BEXUS User Manual

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RX / BX Organisers

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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, testing, design
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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 Agency (SNSA). 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.

BEXUS experiments are lifted by a balloon with a volume of typically 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 project manager or the system engineer of the current project.
2 ALWAYS READ THIS
There is a lot 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 (in particular exposed or ‘open-path’), radiation, pressure vessels 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 permission by ESRANGE via the SSC Payload Manager.

Radio Frequency interference test
After the completed 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 to be outside on the balloon pad without the permission of the Operations Officer. Late access to the experiment on the balloon pad has to be part of the countdown procedure and need to be discussed and planned in advance.
In the final 1 hour and 30 minutes before launch after the sweet spot tests, there is no more access to the experiments. During launch it will be necessary to remain inside a building.

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 your Payload Managers with any questions.
2.1 Definitions

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

<table>
<thead>
<tr>
<th>Component</th>
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<tr>
<td>BEXUS</td>
<td>The complete integrated vehicle to perform the flight.</td>
</tr>
<tr>
<td>Ground Equipment</td>
<td>BEXUS supporting systems on ground.</td>
</tr>
<tr>
<td>EBASS</td>
<td>Balloon service system.</td>
</tr>
<tr>
<td>E-Link</td>
<td>Ethernet up &amp; downlink.</td>
</tr>
<tr>
<td>Esrange Facilities</td>
<td>Equipment used to monitor and control the flight, and telemetry receiving equipment.</td>
</tr>
<tr>
<td>Ground Support Equipment</td>
<td>Equipment used to control and communicate with various modules during test and count down.</td>
</tr>
<tr>
<td>Balloon</td>
<td>The part of BEXUS giving the lifting force.</td>
</tr>
<tr>
<td>Payload</td>
<td>Experiment modules and all subsystems.</td>
</tr>
<tr>
<td>Subsystems</td>
<td>All systems required for flight control, recovery, and telemetry.</td>
</tr>
<tr>
<td>Experiment Gondola</td>
<td>Experiment equipment and the carrier structure.</td>
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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)


[7] EuroLaunch, RXBX_REF_SED Template_v5-1_11Jun14

[8] EuroLaunch, RXBX_REF_SED Guidelines_v5-1_11Jun14

[9] Saft, Primary Lithium battery LSH 20 Data Sheet (https://www.saftbatteries.com)


2.3 Applicable documents


## 2.4 Abbreviations

<table>
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<tr>
<th>Abbreviation</th>
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<tr>
<td>AIT</td>
<td>Assembly, Integration and Test</td>
</tr>
<tr>
<td>APID</td>
<td>Application Identifier</td>
</tr>
<tr>
<td>ASAP</td>
<td>As Soon As Possible</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>BCR</td>
<td>BEXUS Campaign Report</td>
</tr>
<tr>
<td>BEXUS</td>
<td>Balloon-borne EXperiments for University Students</td>
</tr>
<tr>
<td>CD</td>
<td>Count Down</td>
</tr>
<tr>
<td>CDR</td>
<td>Critical Design Review</td>
</tr>
<tr>
<td>CRP</td>
<td>Campaign Requirement Plan</td>
</tr>
<tr>
<td>DLR</td>
<td>Deutsches Zentrum für Luft- und Raumfahrt</td>
</tr>
<tr>
<td>EAR</td>
<td>Experiment Acceptance Review</td>
</tr>
<tr>
<td>EAT</td>
<td>Experiment Acceptance Test</td>
</tr>
<tr>
<td>EBASS</td>
<td>Balloon piloting system</td>
</tr>
<tr>
<td>ECEF</td>
<td>Earth Centered, Earth Fixed</td>
</tr>
<tr>
<td>EGon</td>
<td>Esrange balloon Gondola</td>
</tr>
<tr>
<td>EGSE</td>
<td>Electrical Ground Support Equipment</td>
</tr>
<tr>
<td>EIT</td>
<td>Electrical Interface Test</td>
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<tr>
<td>E-Link</td>
<td>Ethernet up &amp; downlink system</td>
</tr>
<tr>
<td>EMC</td>
<td>Electro-Magnetic Compatibility</td>
</tr>
<tr>
<td>EMI</td>
<td>Electro-Magnetic Interference</td>
</tr>
<tr>
<td>ESA</td>
<td>European Space Agency</td>
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<tr>
<td>ESD</td>
<td>Electrostatic Discharge</td>
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<td>ESRANGE</td>
<td>Esrange Space Center</td>
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<tr>
<td>FAR</td>
<td>Flight Acceptance Review</td>
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<tr>
<td>FRP</td>
<td>Flight Requirements Plan</td>
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<tr>
<td>FRR</td>
<td>Flight Readiness Review</td>
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<tr>
<td>FST</td>
<td>Flight Simulation Test</td>
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<tr>
<td>GMO</td>
<td>Genetically Modified Organisms</td>
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<tr>
<td>GND</td>
<td>Ground</td>
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<tr>
<td>GSE</td>
<td>Ground Support Equipment</td>
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<tr>
<td>H/W</td>
<td>Hardware</td>
</tr>
<tr>
<td>HCD</td>
<td>Hot Countdown</td>
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<tr>
<td>HERCULES</td>
<td>Balloon launch vehicle</td>
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<td>HK</td>
<td>House Keeping</td>
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<tr>
<td>I/F</td>
<td>Interface</td>
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<tr>
<td>ICD</td>
<td>Interface control document</td>
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<tr>
<td>IFU</td>
<td>Interface Unit</td>
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<tr>
<td>IPR</td>
<td>Integration Progress Review</td>
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<tr>
<td>LOS</td>
<td>Line of sight</td>
</tr>
<tr>
<td>LT</td>
<td>Local Time</td>
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<td>LTC</td>
<td>Local Tangent Coordinate System</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>Mbps</td>
<td>Mega bits per second</td>
</tr>
<tr>
<td>MFH</td>
<td>Mission Flight Handbook</td>
</tr>
<tr>
<td>MORABA</td>
<td>Mobile Raketenbasis (DLR)</td>
</tr>
<tr>
<td>NC</td>
<td>Not Connected</td>
</tr>
<tr>
<td>NCR</td>
<td>Non Conformance Report</td>
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<tr>
<td>PCM</td>
<td>Pulse Code Modulation</td>
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<tr>
<td>PDR</td>
<td>Preliminary Design Review</td>
</tr>
<tr>
<td>PFR</td>
<td>Post-Flight Report</td>
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<tr>
<td>PI</td>
<td>Principal Investigator</td>
</tr>
<tr>
<td>PST</td>
<td>Payload System Test</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance</td>
</tr>
<tr>
<td>RNRZ</td>
<td>Randomized NRZ (a signalling modulation)</td>
</tr>
<tr>
<td>RX</td>
<td>Receiver</td>
</tr>
<tr>
<td>S/W</td>
<td>Software</td>
</tr>
<tr>
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<td>Student Experiment Documentation</td>
</tr>
<tr>
<td>SNSA</td>
<td>Swedish National Space Agency</td>
</tr>
<tr>
<td>STW</td>
<td>Student Training Week</td>
</tr>
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<td>T</td>
<td>Time before and after launch noted with + or -</td>
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<tr>
<td>TBC</td>
<td>To Be Confirmed</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Determined</td>
</tr>
<tr>
<td>TC</td>
<td>Tele-Command</td>
</tr>
<tr>
<td>TM</td>
<td>Telemetry</td>
</tr>
<tr>
<td>TVC</td>
<td>Thermal</td>
</tr>
<tr>
<td>TX</td>
<td>Transmission</td>
</tr>
<tr>
<td>WGS84</td>
<td>World Geodetic System 1984</td>
</tr>
<tr>
<td>WT</td>
<td>Walky Talky, handheld radio</td>
</tr>
<tr>
<td>ZARM</td>
<td>Center of Applied Space Technology and Microgravity</td>
</tr>
</tbody>
</table>
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 Agency (SNSA), in the latter case through cooperation with the European Space Agency (ESA).

ESA Academy is the primary point of contact for the SNSA/ESA teams.

EuroLaunch will assign the following key-positions for every flight project:

- Project manager
- Payload manager
- Mechanical design responsible
- Electrical design responsible
- Balloon Pilot
- Telemetry (TM) and Telecommand (TC) systems responsible
- Electrical 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.
- Daytime launch, operations, piloting and recovery of payload.
- Data acquisition with provisions of real time, quick-look and 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. The organisers supports the teams in order to see the good scientific returns. Information and expertise is available where required for assisting decisions related to the design, components, materials, operation, and any other mission related issues. Final decisions are normally left to the experimenters but if required (by safety or otherwise), the organisers withhold the right to enforce decisions on any issue. Before flight, the experimenters must successfully convince the organisers 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 necessary support equipment. The organisers can aid 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. The organisers assist 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

The project management of the REXUS / BEXUS Program is covered by the payload managers provided by ZARM and SSC in collaboration with ESA-Academy. They are responsible for detailed project planning and operations. The payload managers build the interface between the experimenters and SSC-ESRANGE and DLR MORABA.

Invitations for the Project Milestones are sent out by the agencies of ESA/SNSA and DLR.

- T-16 m Call for experiment proposals
- T-12 m Proposal submission deadline
- T-11.5 m Proposal shortlisting
- T-10.5 m Selection workshop at ESTEC (ESA) / Bonn (DLR), presentation of proposals
- T-10 m Final experiment selection
- T-9 m SED v1-0 submitted
- T-7.5 m Student Training Week (STW) at SSC, Esrange Space Center or DLR, MORABA facilities. Preliminary Design Review (PDR)
- T-5.5 m SED v2-0 submitted
- T-5 m Critical Design Review (CDR) at ESTEC (ESA) including soldering course.
- T-4 m SED v3-0 submitted
3.5 Experimenter Documentation Requirements

3.5.1 Student Experiment Documentation (SED)
The SED provides EuroLaunch and other stakeholders from SNSA, 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 Website and teamsite (the latter only after selection) including the SED guidelines (RXBX_SED_guidelines_v5-2_17Dec15.pdf) and SED template (RXBX_SED_template_v5-2_17Dec15.docx) 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. If incorrect information is provided by the student teams it may not be possible for the staff to provide the support required and may impact the safety of the flight.

3.5.2.1 ESRANGE Safety Board Questionnaire
A few weeks prior to the campaign, the Esrange Safety Board (ESB) requires detailed input for the campaign risk analysis and safety evaluation. Therefor the experimenters are requested to fill out a questionnaire form including all required details.

3.5.2.2 Recovery Sheet
During the campaign, the recovery officer of Esrange requests a max. of a single A4 sheet containing dedicated experiment recovery instructions. This recovery sheet shall explain the handling after landing in limited text with coloured pictures of the experiment (e.g. how to switch off / disarm the experiment, how to disassemble protruding equipment for transport…).
3.5.3 Flight Report Documentation
The organisers require 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).

3.5.4 Failure Analysis Report
In case the experiment does not perform as expected resulting in a limited scientific outcome, the experimenter is required to perform a failure analysis. The report need to be submitted as part of the final SED version 5.0.
4 BEXUS SYSTEM

4.1 BEXUS flight configuration

The typical BEXUS flight train can be seen in Figure 4-1. The total mass may be more than 300kg and the flight train length more than 100m.

A typical BEXUS flight configuration consists of a 12,000m$^3$ balloon type Zodiac 12 SF which is filled with Helium. A valve is not foreseen to be used during BX campaigns in October but may be requested by SSC for flight safety.
Figure 4-1: Typical BEXUS flight Train

45m

Balloon: Typically a Zodiac 12 SF (12,000 m³), mass 100.6 kg. Typical lift 120 kg to 30 km to 240 kg to 25 km with Helium. Lift = total mass + 12%  
For lighter payloads a 10 SF may be used  
Total Mass: 111.0 kg

1m

Ballooning Traffic Transponder (ATC)  
Cutter

Parachute: Typically 80 m², 100 m² or 120 m² dependant on flight train mass.  
Approx. 12 kg (100 m²)

1m

ERASS System: See section 5.2  
Approx. 25 kg

10m

Ballast and Ballast container: Not normally used on BEXUS  
Strobe light: SEE-BLITZ strobe light [10]  
Wide spectrum bright light at 0.3 Hz for entire flight  
Total Mass: Approx. 20 kg

Flight Train ATC: See section 4.3  
Radar Reflector: Passive  
Truck Plate

25m

Gondola and E-Link System:  
See sections 4.2 and 4.3  
Approx. 120 kg
There is one primary size of experiment gondola available for the BEXUS programme:

Medium Esrange 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.

Reinforcement wires are attached diagonal between the upper corners and the middle of the lower frame. In exceptional cases a removal of single wires can be discussed. The reinforcement wires are distributing the landing forces and preserve the structural integrity of the gondola.

The sides and roof of the gondola is nominally covered with heavy-duty canvas material. A removal, even partially, should be requested to Eurolaunch.

It is possible to cover the top of the gondola with heavy duty canvas material or aluminium sheeting. This covering is optional and dependent on the gondola configuration.
Figure 4-3: BX 25 Gondola with reinforcement wires
4.3 Tracking

The EBASS System is equipped with its own GPS receiver and transmits its location (see section 5.2). This is the primary tracking method.

Both the balloon envelope and the payload are equipped with an air traffic transponder and altitude encoder (ATC), to aid tracking. These transponders are triggered by transmission from Kiruna and transmit at 1090 MHz with an output power of 200 W. As far the transponder is triggered by a dedicated radar signal, the pulses are sent every 6 seconds with an approximate pulse width of 450 ns as. These transponders are switched off by a barometric switch at around 23 km.
In addition a Globalstar simplex transmitter is located on the balloon, and sometimes additionally on the gondola and/or flight train. These transmitters transmit at 1615 MHz at around 100 mW. These are used primarily for redundancy and to aid recovery of the balloon material.

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, sending an e-mail: rexus-bexus@esa.int.

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

4.4.2 Ascent phase
The nominal ascent speed is 5 m/s. Depending on float altitude and variations in speed, this phase takes approximately 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 (see Figure 4-2). The final altitude is calculated shortly before launch and may vary between 25 and 30 km. The nominal float time is one to five hours depending on the direction and wind speed. The flight is terminated by the balloon pilot before it leaves the dedicated landing area. Hence the flight time can vary and it is not depending on total floating time, but on the location of the balloon and the opportunity of safe recovery.
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 is suggested that this is not particularly suitable for microgravity experiments.

After the short time of free fall, the parachute inflates and the tug force induced by the sudden deceleration can reach up the several g in all directions.

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. Orientation is also not guaranteed and the gondola may be on its side or upside down at landing.

Figure 4-7: Soft landing (BX-14)  
Figure 4-8: Hard landing (BX-15)
The performance of the BEXUS balloon may be adapted to the respective mission requirements. However, Open Valve (4) and 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 nominal range is between 200 km and 300 km. Flight profiles are available in numerical form upon request, and some typical examples from previous missions are given below:
Figure 4-11: Altitude vs. Ground Range for typical BEXUS flights

Figure 4-12: Example of previous BEXUS Flight Trajectory
4.6 Recovery

Nominally, the recovery is carried out by a helicopter, which provides the transport from the landing site to the nearest road. From there, a truck will carry the experiments gondola and the recovered balloon back to Esrange. This procedure can take a couple of days. If the experiments contain any time-critical equipment, it has to be reported and discussed with the Payload Manager in advance.

During the design phase, experimenters should keep recovery accessibility in mind. Each team will be required to produce a short recovery plan detailing how the recovery crew can ensure that the instrument is safe (i.e., any dangerous items are made safe) and how to handle the experiment if necessary (see 3.5.2.2). Teams should note that certain items, and Li-ion batteries in particular, cannot be moved into a recovery helicopter without special handling and so these items should be identified early in the programme.

The transport below the helicopter and on the truck can cause strong wind loads and heavy vibrations towards the experiments. The experimenter shall take a rigid design into account and secure loose items from falling off, even after flight.

Figure 4-13: 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 housekeeping data. 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. One connection is available to each experimenter.

The experimenter is allowed to implement an additional internal Ethernet switch, in case there is more than one connection required.

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
- **Data bandwidth:** 2 Mbps duplex nominal, decreasing with range
- **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
- **Data bandwidth:** 2 Mbps duplex nominal, decreasing with range
- **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 5-3: EBASS Unit](image)

5.2.2 Technical Specification of the EBASS Ground Unit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitting frequency</td>
<td>449.95 MHz</td>
</tr>
<tr>
<td>Modulation</td>
<td>FM</td>
</tr>
<tr>
<td>Total data bandwidth</td>
<td>38.4 kbps Nominal</td>
</tr>
<tr>
<td>Receiving frequency</td>
<td>402.2 MHz Nominal (400-405 MHz)</td>
</tr>
<tr>
<td>Modulation</td>
<td>FM</td>
</tr>
<tr>
<td>Total data bandwidth</td>
<td>38.4 kbps</td>
</tr>
<tr>
<td>IF bandwidth</td>
<td>50 KHz, 100 KHz, 250 KHz and 500 KHz</td>
</tr>
<tr>
<td>Output power</td>
<td>100 Watt</td>
</tr>
<tr>
<td>Antenna type</td>
<td>Helical Antenna</td>
</tr>
<tr>
<td>Antenna polarisation</td>
<td>RHCP</td>
</tr>
<tr>
<td>Antenna gain</td>
<td>12 dBiC</td>
</tr>
<tr>
<td>Maximum range</td>
<td>550 km (at 30 km float &amp; LOS)</td>
</tr>
</tbody>
</table>

5.2.3 Technical Specification of the EBASS Airborne Unit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna type</td>
<td>Cross Broadband Dipole</td>
</tr>
<tr>
<td>Maximum range</td>
<td>550 km (at 30 km float &amp; LOS)</td>
</tr>
<tr>
<td>Transmitting frequency</td>
<td>402.2 MHz Nominal (400-405 MHz)</td>
</tr>
<tr>
<td>Modulation</td>
<td>FM</td>
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<td>Receiving frequency</td>
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</tr>
<tr>
<td>Modulation</td>
<td>FM</td>
</tr>
<tr>
<td>Total data bandwidth</td>
<td>38.4 kbps Nominal</td>
</tr>
<tr>
<td>Output power</td>
<td>2.5-5 Watt</td>
</tr>
</tbody>
</table>

**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 D: Gondola/Experiment Interface Images.

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

![Figure 6-1: M-Egon](image)

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.

Other mounting options are, for example, vertical bars (clamp fixation), through the floor (only if the experiment/component is not too heavy), through the floor support floor beams, on the roof bars, etc.

![Figure 6-2: Experiment mounting rails and anchor bolt (M6).](image)

The experiment should be structured to withstand the loads mentioned below. 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 Accelerations

The most critical phases in terms of accelerations are the following events:

1. Transport prior campaign, rough handling by shipping company personnel. (shock/undefined vibrations)
2. Transport on Launch Pad prior launch (undefined vibrations)
3. Cut Off sequence during flight (centrifugal forces of tumbling payload, shock)
4. Landing (strong shock)
5. Transport by truck back to Esrange (undefined vibrations)

To withstand those loads during transport and operation it is highly recommended to design the experiment hardware according to the specified loads. Those requirements shall be verified by analysis or/and tests.

The design load used for the payload is: Transient excitation (shock) of -10 g vertically and +/- 5 g horizontally according to nominal landing velocities. Unspecified random vibrations and shocks do occur during truck transport while recovery.

6.1.3 Pressure Vessels

All ground support pressure systems must meet Swedish law and regulations (AFS 1999:6) and be approved by the Esrange Safety Board before use.

The pressure systems require a 2:1 safety factor for flight systems and approved procedures to control exposure.

Any deviation from these requirements imply the request for a waiver from the experimenters.

6.2 Electric power

Placed on the outside of the experiment structure/housing, the experiment must have a 4 pin, male, box mount receptacle MIL – C-26482P series 1 connector with an 8-4 insert arrangement (MS3112E8-4P) (Figure 6-3).

Pin A: +
Pin B: -, do not connect to chassis or ground
Pin C: empty
Pin D: empty

One 28.8 V/1 mA (13 Ah) battery pack can be supplied to each experiment if needed. This battery pack consist of eight SAFT LSH20 batteries in series, each battery has got a built-in 5 A fuse (not changeable), and the combined recommended continuous maximum current...
draw is 1.8A. Experiment teams shall be aware of the characteristics of the batteries under flight and load conditions, example characteristics are shown in Figure 6-4, Figure 6-5 and Figure 6-6.

Figure 6-4: Saft (single cell) battery characteristics for varying temperature [9]

Figure 6-5: Saft (single cell) characteristics (capacity) for varying temperatures [9]
Figure 6-6: Saft (single cell) discharge profile at various loads [9]

The supplied battery packs are only loosely thermally insulated and not actively heated. The expected temperature may vary between flights and is dependent on specific gondola accommodation and flight times, but has previously being measured at as low as \(-40^\circ C\) during the floating phase.

In exceptional cases an experiment can be supplied with an additional battery pack which can be connected either through the same connector (where the batteries are internally decoupled by diodes to avoid current back flow) or through an additional connector. The experiment team should make clear which is required.

If the experimenter chooses to use some other electrical system or batteries, it has to be discussed with the BEXUS project manager before the critical design review (CDR).

### 6.3 Interface Description for E-Link Experiment Channels

#### 6.3.1 Front panel connector (E-Link side)

The E-link is a fully transparent connection between the ground based local user and the experiment. This wireless data link can be used for bi-directional purposes the same way as a LAN network connection with the experiment. A RJ45 connection will be supplied by SSC for the use between the experiment and the E-link system.

#### 6.3.2 Cable mating connector (Experiment side)

A panel mounted connector for the E-link is to be used. This connector (Amphenol RJF21B) can be mounted to the front or side panel of the experiment. Insert CODE A should be used for BEXUS. The inside of the connector requires a standard RJ45 (Ethernet) connector. Connector and drilling pattern are depicted below.
Figure 6-7: Drilling pattern for the RJF21B connector (source: http://datasheet.octopart.com/RJF21B-Amphenol-datasheet-11361.pdf). Rightmost: Insert CODE A.

6.4 Design Considerations for Experimenters Ground Station

There are a few fundamental constraints for the ground station design, which have to be taken into account:

- There are two networks provided in the DOME for experimenters
  - Guest Net: This network is distributing internet access on the ground floor and experiment assembly area. It is not allowed to distribute the network via any kind of wireless device. The use of switches is permitted. Connection is provided via Ethernet.
  - E-Net: This network is connected to the experiment network and E-Link during flight. This network is only available in the ground station area of the dome and must not be distributed in anyway. Connection is provided via Ethernet.

- No Internet Connection to Experimenters’ Ground Station Computer. During Testing and flight, there must not be any physical connection between the experimenters’ ground station computer and the internet!
6.5  Thermal Environment

6.5.1 Pre-Launch Phase
In normal conditions, the preparation of the payload is done at a room temperature of approximately 20±5°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.

6.5.2 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.

6.5.3 Flight phase
The thermal environment of the flight may see external air temperatures down to -80°C.

Figure 6-8 below shows temperature graphs of a number of PTU sondes flights during the normal BEXUS campaign period.

Note that the temperature is normally lowest at the tropopause (10-20km), and normally a little higher at float in the stratosphere (>20 km).

Temperatures in the gondola vary depending on the exact configuration, time of flight and float duration. Some detailed recorded information is available on request.

Figure 6-8: PTU Sondes Temperature graphs
Figure 6-9: Typical External Temperature vs. Flight time

Figure 6-10 Measured temperature inside the closed gondola vs. flight time on BEXUS 22 (position of sensor about 100mm distance to canvas)
6.5.4 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.

6.6 Ambient Pressure Conditions

As clearly visible in picture 6-12, which is a zoom view of figure 6-11, the typical pressure to which the BEXUS Gondola is exposed to during the floating phase is around 11mbar.
6.7 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 1: Frequencies that are not allowed for use by any experiment

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>400-405 MHz</td>
<td>E-Bass downlink</td>
</tr>
<tr>
<td>449-451 MHz</td>
<td>E-Bass uplink</td>
</tr>
<tr>
<td>1025-1035 MHz</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>1089-1091 MHz</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>1164-1237 MHz</td>
<td>Satellite Navigation</td>
</tr>
<tr>
<td>1260-1300 MHz</td>
<td>Satellite Navigation</td>
</tr>
<tr>
<td>1544-1545 MHz</td>
<td>Emergency Sea Radio</td>
</tr>
<tr>
<td>1559-1591 MHz</td>
<td>Satellite Navigation</td>
</tr>
<tr>
<td>2405-2496 MHz</td>
<td>S-Band; E-Link</td>
</tr>
<tr>
<td>(Ch 2-14 in 2.4 GHz-band)</td>
<td></td>
</tr>
<tr>
<td>2025-2120 MHz</td>
<td>Satellite uplink</td>
</tr>
<tr>
<td>2200-2300 MHz</td>
<td>Satellite downlink</td>
</tr>
<tr>
<td>3600-3800 MHz</td>
<td>Satellite downlink</td>
</tr>
<tr>
<td>5854 MHz</td>
<td>Satellite uplink</td>
</tr>
<tr>
<td>7145-7235 MHz</td>
<td>Satellite uplink</td>
</tr>
<tr>
<td>7600-8500 MHz</td>
<td>Satellite downlink</td>
</tr>
<tr>
<td>10700-12750 MHz</td>
<td>Satellite downlink</td>
</tr>
<tr>
<td>25500-27000 MHz</td>
<td>Satellite up/downlink</td>
</tr>
</tbody>
</table>

6.8 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, multipoint 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 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. This means that grounding to the gondola chassis is possible.

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.

### 6.9 Operations and durability

#### 6.9.1 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 an experiment on and off should be kept simple and should be possible with a minimum set of tools in a short period of time. In addition, the teams should be able to quickly confirm that an instrument has been turned on and is functioning correctly by looking at their data (i.e., a quick functional test).

#### 6.9.2 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. Refurbishment between countowns should be minimised as much as possible and should not invalidate testing.

#### 6.9.3 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.
6.9.4 Landing considerations

Due to the unpredictable nature of the gondolas’ landings (Chapter 4.4.5), the experimenters should be prepared for a wide range of possible environmental influences for a period of typically one or two days. Submersion of the experiments in water is possible. If this will be an issue for the experimenters, precautions should be taken already during the design phase. 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 or the gondola seriously. The integrity of the gondola hardware must not be endangered by any experiment components.

Recommended Tests for Experimenters

Before planning any tests it’s important to remember that tests are expensive and not easy to perform within the required time-frame. A good technical design based on simple thermal and vacuum analysis may reduce the risk of failure.

In particular, considering the flight duration and the low temperature and pressure to which the payloads will be exposed to, particular attention should be paid to:

- any sensors placed outside the gondola
- the conduction between the experiment and the gondola
- other components which could cool down the experiments (e.g. components pumping external air to the experiment, etc.)

Before designing any passive or active thermal control, a thermal analysis should be made, considering mostly conduction and solar radiation, but also other thermal exchanges, such as convection (at lower altitudes) and albedo (for any part of the experiment outside the gondola).

6.10.1 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. Additionally, any experiments with sealed chambers should be vacuum tested to ensure survival. A margin of 1.5 times the working pressure is required. 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.
6.10.2 Thermal test

A thermal test is mainly performed in order to verify the thermal analysis and the design of the experiment. 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.

If possible, it would be better to combine the thermal and vacuum test in a unique test in Thermal-Vacuum Chamber (TVC).

6.10.3 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 experimenters to perform this test, if necessary.

**Basic Procedure 1 – Verifying the static loads defined in section 6.1.2**

- 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 – Verifying the shock requirements defined in section 6.1.2**

- 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 padded 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.

**Basic Procedure 3 – Verifying the vibration requirements defined in section 6.1.2**

- The experiment should be mounted in the back of a car or in a trailer using the same mechanical interface as for the mounting in the BEXUS gondola.
- The experiment should be driven over a bumpy road or rough terrain for several minutes.
- 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.
6.10.4 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 experimenters 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 of about 2 hours (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.

6.10.5 E-Link Testing
To assure the experiment of handling timeouts in the connection to the ground station, it has to be tested. Insufficient error handling results in problems by reconnecting to the E-Link network.

Ethernet timeouts can occur, while connected to E-Link by hardline or via RF. In particular, if the bandwidth is shared with other experiments. To avoid this happening during the campaign, it is mandatory to test the reconnection of the experiments forehand.

Basic Procedure
1. Write an error handling software into the communications programs that explicitly deals with timeouts.
2. Conduct a simple test by connecting and disconnecting the Ethernet connection multiple times in different stages and modes of the experiment. This will highlight any issues with error handling.
3. Ensure that the software can reconnect under the above test.
4. Monitor dropped packages. There is suitable freeware available for download, e.g. Wireshark (https://www.wireshark.org/).
5. Create network dumps to analyse and qualify that the experiment does not exceed the bandwidth allocation.

6.11 General Design Considerations

6.11.1 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.

6.11.2 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.

6.11.3 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.

6.11.4 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 simply be achieved by separate battery packs, multiple switches, check valves, and other solutions.

6.11.5 Mass and Size Considerations
Minimizing mass is commonly overlooked by experimenters. However, keeping mass low where possible serves multiple functions. For payload organisation, when experiments are light and small, it gives the organisers more flexibility in selecting locations for each experiment. 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 generally allow a higher float altitude (see Figure 4-2).

Significant increase of the mass must be reported as soon as possible and discussed with the payload manager. Not fulfilling the set mass requirement may lead to deselecting from the flight, even in a late stage of the program.

6.11.6 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 the organisers.
6.11.7 Shipping
When designing your experiment, please take into consideration the need for shipment, possible configurations and storage/transport requirements. Please remember that you will be responsible for packing your equipment after launch. Return shipping will be discussed with you once you arrive on the range.

Considering that Esrange is very far away from everything, this should be taken into account, when it comes to shipping times. To be sure and safe, that your goods arrive in time before the campaign, please consider two weeks of delivery time and do not trust any promises of shipping in 24 hours, even for the big well known shipping companies.

Lithium Batteries:
Check with your shipping company the requirements in terms of the transport of Lithium Batteries. It is no problem to receive shipments including Lithium Batteries on Esrange. but In case you will need to send them home, the shipment has to fulfil the new Swedish regulations (since 1st Jan 2017) and Esrange has to be informed prior to shipment. Please contact the payload manager at the beginning of the campaign, if you wish to do so. Consider the disposal option on Esrange as alternative to complicated and expensive shipment.

Please take into account:

• Number of items
• Dangerous contents, add Safety Data Sheets (SDS)
• Special requirements for treatment or storage
• Are any of the goods Export Controlled?

6.11.8 Safety
Safety is of the outmost 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 and handle. 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 or on the ground during preparation, 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.

The following items, for example, may be rated critical and need to be reported to the ESB via the payload managers:

- Explosives
- Flammables
- Chemicals
- Batteries
- Biological items
- RF transmitters
- Pressure vessels
- Radioactive materials
- Hazardous mechanical systems (such as high-energy mechanical devices)
- Laser (particularly exposed or ‘open-path’)
- High voltages and currents
- Sources of extreme temperatures (heat/cold)
- Experiments on animals or GMO
- Hazardous ground support equipment

To simplify the procedure, the experimenters are required to fill out the Esrange Safety Board Questionnaire about three weeks before the campaign. The questionnaire is managed by the payload managers.

Sources of hazard, which are not declared prior to the ESB may lead to deselection from the flight opportunity, even in a late stage of the programme.

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. As plans are made based on the CRP it is important that it is correct and updated if requirements change. Once the CRP is issued any changes that effect the document must be discussed with the BEXUS Project Manager before implementing the changes.

The first version of the CRP will be distributed after the IPR. Inputs are requested from every experiment team, regarding interfaces, telemetry, power consumption and special experiment requirements.
7.3 Experiment Acceptance Review (EAR)

The manufacturing phase ends with the Experiment Acceptance Review (EAR), following delivery of the experiment to EuroLaunch.

The EAR consists of:

- Experiment checkout / functional tests
- Experiment mass properties determination
- Mechanical and electrical interface checkout
- Electrical Interface Test (EIT)
- Flight Simulation Test (FST)

The EAR is performed by EuroLaunch, together with a representative from the student experiment team.

7.3.1 Experiment Status by Delivery

EuroLaunch strongly recommends that the experiment teams conduct the following qualification/acceptance tests before delivering the experiment:

- Electrical/functional tests
- Shock tests
- Environmental tests (e.g. Thermal Vacuum tests)
- Mechanical interface checkout
- Electrical interface checkout

Students should ensure that there is enough time to repair or fix any problems which arise during these tests.

7.3.2 Experiment Incoming Inspection

All the mechanical and electrical interfaces of the experiment will be inspected at delivery at the beginning of the launch campaign in the framework of the individual experiment tests.
8 CAMPAIGN ACTIVITIES
BEFORE START OF COUNTDOWN

8.1 Description of Esrange Space Center
All the necessary information for a user of Esrange can be found at:
www.sscspace.com under ‘SSC Worldwide/Esrange 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 Esrange. Before the start of a campaign, a safety briefing will be held. It is mandatory for all visiting personnel to attend this briefing.

If a safety issue arises during a campaign, there might be a need for an additional Safety Board meeting 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.

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 2: Typical BEXUS Campaign schedule

<table>
<thead>
<tr>
<th>Day</th>
<th>Action</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nominal day of student arrival</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Esrange Safety briefing</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>SSC, DLR, ESA, ZARM Team introduction</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>Campaign Information</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>Experiment Preparation</td>
<td>DOM/CATH</td>
</tr>
<tr>
<td></td>
<td>Individual Experiment Tests</td>
<td>DOM/CATH</td>
</tr>
<tr>
<td>2</td>
<td>Morning meeting</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>Experiment Preparation</td>
<td>DOM/CATH</td>
</tr>
<tr>
<td></td>
<td>Individual Experiment Tests</td>
<td>DOM/CATH</td>
</tr>
<tr>
<td>3</td>
<td>Morning meeting</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>Gondola Interference Tests</td>
<td>DOM/CATH</td>
</tr>
<tr>
<td>4</td>
<td>Morning meeting</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>BX 18 Flight Compatibility Test (FCT)</td>
<td>PAD</td>
</tr>
<tr>
<td></td>
<td>BX 19 FCT</td>
<td>PAD</td>
</tr>
<tr>
<td></td>
<td>Meteorology briefing</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>Flight Readiness Review (FRR)</td>
<td>Polaris</td>
</tr>
<tr>
<td>5</td>
<td>Morning meeting</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>1\textsuperscript{st} launch opportunity</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Morning meeting</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>2\textsuperscript{nd} Launch opportunity</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>OPTIONAL: Launch opportunities</td>
<td>Polaris</td>
</tr>
<tr>
<td></td>
<td>Experiment results presentations</td>
<td></td>
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<tr>
<td></td>
<td>Feedback session</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Campaign Dinner</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Reserve launch Day</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Reserve launch Day</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Nominal day of student departure</td>
<td></td>
</tr>
</tbody>
</table>
### 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

<table>
<thead>
<tr>
<th>Note</th>
<th>Test</th>
<th>Comment</th>
</tr>
</thead>
</table>
| 1 | Individual Experiment Tests | Each experiment is:  
- Mounted into gondola  
- Power connection checked and connected to gondola power  
- E-link connector checked  
- Ground station connected directly to experiment  
- Communication and functional test  
- Dismount – only if needed |
| 2 | Interference Test | Gondola Interference Test Part I (Hardline)  
- Experiment remain (or are re-mounted in the gondola)  
- Experiments connected to the E-Net and gondola power supply.  
- G/S set up in ground station area  
- Communication and functional test  
  - Experiment by experiment  
  - All experiments  
Gondola Interference Test Part II (E-Link)  
- Experiments connected to the E-Link  
- RF Interference Check with E-link (low power)  
- Communication and functional test  
  - Experiment by experiment  
  - All experiments |
| 3 | Flight Compatibility Test (FCT) | Gondola moved to the balloon launch pad (by Hercules):  
- Check for interference with EBASS etc.  
- Experiments switched on, one after the other  
- All experiment systems must be running on Battery Power  
- Mass measurement  
Long waiting times (3-4 h) possible  
**Notice that after this test:**  
- No more experiment preparation is allowed.  
- Only the batteries can be exchange/charged. |
| * | Note I: Working after Dinner (1900) is NOT nominal and should be avoided where possible.  
Note II: Working through meal times is NOT nominal, but is possible for operational reasons, and takeaway meals can be collected from the restaurant. Takeaway meals will not be available for those who simply wish to eat elsewhere or at a different time not due to operational reasons. |
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. A good checklist includes a verification method such as checking torque (and writing it down) or taking a photo.

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 Dome 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 Dome assembly hall. There is also basic measurement equipment and toolboxes available to borrow.

Please note that ESRANGE is situated in a remote location. Therefore, acquiring any equipment could be difficult once arrived at the site.

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 (Max. 2.5 A)
### 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 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 on internal power 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.

During the FCT, the experiments run on the internal batteries.

### 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 countdown 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 countdown list.
- To inform all relevant personnel of the safety regulations applicable during the countdown phase.
- to inform all relevant personnel of general arrangements implied during the countdown 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 countdown. There are no magic numbers and the decision to start a countdown 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. This does not mean that the gondola will be returned the same day.

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. You will only be allowed access to the launch pad when permitted by the Operations Officer.

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 (LO) handles all personnel and equipment related to the launch. The LO 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 (SO). The SO 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
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 0800 and 1600 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 a preparation building; transparent communication with the experiment is provided via a designated Ethernet network.

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Operations</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-4H30</td>
<td>Decision meeting</td>
<td></td>
</tr>
<tr>
<td>T-4H00</td>
<td>Start of Count Down</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Start pad preparations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experiments on external power</td>
<td>External Power Supply</td>
</tr>
<tr>
<td></td>
<td>Experiment check-outs</td>
<td>Via E-Link on RF low power</td>
</tr>
<tr>
<td></td>
<td>Experiments powered off for pickup</td>
<td></td>
</tr>
<tr>
<td>T-2H30</td>
<td>Gondola pick-up</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sweet-spot tests</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experiments powered on on external Power</td>
<td>Hercules Power</td>
</tr>
<tr>
<td></td>
<td>Experiment check-outs</td>
<td>Via E-link on RF low power, then high power</td>
</tr>
<tr>
<td></td>
<td>Final experiment preparations</td>
<td>Latest preferred Access to experiments</td>
</tr>
<tr>
<td></td>
<td>Go decision from experimenters</td>
<td>Ready for Line-up</td>
</tr>
<tr>
<td>T-1H30</td>
<td>Line-up</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Final payload preparations</td>
<td></td>
</tr>
<tr>
<td>T-1H00</td>
<td>Balloon unfolding</td>
<td>Point of no return</td>
</tr>
<tr>
<td></td>
<td>Experiments on gondola/internal batteries</td>
<td>Removal of external power umbilical</td>
</tr>
<tr>
<td></td>
<td>Experiment check-outs</td>
<td>Via E-Link</td>
</tr>
<tr>
<td>T-0H40</td>
<td>Start of balloon inflation</td>
<td></td>
</tr>
<tr>
<td>0H00</td>
<td>Balloon release</td>
<td>Launch</td>
</tr>
<tr>
<td>T+~4H00</td>
<td>Command cut down followed by recovery</td>
<td></td>
</tr>
</tbody>
</table>
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 misreading
- No horse play or bad language
- Minimize radio traffic
- Speak loud and clearly

<table>
<thead>
<tr>
<th>Pro words</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affirmative</td>
<td>YES</td>
</tr>
<tr>
<td>Negative</td>
<td>NO</td>
</tr>
<tr>
<td>Active</td>
<td>Work commanded is in progress, completion will be reported</td>
</tr>
<tr>
<td>Break – Break</td>
<td>I must interrupt this conversation because of an urgent message.</td>
</tr>
<tr>
<td>Correction</td>
<td>You have made a mistake. You should have said (or performed) or, I have made a mistake; I should have said</td>
</tr>
<tr>
<td>Disregard</td>
<td>Disregard what I have just said. It is not applicable or is in error</td>
</tr>
<tr>
<td>Execute</td>
<td>Carry out the instruction</td>
</tr>
<tr>
<td>Go ahead</td>
<td>I am on the net. Proceed with your transmission</td>
</tr>
<tr>
<td>I say again</td>
<td>I am repeating the message for clarity</td>
</tr>
<tr>
<td>Out</td>
<td>I have completed this conversation</td>
</tr>
<tr>
<td>Proceed</td>
<td>Go ahead with your task</td>
</tr>
<tr>
<td>I copy</td>
<td>I received your last message satisfactorily and understand</td>
</tr>
<tr>
<td>I copy, Wilco</td>
<td>I have received your message, understand it, and will comply</td>
</tr>
<tr>
<td>Say again</td>
<td>Repeat your last communication</td>
</tr>
<tr>
<td>Speak slower</td>
<td>You are talking too fast</td>
</tr>
<tr>
<td>Standby</td>
<td>I must pause for time or wait a few moments</td>
</tr>
<tr>
<td>Verify</td>
<td>Check status or correctness</td>
</tr>
<tr>
<td>Roger</td>
<td>Acknowledge your transmission</td>
</tr>
</tbody>
</table>
Table 4: Call sign during pad preparation

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

9.7 During the flight

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

9.8 Recovery

The helicopter is equipped with tracking receivers for the payload beacon signal. 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 coordinates is reported to the helicopter from Esrange. 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 Esrange. Any actions that should be performed on your experiment (such as securing samples, powering off, plug removal) shall be detailed in a simple annotated recovery sheet, a copy of which will be flown in the gondola and provided to the recovery crew. 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.

9.9 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 logbook; 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 experimenters 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 EAR. 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 C: 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>
<thead>
<tr>
<th>ECEF</th>
<th>Earth Centered, Earth Fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>WGS84</td>
<td>World Geodetic System 1984</td>
</tr>
<tr>
<td>LTC</td>
<td>Local Tangent Coordinate System</td>
</tr>
</tbody>
</table>

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 [12].

### 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 $\phi_{gc}$, which is measured positive North of the equator, the Longitude $\theta$, which is measured positive towards East from the Greenwich Meridian and the distance $d$ from the Earth center.

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

$$f_\oplus = \frac{R_\oplus - R_{\text{Pole}}}{R_\oplus}$$  \hspace{1cm} \text{Eq. 10-2}

The WGS84 Ellipsoid has a flattening of $f_\oplus = \frac{1}{298.257223563}$ and the equator radius, $R_\oplus$, is 6378137 m [Ref [12]]. The Earth eccentricity, $e_\oplus$, can be calculated with the following equation:

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

The position of the vehicle is given in geodetic coordinates relative to the reference ellipsoid. The geodetic longitude $\theta$ corresponds to the geocentric longitude. Not like the geocentric latitude, $\varphi_{gc}$, which is the inclination of the position vector to the equatorial plane. The geodetic latitude, $\varphi_{gd}$, 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:
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 $\varphi_{gd}$ and geodetic longitude $\theta$.

Two observation angles define the position of the vehicle from the observation location. The azimuth $\beta$ is measured clockwise around the observation location starting at North. It varies between 0° and 360° and is calculated with the following equation:
\[ \beta = \arctan \left( \frac{\text{east}_{LTC}}{\text{north}_{LTC}} \right) \] 

Eq. 10-4

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

\[ \varepsilon = \arctan \left( \frac{h_{LTC}}{\sqrt{\text{east}^2_{LTC} + \text{north}^2_{LTC}}} \right) \] 

Eq. 10-5

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

\[
\begin{pmatrix}
\text{east}_{LTC} \\
\text{north}_{LTC} \\
h_{LTC}
\end{pmatrix} = d \cdot 
\begin{pmatrix}
\sin \beta \cdot \cos \varepsilon \\
\cos \beta \cdot \cos \varepsilon \\
\sin \varepsilon
\end{pmatrix}
\]

Eq. 10-6

The distance \( d \) between the vehicle and the observation location is also called Slantrange.
APPENDIX A: GONDOLA DRAWINGS

Figure A-1: Gondola dimensioned drawing
Figure A-2: Section view (A-A: Isometric) of gondola floor
APPENDIX B: EXAMPLE OF RECOVERY SHEET

RECOVERY SHEET
ARCADE-R2 EXPERIMENT

1 - Switch off the three power connectors (turn counter clockwise and pull out)
2 - Keep in contact the external body to the PROXBOX and lock the external body to the mechanical rail by the given screw

Figure B-0-1: Example of Recovery Sheet of the Team ARCADE-R2 Experiment of BEXUS 17
APPENDIX C: 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
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