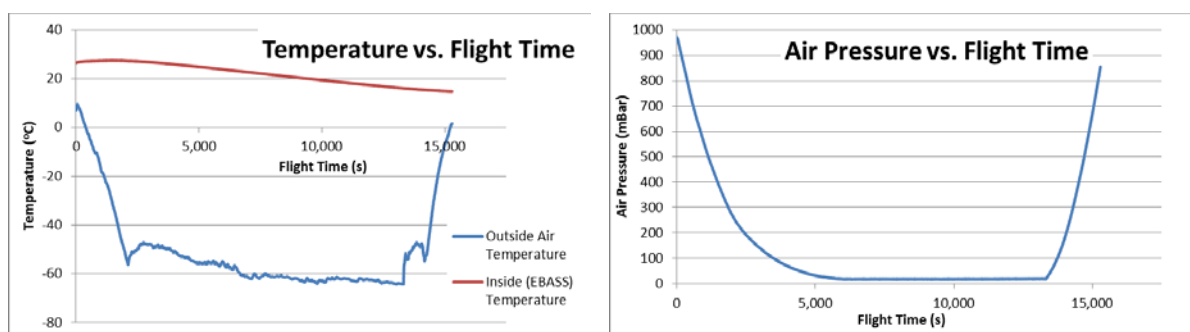


Figure 4-10: Measured Atmospheric Data from BEXUS 12

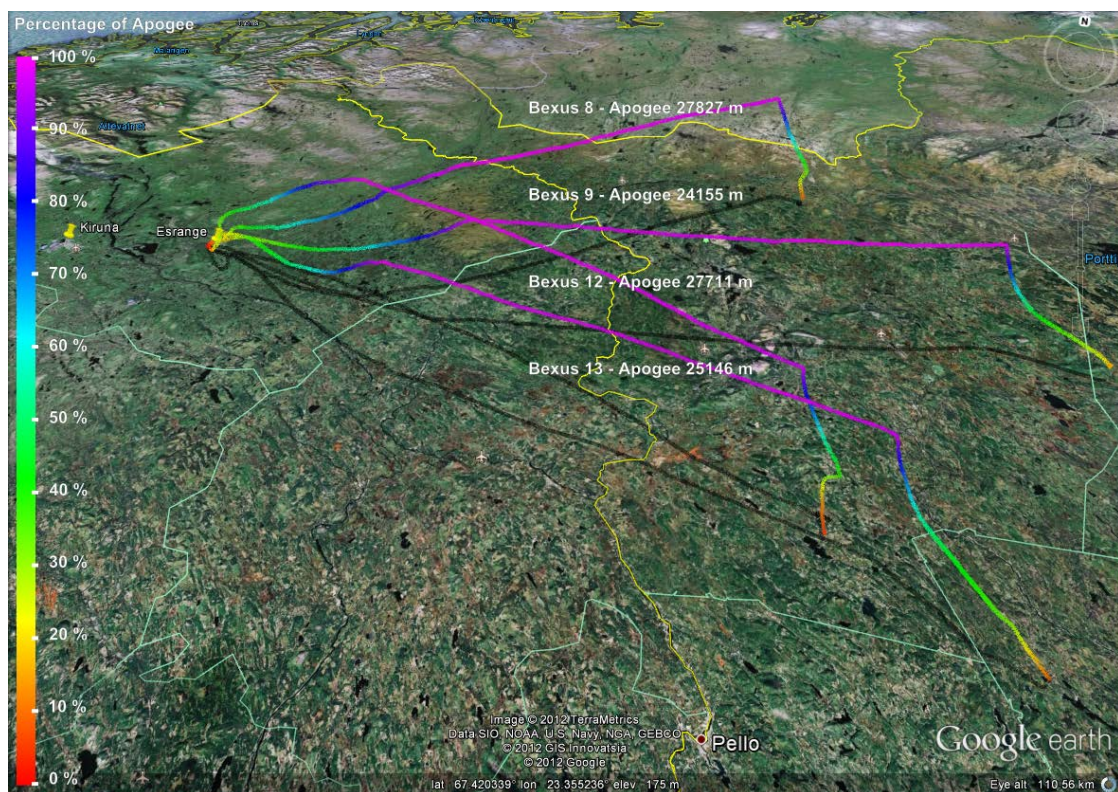


Figure 4-11: Example of previous BEXUS Flight Trajectory

4.6 Recovery

The payload will be picked up by helicopter for further transport by truck back to Esrange. The payload is normally brought back to Esrange within a day or two after launch.

During the design phase, experimenters should keep recovery accessibility in mind. It is a good idea to create a recovery plan document for the helicopter crew early in the design process in order to avoid overlooking how this aspect will affect accessibility and other issues.



Figure 4-12: Landing position of BEXUS-7

5 TELEMETRY SYSTEMS

The two telemetry systems used are E-Link and EBASS. E-Link is used by experimenters to transfer data to and from ground. EBASS is used by Esrange for piloting and data-taking. EBASS is used only by Esrange and not by BEXUS experimenters.

5.1 E-Link telemetry system

Esrange Airborne Data Link (E-Link) is a telemetry system that offers a simplified interface to experiments with a standard Ethernet protocol. The system can also handle other types of synchronous and asynchronous user interfaces. Only the Ethernet interface is provided for BEXUS Experiments.

5.1.1 E-Link System Overview

The E-Link system consists of a ground station and an airborne unit. The ground station consists of an antenna, an antenna controller and a Monitor & Control Unit. The airborne system includes the main unit, an antenna, a battery, and an RF interface unit. At least one connection is available to all experimenters.

The main features of the system are:

- A standard and easy-to-use interface for payloads: Ethernet 10/100 Base-T Protocol
- MIL-C-26482-MS3116F-12-10P connectors (as seen in Figure 5-1)
- High data bandwidth, 2 Mbps duplex nominal
- Optional synchronous and asynchronous interfaces
- All electrical parts are approved by FCC and ETSI (standards)
- Fixed IP address allocations



Figure 5-1: E-Link Airborne Unit

5.1.2 Technical Specification of the E-Link Airborne Unit

Antenna:	Vertical polarised omni
Operating frequency:	S-band
Max output power:	Peak 10 watt
Modulation:	DSSS
Channel bandwidth:	Nominal ± 11 MHz
Maximum range at LOS:	500 km at 30 km altitude (TBC)
Data bandwidth:	2 Mbps duplex nominal
User interfaces:	2 Ethernet 10/100 Base 3 asynchronous duplex RS-232/422 channels
Power supply:	20 to 38 volt DC
Operation time:	Nominal > 11 hours
Weight:	Nominal ~20 kg, including batteries

5.1.3 Technical Specification of the E-Link Ground Unit

Antenna:	1.8 meter parabolic dish
Operating frequency:	S-band
Max output power:	Peak 10 Watt
Modulation:	DSSS
Channel bandwidth:	Nominal ± 11 MHz
Maximum range at LOS:	500 km at 30 km altitude (TBC)
Data bandwidth:	2 Mbps duplex nominal
User interfaces:	Ethernet 10/100 Base-T – 2 asynchronous RS-232/422 channels – 1 synchronous channel up to 1 Mbps

5.2 Esrange Balloon Service System - EBASS

This system is used by Esrange for piloting of the balloon. It is not used by BEXUS experiments and interference with it must be avoided at all costs.

5.2.1 EBASS Overview

The Esrange Balloon Service System (EBASS) provides functions for:



- Altitude control
- Flight termination
- Load cell controlled emergency termination
- On-board GPS
- Housekeeping
- Three full duplex, asynchronous, transparent serial connections for payload control and data reception.

Figure 5-2: EBASS Unit

5.2.2 Technical Specification of the EBASS Ground Unit

Transmitting frequency:	449.95 MHz
Modulation:	FM
Total data bandwidth:	38.4 kbps Nominal
Receiving frequency:	402.2 MHz, Nominal (400-405 MHz)
Modulation:	FM
Total data bandwidth:	38.4 kbps
IF bandwidth:	50 KHz, 100 KHz, 250 KHz and 500 KHz
Output power:	100 Watt
Antenna type:	Helical Antenna
Antenna polarisation:	RHCP
Antenna gain:	12 dBiC
Maximum range:	550 km (at 30 km float & LOS)

5.2.3 Technical Specification of the EBASS Airborne Unit

Antenna type:	Cross Broadband Dipole
Maximum range:	550 km (at 30 km float & LOS)
Transmitting frequency:	402.2 MHz Nominal (400-405 MHz)
Modulation:	FM
Total data bandwidth:	38.4 kbps Nominal
Receiving frequency:	449.95 MHz
Modulation:	FM
Total data bandwidth:	38.4 kbps Nominal
Output power:	100 Watt
Operation time with maximum battery configuration:	40 hours
Cut down system:	Two independent, one is timer controlled
Altitude control:	Valve and ballast release

6 DESIGN CONSTRAINTS

6.1 Mechanical design

The balloon gondola (M-Egon) used within BEXUS is shown below. At the bottom bulkhead in each gondola rails are provided for experiment fixation.

Distances between the rails (centre points) are 360 mm. See drawing of rails and gondola in Appendix A: Gondola drawings and more gondola images in Appendix C: Gondola/Experiment Interface Images

3D CAD Models are available on the REXUS/BEXUS Teamsite.

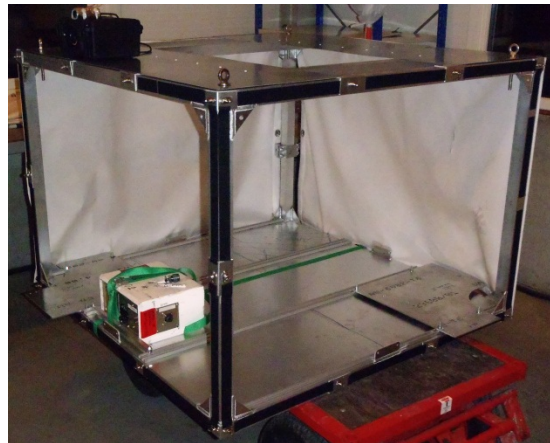


Figure 6-1: M-Egon

6.1.1 Experiment mounting

Each experiment must be supplied with a sufficient number of brackets or a bottom plate, in order to facilitate a safe mounting of the experiment. Nominally this happens by bolting to the gondola rails (see profile in the figure below). Bolt: M6 with 23 mm thread length.

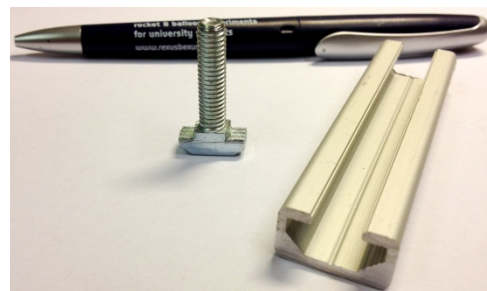
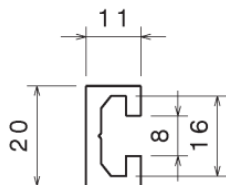


Figure 6-2: Experiment mounting rails and anchor bolt (M6).

The experiment should be structured to withstand the loads mentioned below, as well as the loads that will be applied during the integration tests. It is the experimenters' responsibility to show that the structure and attachment of an experiment is strong enough. This can be done by stress calculations or load tests. Under no circumstances will there be a flight with an experiment that has a risk of falling off the gondola.

6.1.2 Acceleration

The design load used for the payload is: - 10 g vertically and +/- 5 g horizontally.

6.4 Thermal Environment

6.4.1 Pre-Launch Phase

In normal conditions, the preparation of the payload is done at a room temperature of approximately $20 \pm 5^\circ\text{C}$.

After preparation, the payload is brought outdoors to the launch pad. The outdoor temperature at the launch pad in Sept/Oct is normally between 0°C and -15°C and the exposure time can be up to several hours.

6.4.2 Count Down Phase

Experience shows that during count down, the experiment modules tend to see an increase in temperature over time, especially if long holds are required. Some actions can be taken at the launch pad to improve the situation, however it is recommended that heat sensitive experiment modules, or experiment modules that create high temperatures within the gondola, should include temperature regulation in the experiment design.

6.4.3 Flight phase

The thermal environment of the flight may see temperatures down to -80°C . Figure 6-5 below shows temperature graphs of a number of PTU sondes flights during the normal BEXUS campaign period.

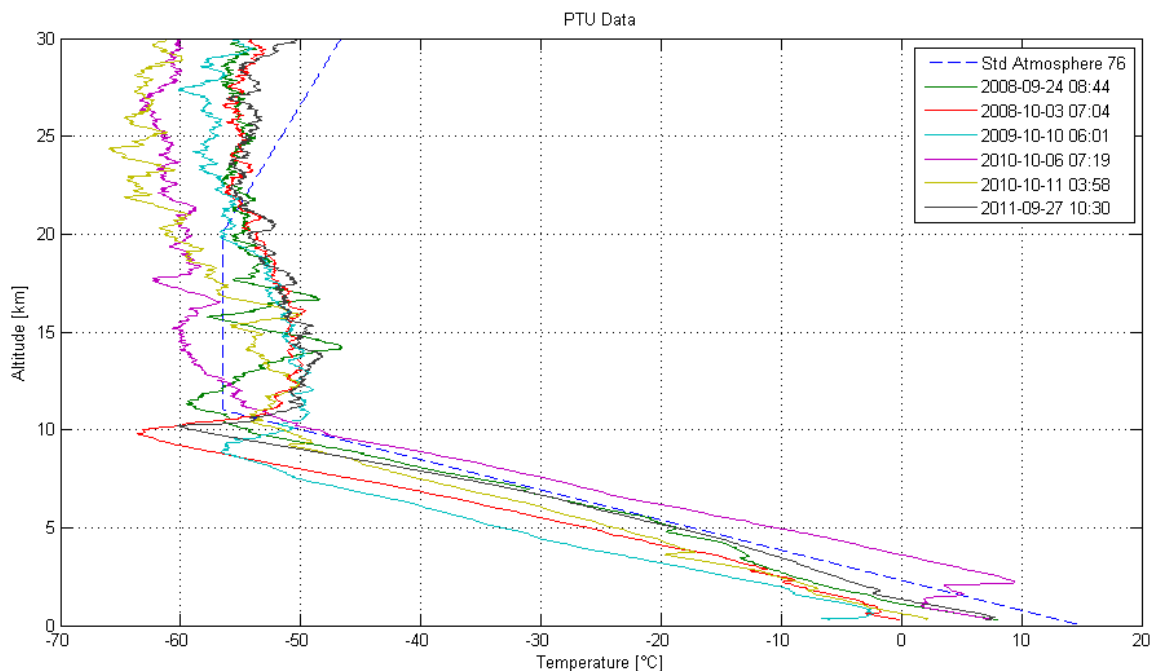


Figure 6-5: PTU Sondes Temperature graphs

6.4.4 Post-flight phase

After the impact, the payload will most likely be subjected to snow and cold air in the impact area for a period of typically one to two days. The temperature during the season when BEXUS is launched is normally between 0°C and -15°C . Experiments sensitive to low temperatures must be designed for these post-flight conditions.

6.5 Radio frequency constraints

In general, for every transmitter or receiver that will be used at SSC/Esrange during a campaign, information must be given to Esrange well in advance, in order to receive permission to transmit RF.

At Esrange, the reception of weak satellite signals might be jammed and special care must therefore be taken regarding when and how RF transmitting occurs.

It is also necessary to apply for frequency permission at the PTS (Swedish Post and Telecom agency). SSC/Esrange can either apply on behalf of experimenters or give the information needed to perform such applications. The information required in advance includes parameters such as transmitting frequency, radiated power, bandwidth of signal, antenna, antenna pattern, and modulation type.

The following frequencies are used in safety, telemetry, and recovery systems and are therefore not allowed for use by any experiment:

Table 6-1: Frequencies that are not allowed for use by any experiment

400-405 MHz
449-451 MHz
1025-1035 MHz
1089-1091 MHz
2405-2496 MHz (Ch 2-14 in 2.4 GHz-band)

6.6 Electrical Grounding

Having a well-considered and documented grounding concept for your experiment is important, in particular to:

- To provide an equipotential reference plane
- To minimise the common mode based on the requirements
- To avoid ground loops
- To protect against shock hazards due a high voltage ESD on a frame or box housing due to electrical harness damage

Several grounding options are available to teams, such as single point grounding, multi-point grounding and hybrid systems. Different approaches will be suitable for different experiments. In special cases (due to scientific requirements), a total isolation approach may be required, this should be done in coordination with your EuroLaunch contact.

It is suggested that a possible good approach for power complex BEXUS experiments is to utilise Distributed Single Point Grounding (DSPG).

If required an equipotential reference plane to the gondola electric can be provided.

It is also important to consider the grounding scheme of any EGSE used, as problems can also arise during testing due to physical connection with the experiment's EGSE.

6.7 Operations and durability

6.7.1 Operations

During the pre-flight tests and the count down, the experiments must be turned on and off several times to test systems such as E-Link and power and to check for interference with other experiments and balloon systems. These operations are partly performed outdoors during the RF interference test under difficult conditions. Also, once carried out, they may have to be repeated several times. BEXUS experiments should be designed with these operations in mind. The procedures to turn and experiment on and off should be kept simple and should be possible with a minimum set of tools in a short period of time.

6.7.2 Power

Operations during the pre-flight tests have a significant impact on the experiment's power and memory budget. Make sure that there is enough battery, memory, etc. to survive these activities, in addition to that which is required for the flight.

All experiments must have a power connector for external power (even if own internal batteries are used), power will be supplied via this connector from the gondola power system or a power source on the launch vehicle (Hercules). At approx. T-40 min the power will be switched over to internal (gondola or experiment) batteries and the external power umbilical (between Gondola and Hercules) will be removed. Note that there will be no access to experiments at that time.

When considering the power budget (see chap. 9.5 for count down and launch), the possible wait times when the experiment is turned on but cannot be accessed should be taken into account (most commonly testing and launch attempts). Be prepared to have power supplies for 2 hours of testing, 2 hours on ground and for a flight time of 6 hours as a minimum (tot. 10 hours minimum).

Be prepared for possible aborted launch attempts as it is not uncommon to go through a countdown 2 or 3 times before a launch is achieved.

6.7.3 Hercules impact

Although relatively rare, for experiments that protrude from the gondola, it should be considered that an impact with the Hercules during the launch is a possibility. Location on the gondola, housings and materials can be selected to minimize a component failure in the case of a collision.

6.7.4 Landing considerations

Due to the unpredictable nature of the gondolas' landings (Chapter 4.4.5), the experimenter should be prepared for a wide range of possible environmental influences. Submersion of the experiments in water is possible, if this will be an issue for the experimenters, precautions should be taken. During the landing, organic matter and soil may become lodged in the experiments, especially if they protrude beyond the gondola.

If the experiment protrudes beyond the gondola, sacrificial joints (or other contingency plans) should be considered if it is foreseen that an impact could damage the experiment seriously.

6.8 Recommended Tests for Experimenters

6.8.1 Vacuum test

This test is applicable not only for experiments which will take place under vacuum conditions, but also helps to verify that systems, mainly electrical, have nominal performance in the absence of convective cooling. It is the responsibility of the experimenter to perform this test, if necessary.

Basic Procedure

- The experiment shall be integrated and placed in a vacuum chamber (pressure below 5 mbar).
- Experiment data shall be supervised and recorded during the test.
- The experiment shall be operating during the lowering of the pressure in the vacuum chamber. The experiment shall be in a similar mode as during the real BEXUS flight.
- After this functional test / flight sequence has been performed, it is recommended that the module is kept operating for an additional 15 minutes, in order to detect any leakages or overheating problems.

6.8.2 Thermal test

A thermal test is mainly performed in order to verify a nominal function of the experiment during the worst-case temperatures that can be experienced during count down and launch. It is the responsibility of the experimenter to perform this test, if necessary. The heating of the outer structure/gondola is normally not included or tested.

Basic Procedure

- The experiment shall be integrated and placed in a thermal chamber.
- Experiment data shall be supervised and recorded during the test.
- The temperature shall preferably be measured in several places in the experiment.
- **Low temperature test:**
Regulate the temperature in the thermal chamber, preferably down to -80°C but at least to -40°C . When the measured temperatures in the experiment have stabilised, perform a functional test / flight sequence. Be aware of condensation problems if the test is performed in normal humidity.

6.8.3 Mechanical Test

Mechanical tests are necessary to ensure performance of the experiment during flight after possible shocks that occur during launch. If not, it is possible that the balloon will be launched with the experiment non-operational. There are two major risks to be identified, structural integrity and experiment durability. It is the responsibility of the experimenter to perform this test, if necessary.

Basic Procedure 1

- The experiment should be placed on a solid surface with a clear area around the test area.

- The experiment should then be loaded with between 10 and 30 times the experiment's own weight (depending on the structural design) in a stable and secure manner.

Basic Procedure 2

- An area should be cleared in which the experiment can be safely dropped (the persons carrying out the procedure should be wearing a sufficient level of safety gear).
- The experiment should be dropped from a height of 1-3 metres onto a solid surface.
- Afterwards, the experiment should be checked for full functionality by system tests but a visual check is also important to see if any cabling or mechanisms have been affected.

6.8.4 Bench Test

All experiments should carry out a bench test of their experiment before transport. The test should be carried out for a maximum duration mission (2 hours wait before launch, 6 hour flight and possibly a wait time before recovery when appropriate). This test should be carried out as there are many issues which arise only after long duration of operation.

Where possible, this is best done using the same power system as for flight (with voltage and temperature monitoring of the batteries). Possible issues that have occurred in the past are microcontroller malfunction with low power and battery rupture due to overdrawn current.

The experiment should be supervised at all times in case of a failure. It is the responsibility of the experimenter to perform this test, if necessary.

Basic Procedure

- The experiment should be assembled as for flight in a safe area removed from interference (both environmental and human).
 - Monitoring of temperature and voltages for critical electronic components should be set up where desired.
 - The experiment should be run through a simulated countdown (chap. 9.5) (including Ethernet connection, external/internal power and wait period after switching on). During this period, procedures for interaction with the experiment should be tested.
 - Following simulated launch, the experiment should be run as desired for ascent, float and descent of 6 hours. Here, the possibility of E-Link dropouts should be simulated where appropriate to ensure that correct operation of the experiment will occur when there is no telemetry available.
 - Experimenters should also seriously consider running the experiment as they plan for another 24 hours to simulate the wait time on ground before recovery.
-

6.9 General Design Considerations

6.9.1 Experiment Accessibility

Bear in mind that designing for accessibility will make your task easier throughout the assembly and testing phases. This is an important point that is often overlooked by experimenters. It is in your interest that items such as switches, battery packs and cable connections are easy to access. Considering access to fasteners is also worth the time.

6.9.2 Availability of Parts

A major issue for many experimenters is late delivery and procurement delays. Rather than merely basing a design on parts from catalogues, ensure that they are available, this can save a lot of time and money for experimenters. Avoid designs based on hard to procure items or irreplaceable items where possible.

6.9.3 Experiment Construction Costs

Consider enforcing a three-quote minimum on components where possible (this is often not possible due to the specialized nature of items). When designing, remember that the cost for machining can differ greatly depending on early design decisions. Avoid close tolerances wherever possible, not only is it cheaper but it can save time with assembly. Remember to use experience and judgement; the cheapest items are not always the best selection.

6.9.4 Redundancy

Redundancy is desirable, especially where there are safety or failure risks. It is not as simple for mechanical as electrical but it should be considered during the design process. Redundancy can be simply achieved by separate battery packs, multiple switches, check valves, and other solutions.

6.9.5 Weight and Size Considerations

Minimizing weight is commonly overlooked by experimenters. However, keeping weight low where possible serves multiple functions. For payload organization, when experiments are light and small, it gives EuroLaunch more flexibility in selecting locations for each experiment. It can also result in more experiments being flown. In order to do this, early system design solutions must be generated so that the mechanical engineers can determine the best approaches to minimizing size and weight.

Perhaps most importantly, lighter payloads will general allow a higher float altitude.

6.9.6 Effectiveness of Testing

When designing your experiment, please take into consideration the testing in the future. This is an issue of accessibility, but also of design. Fast and simple methods of testing, calibrating, or adjusting important items will save experimenters' time. This will also make it simpler for testing carried out by EuroLaunch.

6.9.7 Shipping

When designing your experiment, please take into consideration the need for shipment, possible configurations and storage/transport requirements.

6.9.8 Safety

Safety is of the utmost importance to EuroLaunch. Any experiment that is deemed risky to the public, staff or experimenters will not be flown. Take care to ensure that you perform any simulation, analysis, and testing that will help to convince EuroLaunch that the experiment is safe to fly. If there are any items that you can identify as safety risks, keep them in mind during your design as the possibility exists that the experiment will be removed from the vehicle if it poses a danger.

7 PRE-CAMPAIGN ACTIVITIES

7.1 Esrange Safety Board (ESB)

Every campaign or project at Esrange has to be accepted by the Esrange Safety Board. A standard balloon is normally no problem. If there are hazardous items such as chemicals, lasers, radiation, etc. included in the experiments, there may be a need for further investigation. This may take some time and should be done early in the design process, well ahead of the start of the campaign.

7.2 Campaign Requirements Plan (CRP)

The BEXUS Project Manager provides Esrange Space Center, as well as all parties involved in the project, with the Campaign Requirements Plan. This document gives a complete description of the specific project, including payload information, a list of hazardous materials, experiment requirements on the launch operations, tools required, participants expected, etc. This is an important document used to inform all participants in the campaign.

The first version of the CRP will be distributed after the PDR (training week). Inputs are requested from every experiment team, regarding interfaces, telemetry, power consumption and special experiment requirements.

7.3 Payload Assembly and Integration

The payload integration tests are performed at EuroLaunch premises and/or premises leased by EuroLaunch. Nominally, these tests start two weeks before the planned start of the launch campaign.

7.3.1 Experiment Incoming Inspection

All experiment mechanical and electrical interfaces will be inspected upon delivery to the payload assembly and integration premises.

8 CAMPAIGN ACTIVITIES BEFORE START OF COUNTDOWN

8.1 Description of Estring Space Center

All the necessary information for a user of Estring can be found at:
www.sscspace.com under 'Science Services/Estring Space Center'.

Its main content is:

- Range description (capabilities, layout, environment...)
- Range administration (communications, accommodation, freight, supplies...)
- Safety regulations
- Instrumentation (telemetry, tracking, observation, scientific...)
- Operations (assembly, checkout, flight control, recovery, requirements, procedures)
- Satellite facilities

8.2 Safety

Safety always comes first at Estring. Before the start of a campaign, a safety briefing will be held. It is mandatory for all visiting personnel to attend this briefing.

8.2.1 Additional Estring Safety Board meetings

If a safety issues arise during a campaign, there might be a need for extra Safety Board meetings before a launch is possible.

8.3 Time schedule

The BEXUS launch campaign takes place over approximately 10 days. This does not allow any time for errors or delays and it is important to be well prepared.

Every morning, there is a status meeting in one of the conference rooms, where the upcoming activities are discussed.

8.3.1 Overview of build-up schedule

A more detailed schedule will be issued closer to the campaign week. Depending on how the preparation work progresses and the weather forecasts, there might be changes during the campaign week itself.

Table 8-1: Typical BEXUS Campaign schedule

Day	Action	Location
0	Nominal day of student arrival Estrange Safety briefing	Polaris
1	Launch Safety briefing SSC, DLR, ZARM, ESA Team introduction Campaign Information Experiment Preparation	Polaris
2	Morning meeting Experiment Preparation Electrical Check-Outs ¹ Interference Tests ²	Polaris CATH CATH CATH
3	Morning meeting Flight Compatibility Test (FCT) ³ Meteorology briefing Flight Readiness Review (FRR)	Polaris CATH Polaris Polaris
4	Morning meeting 1 st balloon launch opportunity	Polaris
5	Morning meeting 2 nd balloon launch opportunity	Polaris
6	Morning meeting OPTIONAL: Launch opportunities Experiment results presentations	Polaris
7	Spare day	
8	Spare day	
9	Spare day	
10	Nominal day of student departure	

Note:	Test:	Comment:
1	Electrical Check-Out	All experiments are mounted and connected: <ul style="list-style-type: none"> • External power connection • Power on/off • E-Link communication test Carried out for all experiments, one-by-one
2	Interference Test	Experiments are checked: <ul style="list-style-type: none"> • For interference amongst themselves • All Experiments switched on and verified
3	Flight Compatibility Test (FCT)	Gondola moved to the balloon launch pad (by Hercules): <ul style="list-style-type: none"> • Check for interference with EBASS etc. • Experiments switched on, one after the other • All experiment systems must be running • Mass measurement Long waiting times (3-4 h) possible Notice that after this test: <ul style="list-style-type: none"> • No more experiment preparation are allowed. • Only the batteries can be exchange/charged.

8.4 Planning

Experiment teams are strongly advised to think through all aspects of the experiment, the build-up, all tests, the launch and the flight phase. With this input, make a detailed plan of how to work, who is doing what (team member, Esrange staff, etc.) and how much time is needed to do all this.

A checklist is the key item to success: even the smallest thing, such as flipping a switch, should be in the list.

Without good build-up plans and checklists there is a significant risk of failures and delays during the campaign week. All of this should be documented in the SED.

8.5 Assembly of balloons and payloads

8.5.1 Assembly of balloons

All assembly and preparation activities related to the balloon and its subsystems are the responsibility of the EuroLaunch team. This is normally done in the Basilica building.

8.5.2 Assembly and checkout of payloads

Payload assembly and preparations are conducted by the BEXUS Project Manager together with EuroLaunch staff and the experiment teams. A dedicated person will be assigned to each gondola. Working space in the launching area will be allocated to each team, normally in the Cathedral building.



Figure 8-1: From left to right: the Dome, the Chapel, Cathedral and Basilica preparation & assembly buildings

8.5.3 Equipment

There is one soldering station located in the Cathedral assembly hall. There is also basic measurement equipment and toolboxes available to borrow.

If you need some special tools or equipment, be sure to either bring it with you, or specifically state that you need it when you give input to the Flight Requirements Plan.



Figure 8-2: Standard Equipment Set at ESRANGE



Figure 8-3: Standard Power Supply at ESRANGE

8.6 Flight Simulation Test (FST)

When all experiments are operating nominally and there is enough time for this test, a simulated count down and flight sequence is performed. All telemetry and telecommand signals will be recorded in the telemetry ground station, during the test.

It is important that the any changes/modifications made to H/W or S/W after the Flight Simulation Test are restricted to a minimum. Non-conformances discovered during the test can of course be corrected, but care must be taken to verify that no further malfunctions are induced by the correction.

Basic Procedure

- The experiment shall be integrated and in flight configuration. The telemetry and telecommand checkout system or simulator shall be connected via the interface harness.
- Experiment data shall be supervised and recorded during the test.
- A nominal realistic count down and flight procedure shall be followed.

8.7 Flight Compatibility Test (FCT)

When all experiments are installed in the gondola, a RF interference test is conducted. The gondola is picked up by the launch vehicle and placed together with all other transmitting / electrical hardware at the same distances as in a real flight. A test with all electronic equipment as well as experiments operating in flight mode is then performed. If an experiment is causing interference with EBASS or E-Link it will not be granted permission to fly. If there is interference between two experiments, the problem will be discussed and a solution or compromise will be found. After the FCT, the gondola is sealed and there are no further changes possible to any experiment. During count down there are very limited possibilities to fix any problem. If there is no quick fix available, the experiment may have to fly with limited functionality or in switched-off mode.

8.8 Flight Readiness Review (FRR)

The Flight Readiness Review (FRR) is conducted by the EuroLaunch coordinator of the launch campaign, after successful completion of the RF test and ground support stations checkout.

The purpose of the FRR is to authorise start of the count down phase

In order to do this it is necessary:

- To ensure that all experiments are ready for the flight. For this, each appointed experiment module manager (team leader) shall give a status report at the meeting. In addition, the PI is requested to state the operative status of the experiment
 - To ensure that all ground and payload service systems essential for a successful launch, flight and recovery are operating nominally. For this each appointed system responsible shall give a status report at the meeting
 - To review the count down list
 - To inform all relevant personnel of the safety regulations applicable during the count down phase.
-

- to inform all relevant personnel of general arrangements implied during the count down phase

8.9 Pre-flight meeting

After a successful FRR meeting there will be a pre-flight meeting. The objective of this meeting is to verify that all flight hardware is ready, Esrange stations are prepared and other flight conditions are in favour of a possible start of count down.

9 CAMPAIGN ACTIVITIES

9.1 Weather constraints

Wind, flight trajectory and visibility are important variables taken into consideration before starting a count down. There is no magic numbers and the decision to start a count down is solely in the hands of Esrange personnel.

Note: It is not possible to guarantee that a launch can take place on one of the 5 days allocated during the campaign week. Plan and prepare so that it is possible for someone else to operate and document the functions of your experiment if the launch is postponed to a later opportunity. This should be documented in the SED.

9.2 Balloon launch conditions

Launch period: September / October

Launch window: 05.00 – 20.00 LT

Ground wind: less than 4 m/s.

Vertical visibility: more than 75 m

Conditions should be sufficient for helicopter recovery on the same day for a short flight or on the next day for other cases.

9.3 Safety on the balloon pad

Esrange has the overall responsibility for safety and has the Veto right in all safety issues during all activities within the Esrange base area. In the case of clients / guests with stronger safety rules than those of Esrange, the stronger rules will apply.

No one is allowed on the pad during count down without the permission of the Operations Officer.

There are several heavy vehicles with limited visibility moving on the pad. To be visible to the drivers, Esrange provides participants with fluorescent safety vests. It is mandatory to wear these when entering the launch pad

When E-link is in a high-power-transmitting mode there is a 10 meter safety distance around the gondola. This is marked with cones.

In the final 1 hour and 30 minutes before launch after the sweet spot tests there is no more access to the experiments.

At launch, everyone must be inside the balloon pad buildings and remain there until instructed otherwise.

9.4 Personnel during the launch

9.4.1 Esrange Project Manager

This person acts as an interface between the guests and Esrange personnel. All requirements must be sent to him before the campaign, so that he can compile the Flight Requirements Plan. It is important that he has all information as early as possible in order to avoid delays during the campaign week.

9.4.2 Payload Manager

This person acts as the contact point for the experimenters during the count down. He relays questions between the experimenters and the Operations Officer, via WT or telephone. He also informs the Operations Officer about status of the Gondola and the experiments and informs him when the PL is ready for pick up.

The Payload Manager communicates with the Electronic Supervisor and the electronic team regarding the E-Link telemetry issues. Finally, he is responsible for keeping experimenters and guests at the necessary safe distances during pick up and launch.

9.4.3 Operations Officer

The Operations Officer handles the count down and is the focal point for all activities.

9.4.4 Launch Officer

The Launch Officer handles all personnel and equipment related to the launch. He is also responsible for safety on the launch pad.

9.4.5 Safety Officer

The safety for third parties is the concern of the Safety Officer. He authorises the Balloon Pilot to send commands to end the flight.

9.4.6 Electronic Supervisor

Handles all issues related to EBASS, E-Link and the RF interference test.

9.4.7 Esrange Telemetry Station (ETM)

The Esrange Telemetry Station (ETM) handles the receiving, transmitting and recording equipment during preparations and launch.

9.4.8 Balloon Pilot

The Balloon Pilot handles the balloon piloting system and monitors the housekeeping data.

9.5 Count down and launch

During the countdown phase, important count down information is displayed on 'PA video monitors' at various locations around the launch site.

The nominal lift off time is planned for between 0500 and 2000 LT. The launch window is determined by the payload preparation time, hold requirements and the time of daylight.

The decision to start the countdown is taken at a weather briefing immediately before the planned start of count down. This decision is based on dedicated weather forecasts, as well as wind data obtained by a meteorological balloon released from Esrange some minutes beforehand. If the weather conditions are unsuitable for launching the vehicle, the launch will be delayed until the flight conditions are fulfilled.

The general launch procedure may be subject to changes. Be sure to design your experiment so it can handle not only the flight but also tests and at least 2 hours of CD (on internal batteries) in case of possible holds.

Experiment teams' ground equipment will be situated in the Cathedral building; transparent communication with the experiment is provided via a designated Ethernet network.

The schedule below indicates the standard count down actions relative to launch ($T = 0$). A final version of these actions is issued at the pre-flight meeting.

Time	Operations	Comments
T-4H30	Decision meeting	
T-4H00	Start of Count Down	
	Start pad preparations	
	Experiments on external power	External Power Supply
	Experiment check-outs	
T-2H30	Gondola pick-up	
	Experiments on external Power	Hercules Power
	Sweet-spot tests	
	Final experiment preparations	Latest Access to experiments
	Go decision from experimenters	Ready for Line-up
T-1H30	Line-up	
T-1H00	Balloon unfolding	Point of no return
	Experiments on gondola/internal batteries	Removal of external power umbilical
T-0H40	Start of balloon inflation	
0H00	Balloon release	Launch
T+~4H00	Command cut down followed by recovery	

9.6 Radio discipline

Please observe the following regarding radio communication:

- Use functional names, avoid personal names
- Use basic English
- Spell by analogy if necessary
- Use 'pro-words' below to minimize the risk of mis-readings
- No horse play or bad language
- Minimize all radio traffic from -5M until +1M

Table 9-1: Radio pro-words and meaning

Pro words	Meaning
Affirmative	YES
Negative	NO
Active	Work commanded is in progress, completion will be reported
Break – Break	I must interrupt this conversation because of an urgent message.
Correction	You have made a mistake. You should have said (or performed) or, I have made a mistake; I should have said
Disregard	Disregard what I have just said. It is not applicable or is in error
Execute	Carry out the instruction
Go ahead	I am on the net. Proceed with your transmission
I say again	I am repeating the message for clarity
Out	I have completed this conversation
Proceed	Go ahead with your task
I copy	I received your last message satisfactorily and understand
I copy, Wilco	I have received your message, understand it, and will comply
Say again	Repeat your last communication
Speak slower	You are talking too fast
Standby	I must pause for time or wait a few moments
Verify	Check status or correctness
Roger	Acknowledge your transmission

Table 9-2: Call sign during pad preparation

Functional names	Function in the balloon processes
Operation	Operations Officer
Launch Officer	Launch Officer on balloon pad
Electronics	Electronic responsible person at launch pad (for EBASS, E-Link)
Assistant Electronics	Assistant electronic responsible at launch pad (for EBASS, E-Link)
Safety	Safety Officer
TM	Telemetry station
Pilot	Balloon Pilot
Scientist	Scientist / experimenter responsible
Payload	Payload Manager

9.7 Deliverables (data)

EuroLaunch will add this information when available.

9.8 During the flight

As soon as the balloon is in a steady ascent, the Balloon Pilot and Operations Officer will move to the Operations Office in the main building. The flight will then be monitored by the Balloon Pilot and the Safety Officer.

9.9 Recovery

The helicopter is equipped with tracking receivers for the payload beacon signal, and can also be equipped with a payload TM receiver for data reception of the payload's GPS position.

During the flight, the payload trajectory will be tracked by means of the transmitted GPS-data in the TM ground stations.

During the descent of the payload, the prediction on the impact point co-ordinates is reported to the helicopter from Erange. The helicopter starts their operation to locate the payload after the impact. At the impact site, the helicopter crew disassembles the flight train for transport by truck back to Erange. Your experiment will then be exposed to vibration, shock loads and the hostile environment on the back of the truck.

The whole operation is normally completed within two days after launch.

9.10 Post-Flight Meeting

After the recovery, a Post-Flight Meeting is held to debrief the flight and a short flight performance report is stated. A short presentation of the performance of each experiment is requested.

10 EXPERIMENT QUALITY ASSURANCE

The major concerns of EuroLaunch related to Quality Assurance (QA) on the experiment level are that the experiment shall fulfil the interface requirements and that the module can fly in a BEXUS payload without jeopardising the performance of the other systems or experiments. In addition, EuroLaunch has a strong concern that the experiments shall perform nominally.

The following advice reflects this concern.

10.1 Materials

In addition to normal concerns when choosing materials, special attention shall be paid to out gassing phenomena due to vacuum environment during flight.

As an aid the ECSS-Q-70-71 [6] (*Data for selection of space materials and processes*) may be used.

10.2 Components

All electrical and mechanical components must have a reliability that is consistent with the overall reliability of the payload. For electronic components, MIL-std specified types are recommended.

10.3 Additional quality topics

In addition to the QA-topics above, the following topics shall be treated if required by EuroLaunch:

- Procured products and audits
Careful planning of the procurement and manufacturing must be made for identification of long lead items. Preferably, a flow chart shall be made which shows the sequence of operations.
- Manufacturing control and inspection
For the manufacturing and inspection of critical processes, the personnel should be aware of standards in applicable areas, such as:

- Manual soldering according to ECSS-Q-ST-70-08C
- Crimping of connections according to ECSS-Q-ST-70-26C

Specific requirements of the project or product concerning cleanliness, contamination and environment shall be stated in the input to the Flight Requirements Plan.

When positioning the parts or components, the sensitivity to, heating, ESD and electrical disturbances shall be considered.

Connectors shall be well marked and preferably keyed.

- Re-used item

It is important to consider the complete history of the re-used item, by consulting the hardware logbook or former project log-book; to be sure that it does not include any hidden failures.

- Availability and maintainability

Spare parts for components susceptible of failure, shall be available during the payload AIT and the launch campaign. The design shall allow for easy and fast replacements of such components.

- Handling, storage, and packing

ESD susceptible components shall be handled in an ESD protected environment.

Before transport, the product shall be thoroughly packed to withstand the expected loads. The use of a bump recorder is recommended.

10.4 Personnel Safety

The BEXUS experiments and dedicated equipment must fulfil safety requirements according to Swedish law. The Swedish Work Environment Act is a general act that is backed up by special laws and regulations in different fields. The Swedish work environment authority issues these regulations.

Special provisions apply (among others) to the following fields:

- Explosives

- Inflammable material

- Chemical hazards

- Electrical facilities

- Radiological work

All the above mentioned laws and regulations are available at:

<http://www.av.se/inenglish/lawandjustice/workact>

The experimenter shall state that the module fulfils the applicable requirements and establish a list of hazardous materials, which shall be communicated to EuroLaunch no later than the MTR. This information shall always accompany the experiment.

10.5 Safety at Esrange Space Center

The Safety Regulations that apply at Esrange may be found in the Esrange Space Center Safety Manual [Ref 4]. It is a requirement that all personnel participating in the campaign shall have read the safety regulation in [Ref 5] prior to their arrival at Esrange Space Center. Each team leader will have to sign a document to verify that all team members have been provided with a copy of the safety manual. See Appendix B: Esrange safety and security compliance confirmation – balloon

11 COORDINATE SYSTEM DEFINITION

This chapter will give a short overview on the coordinate systems that are used for the BEXUS onboard sensors, GPS and tracking systems. Knowledge about the coordinate definition and transformations is important for the analysis of sensor data during the flight and for the post-flight analysis. The following table lists the used coordinate systems.

Table 11-1 Coordinate Systems

ECEF	Earth Centered, Earth Fixed
EGS84	World Geodetic System 1984
LTC	Local Tangent Coordinate System

The global reference system **World Geodetic System 1984** (WGS84) is used for the BEXUS GPS position data. This system is based on the ECEF system. The Local Tangent Coordinate System (LTC) is important for observation of the vehicle from Launcher, Tracking or Radar Station. Details are described in Ref [9].

11.1 Earth Centered, Earth Fixed (ECEF)

If a geocentric coordinate system rotates with the Earth, it results in **Earth-Centered Earth-Fixed Coordinate System**, abbreviated as **ECEF**. The main difference with this system is that the primary axis is always aligned with a particular meridian. The x_{ECEF} -Axis points toward the Greenwich-Meridian which is defined as longitude 0° . This coordinate system rotates with the Earth with the primary axis x always through the Greenwich Meridian.

The position of an object is defined with the geocentric Latitude φ_{gc} , which is measured positive North of the equator, the Longitude θ , which is measured positive towards East from the Greenwich Meridian and the distance d from the Earth center.

$$\vec{r}_{ECEF} = \begin{pmatrix} x_{ECEF} \\ y_{ECEF} \\ z_{ECEF} \end{pmatrix} = d \cdot \begin{pmatrix} \cos \varphi_{gc} \cdot \cos \theta \\ \cos \varphi_{gc} \cdot \sin \theta \\ \sin \varphi_{gc} \end{pmatrix} \quad \text{Eq. 10-1}$$

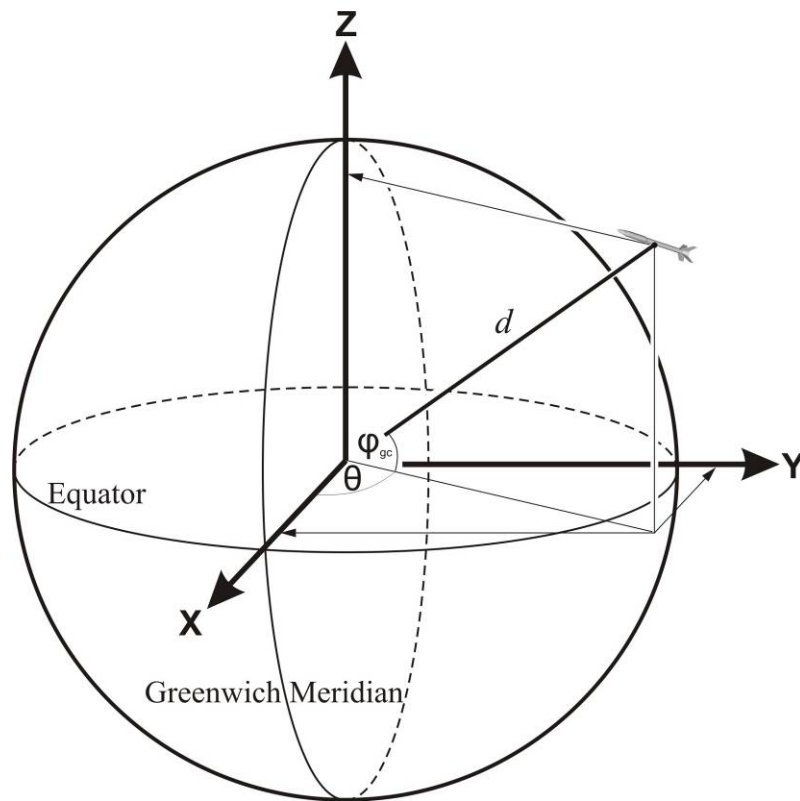


Figure 11-1: ECEF Coordinate System

The reference ellipsoid is rotation-symmetric and every plane cuts the ellipsoid to an ellipse with the flattening f_{\oplus} , which is defined with the relative difference of the equator and pole radius.

$$f_{\oplus} = \frac{R_{\oplus} - R_{pole}}{R_{\oplus}} \quad \text{Eq. 10-2}$$

The WGS84 Ellipsoid has a flattening of $f_{\oplus} = 1/298.257223563$ and the equator radius, R_{\oplus} , is 6378137 m [Ref [9]]. The Earth eccentricity, e_{\oplus} , can be calculated with following equation.

$$e_{\oplus} = \sqrt{1 - (1 - f_{\oplus})^2} \quad \text{Eq. 10-3}$$

The position of the vehicle is given in geodetic coordinates relative to the reference ellipsoid. The geodetic longitude θ corresponds to the geocentric longitude. Not like the geocentric latitude, ϕ_{gc} , which is the inclination of the position vector to the equatorial plane, the geodetic latitude, ϕ_{gd} , describes the angle between equatorial plane and the normal to the reference ellipsoid. It is positive to the North and negative to the South.

The difference of geodetic and geocentric latitude is shown in the following figure:

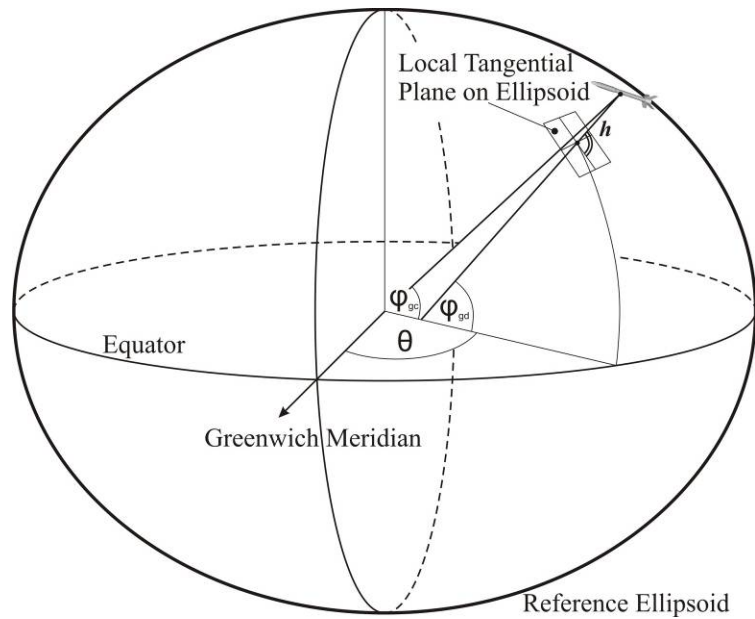


Figure 10-2: WGS84 Reference Ellipsoid

The flattening of the Earth is very small because the difference between the Earth radius at the equator and the poles is less than 22 km. Therefore the difference between geodetic and geocentric latitude is 12 arcminutes.

11.2 Local Tangential Coordinate System (LTC)

The **LTC system** rotates with the Earth. The E axis points to East, the N-axis points to the North and the Z axis is the zenith that is perpendicular to the tangential plane at the observation location (usually Launcher). This location is defined by the geodetic latitude φ_{gd} and geodetic longitude θ .

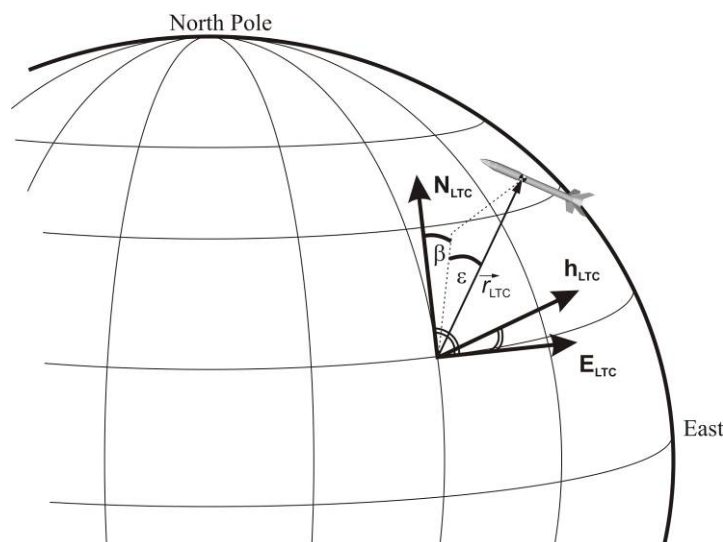


Figure 10-3: Local Tangent Coordinate System (LTC)

Two observation angles define the position of the vehicle from the observation location. The azimuth β is measured clockwise around the observation location starting at North. It varies between 0° and 360° and is calculated with following equation:

$$\beta = \arctan\left(\frac{east_{LTC}}{north_{LTC}}\right) \quad \text{Eq. 10-4}$$

The **Elevation**, ε , is measured between the horizon and the vehicle position. It varies between -90° and 90° and is calculated with the following equation:

$$\varepsilon = \arctan\left(\frac{h_{LTC}}{\sqrt{east_{LTC}^2 + north_{LTC}^2}}\right) \quad \text{Eq. 10-5}$$

The transformation between azimuth and elevation to Cartesian LTC-coordinates is done with the following equation:

$$\begin{pmatrix} east_{LTC} \\ north_{LTC} \\ h_{LTC} \end{pmatrix} = d \cdot \begin{pmatrix} \sin \beta \cdot \cos \varepsilon \\ \cos \beta \cdot \cos \varepsilon \\ \sin \varepsilon \end{pmatrix} \quad \text{Eq. 10-6}$$

The distance d between the vehicle and the observation location is also called Slanrange.

APPENDIX A: GONDOLA DRAWINGS

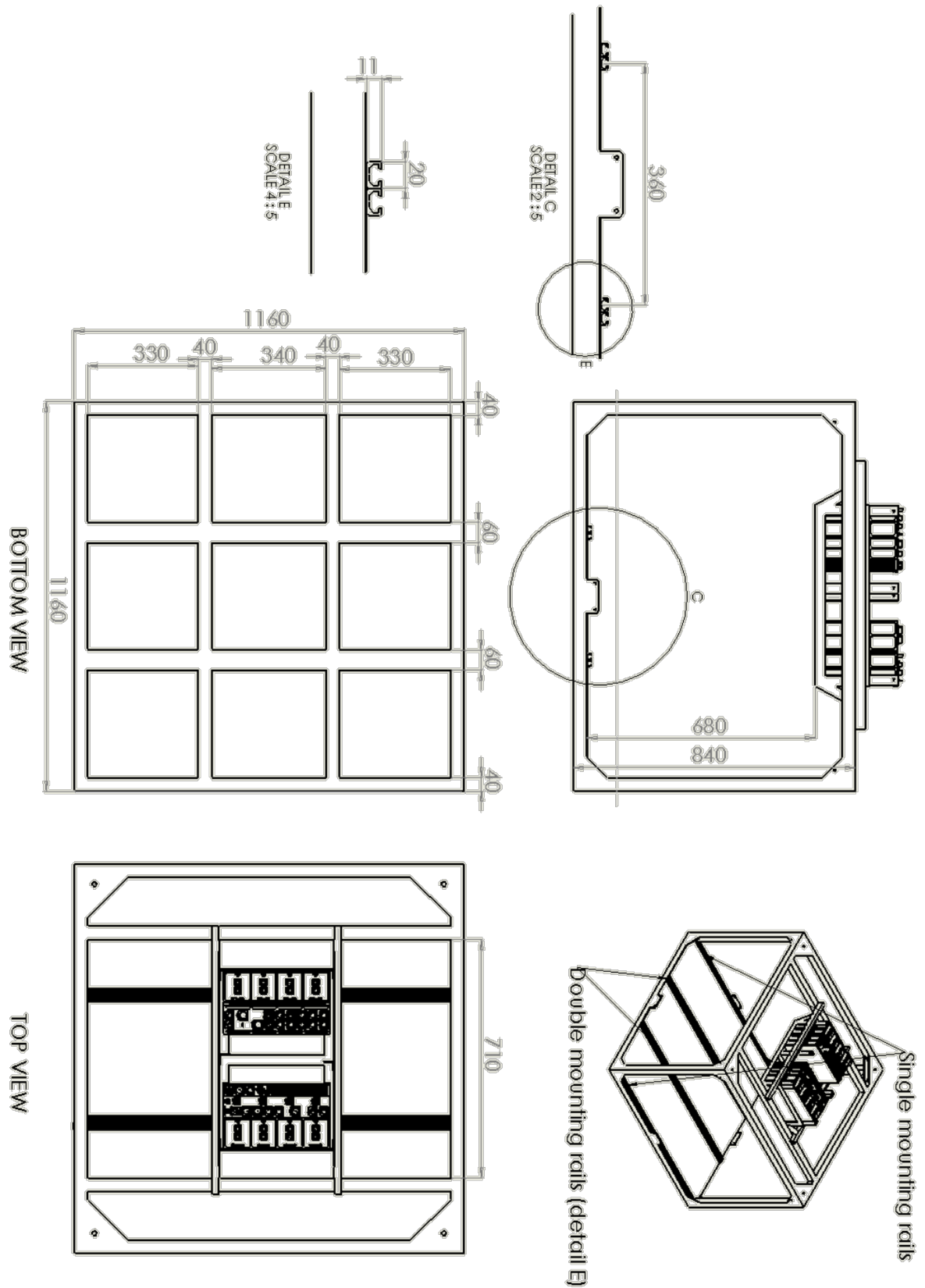


Figure A-1: Gondola dimensioned drawing

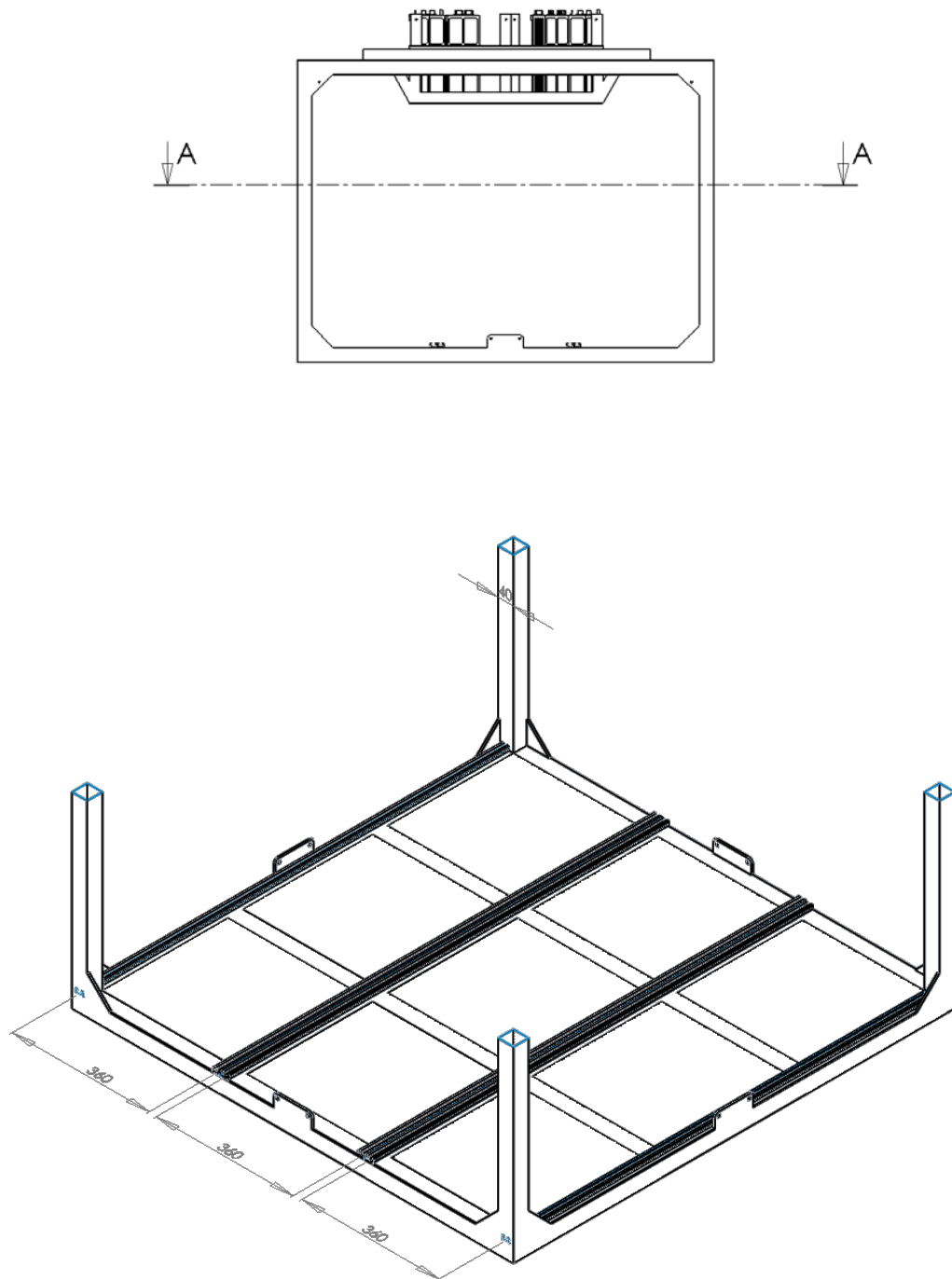


Figure A-2: Section view (A-A: Isometric) of gondola floor

APPENDIX B: ESRANGE SAFETY AND SECURITY COMPLIANCE CONFIRMATION – BALLOON

This document clarifies the basic safety and security conditions for the campaign

..... at the Esrange Space Center.

This document shall be signed by the customer's (range user's/prime contractor's) Mission Manager/Project Manager and by the Esrange Project Manager. One copy of this document and of the *Esrange Safety Manual* (ESM, REA00-E60), is submitted to the customer's Mission Manager/Project Manager.

Swedish law and Swedish safety and security regulations apply to all activities at Esrange.

The *Esrange Safety Manual* provides safety regulations and criteria associated with launching of sounding rockets, UAV's and stratospheric balloons and must be followed by all parties involved.

Temporary and complementary regulations may be issued at any time via the Esrange Project Manager and conveyed to the Mission Manager/Project Manager.

If the customer has own rules that are more stringent, the customer's rules shall be respected when relevant and applicable.

Customer Positions and Responsibilities

Mission Manager/Project Manager is responsible for the customer's work at Esrange and is responsible to see that all customer and customer's contractor personnel follow existing rules and instructions. He/she is the contact point between the customer and Esrange.

SSC Esrange Positions and Responsibilities

Esrange Project Manager is responsible for the campaign coordination at Esrange and is the contact point between Esrange and the customer. He/she shall also superintend all safety and security regulations and arrangements related to the campaign.

Head of Esrange Launch Team is responsible for the ground safety in the launch areas and also all work with explosives at Esrange.

Operations Officer (OP) coordinates all operational work and is the interface with the customer and with Swedish and foreign authorities during **countdown, flight and recovery**.

Safety Officer/Flight Control Officer (SO) is responsible for flight safety during **countdown and flight**. He/she decides in coordination with the customer when to abort a flight.

Launch Officer (LO) is during **countdown** responsible for the ground safety in the launch areas and also all work with explosives at Esrange.

We accept the content of the text above.

Date

.....
Customer Mission Manager/Project Manager

.....
Esrange Project Manager

APPENDIX C: GONDOLA/EXPERIMENT INTERFACE IMAGES



Figure C-1: BEXUS-8 exterior with experiment equipment mounted to the outside of the Gondola

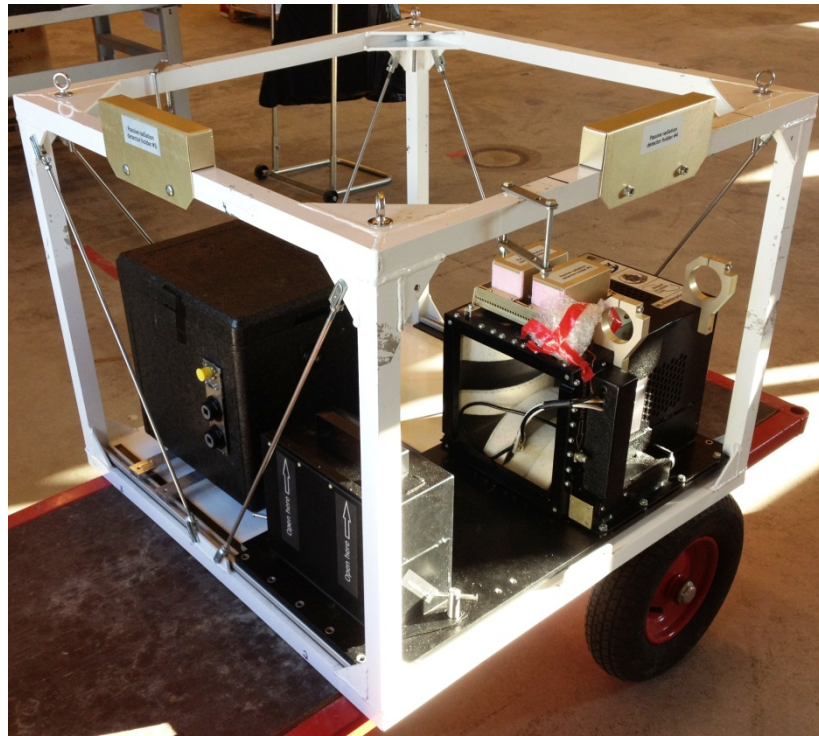


Figure C-2: BEXUS-14 interior showing connections to gondola frame and rails

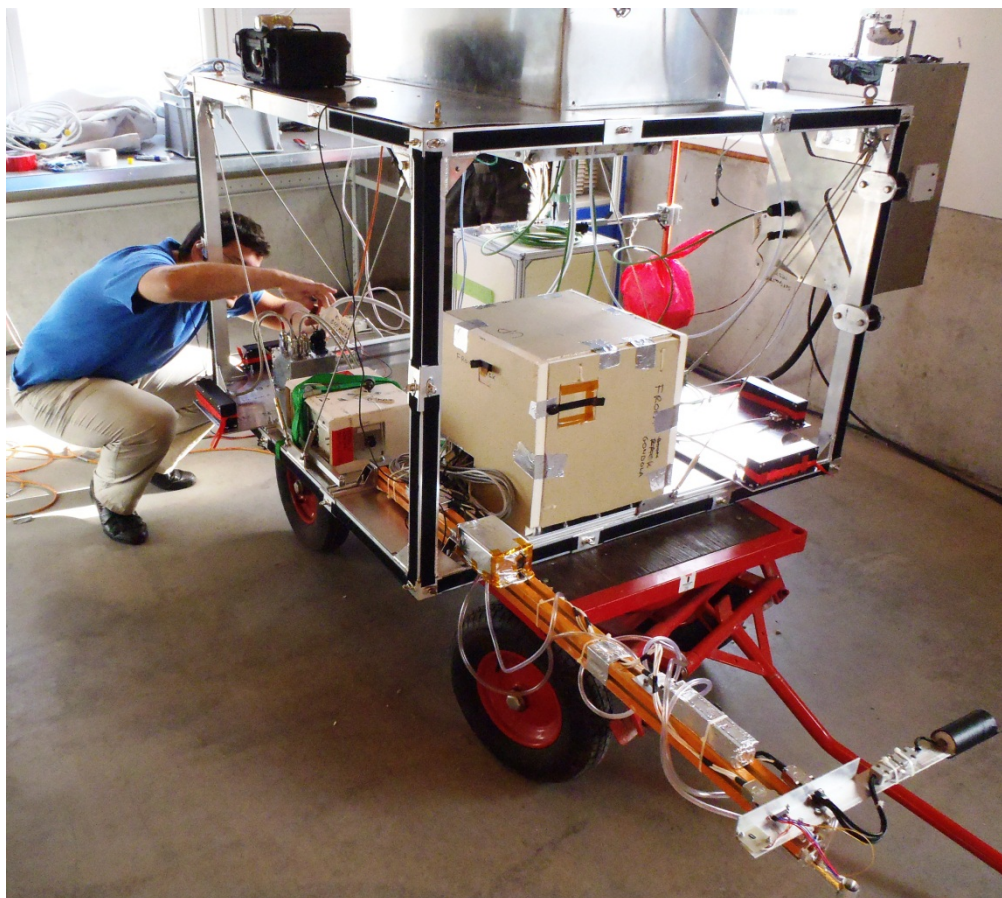


Figure C-3: BEXUS-15 showing different mounting techniques