A DLR and SSC cooperation

REXUS User Manual

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Abstract: This document has been created to aid experimenters taking part in a REXUS 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: REXUS, manual, interface, EuroLaunch, testing, design

This is not an ICD document.

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1 INTRODUCTION

The REXUS (Rocket-borne EXperiments for University Students) programme is an annual sounding rocket programme for university students, which aims to provide practical experience of real space projects.

REXUS is conducted by EuroLaunch and is a cost effective, easily accessible experiment facility giving 3 minutes of spaceflight up to a height of approximately 90 km.

EuroLaunch is a co-operative agreement between SSC and the German Aerospace Center (DLR), Mobile Rocket Base (MORABA) in the area of suborbital services for sounding rocket launches and stratospheric balloon flights.

REXUS is financed by the Swedish National Space Board (SNSB) and the German Aerospace Center (DLR).

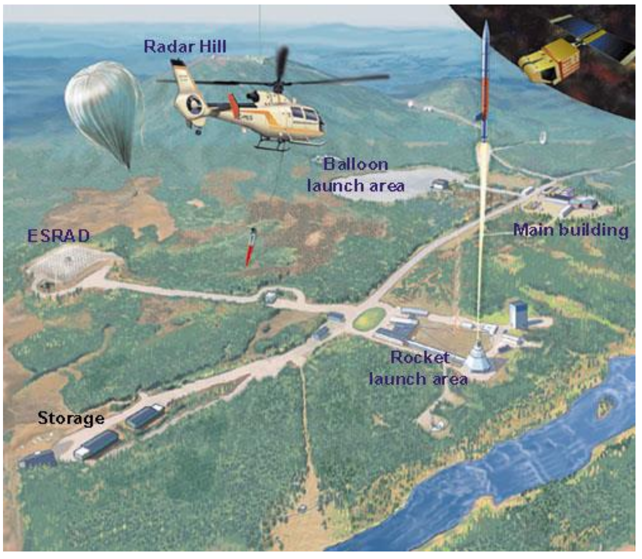

Figure 1-1: SSC, Esrange Space Center

The REXUS launch campaigns are held at the SSC, Esrange Space Center near Kiruna in northern Sweden.

The REXUS payload is modularised to provide simple interfaces, good flexibility and independence between experiment modules. Up to four experiment modules with a 355.6 mm (14 inch) diameter and maximum total length of 800 mm can be accommodated in one payload. All payload service systems necessary for telecommunication, payload control, launch, flight and recovery are included in the system.

This document describes information for a user of the REXUS system, including the services offered by EuroLaunch. It defines the requirements that apply to the REXUS experiment modules and gives design recommendations. It also includes a description of the REXUS 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 REXUS system, please contact the EuroLaunch project manager or the system engineer of the current project.

1.1 Definitions

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

REXUS	The complete integrated vehicle to perform the flight.
Esrange Facilities	Equipment used to monitor and control the vehicle during flight, and telemetry receiving equipment.
Ground Support Equipment (GSE)	REXUS supporting systems and equipment on ground.
Electric Ground Support Equipment (EGSE)	Equipment used to control and communicate with various modules during tests and flight.
Rocket Motor	The part of REXUS giving the accelerating force.
Payload	Experiment modules and all EuroLaunch subsystems.
Subsystems	All systems required for flight control, recovery and telemetry.
Scientific Payload	All experiment modules including the experiments
Experiment Module	Experiment equipment and its outer structure.

Hierarchy:

```
REXUS System
        ├Vehicle
        |       ├Payload
        |       |       ├Scientific Payload / Experiment Modules
        |       |       └Payload Service Subsystems
        |       |               ├TM/TC Systems
        |       |               ├Power System
        |       |               ├Sensors
        |       |               ├Radio System
        |       |               └Recovery System
        |       └Rocket Motor
        |
        └Ground Equipment
                ├Esrange Facilities
                ├Experiment Module Ground Support Equipment
                └Service System Ground Support Equipment
```

1.2 Abbreviations

AIT	Assembly, Integration and Test
APID	Application Identifier
ASAP	As Soon As Possible
BF	Body Frame Coordinate System
BNC	Bayonet Neill-Concelman
CD	Countdown
CDR	Critical Design Review
CPU	Central Processing Unit
CRP	Campaign Requirements Plan
CRC	Cyclic Redundancy Check
CRP	Campaign Requirements Plan
CSM	Checksum
DLR	Deutsches Zentrum für Luft- und Raumfahrt (The German Aerospace Centre)
DTM	Operation Call sign for DLR telemetry station
EAT	Experiment Acceptance Test
EAR	Experiment Acceptance Review
ECSS	European Cooperation for Space Standardization
EGSE	Electric Ground Support Equipment (e.g. Service Module control box)
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESA	European Space Agency
ESD	Electro-Static Discharge
ESRANGE	Esrange Space Center
ESR	ESRANGE
ETM	Operational Call sign for Esrange telemetry station
EXP	Experiment
E-Box	Electronics Box
FAR	Flight Acceptance Review
FEC	Forward Error Correction
FET	Field Effect Transistor
FRP	Flight Requirements Plan
FRR	Flight Readiness Review
FST	Flight Simulation Test
GMSK	Gaussian Minimum Shift Keying
GND	Ground
GPS	Global Positioning System
GS	Ground Station
GSE	Ground Support Equipment
HCD	Hot Countdown
HK	House Keeping
H/L	Hard Line
H/W	Hardware
ICD	Interface control document
IH	Igniter Housing

I/F	Interface
IPR	Integration Progress Review
LB	Launcher Box
LO	Lift-Off (Signal)
LT	Local Time
M	Minute
M	Month
MFH	Mission Flight Handbook
MORABA	Mobile Raketenbasis (DLR)
MRL	Medium Range Launcher
MTR	Mid Term Review
NCR	Non Conformance Report
NSROC	NASA Sounding Rocket Operations Contract
PA	Public Announcement (e.g. video monitors)
PAL	Phase Alternating Line
PCM	Pulse Code Modulation
PDR	Preliminary Design Review
PE	Payload Engineer
PI	Principal Investigator
PSD	Power Spectral Density
PST	Payload System Test
PTS	Swedish Post and Telecom Agency
P/L	Payload
QA	Quality Assurance
REXUS	Rocket-borne Experiments for University Students
RF	Radio Frequency
RFW	Request for Waiver
RNRZ	Randomized NRZ (a signalling modulation)
RXSM	REXUS Service Module
SAF	Safety Officer
SCI	Project Scientist
SDC	Serial Data Commands
SED	Student Experiment Documentation
SMC	Service Module Commands
SNSB	Swedish National Space Board
SODS	Start/Stop of Data Storage (Signal)
SOE	Start/Stop of Experiment (Signal)
STW	Student Training Week
S/W	Software
T	Time before and after launch noted with + or -
TBC	To Be Confirmed
TBD	To Be Determined
TC	Telecommand
TCU	Telemetry Central Unit
TM	Telemetry
TV	Television

UTE	User-defined Timer Event (Signal)
WGS84	World Geodetic System 1984
WT	Walkie Talkie
ZARM	Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation

1.3 References

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

[1] ECSS, *Space project management / Project planning and implementation*, ECSS-M-ST-10C Rev. 1 (ESA Publications Division, 2009) http://www.ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100743/d20090306173339/No/ECSS-M-ST-10C_Rev.1(6March2009).pdf

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[3] ECSS, *Space product assurance / Crimping of high-reliability electrical connections*, ECSS-Q-ST-70-26C (ESA Publications Division, 2008) (http://ecss.nl/forums/ecss/dispatch.cgi/standards/showFile/100679/d20081111131154/No/ECSS-Q-ST-70-26C(31July2008).pdf)

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[5] SSC Esrange, *User's Handbook* ver. 2 (Esrange, 2011) http://www.sscspace.com/file/usershandbook.pdf

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[10] Tutiempo Network, *Historical Weather: KIRUNA GEOFYSISKA, Sweden*, TuTiempo.net (Tutiempo Network, 2010) (http://www.tutiempo.net/en/Climate/KIRUNA_GEOFYSISKA/02-1998/20450.htm)

1.4 Applicable documents

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[12] Vallado, David A.: *Fundamentals of Astrodynamics and Applications* (McGraw-Hill Companies, Inc, 1997)

[13] Sounding Rockets Program Office, *NASA Sounding Rocket Program Handbook*, (Suborbital & Special Orbital Projects Directorate, 2005)

2 ALWAYS READ THIS

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

Experiment safety

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

Durability of your experiment

During the pre-flight tests and the countdown, 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.

Spin and balance

Before the start of the campaign, the rocket will be balanced (during the Environmental Tests). After this there will not be any changes permitted in the payload configuration that could result in changes in mass, inertial moment or balance.

Transceivers

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

Radio Frequency interference test and flight simulation

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

No one is allowed to visit the motor preparation hall or the launch-towers without the permission of the Operations Officer.

Radio Silence

During arming of the rocket motors, it is strictly forbidden to transmit or to do any power-switching of the experiments or their subsystems.

Campaign Requirements Plan / Flight Requirements Plan

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

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

3 REXUS 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 (MORABA) of the German Aerospace Centre (DLR). The DLR project share concerning integration, testing and student support is provided by ZARM under contract of DLR Space Administration.

When EuroLaunch is mentioned in this document, it means that all three institutions (SSC, MORABA and ZARM) may be involved.

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

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

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

One person can have dual assignments.

Additional positions will be assigned during the campaign, see chapter 12.4.

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

3.2 Flight Ticket

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

- General management and planning of the REXUS project.
- Provision of the launch vehicle and subsystems necessary for a spaceflight mission.
- Integration of participating experiment modules into the flight configured payload and pre-flight testing of the payload (TM, TC, flight simulation test, dynamic balancing, vibration tests and determination of physical properties).
- Transport of modules from the integration facility to Esrange.
- Payload assembly and testing at the range over 5 days (nominally).
- Provision of laboratory facilities at the range.
- Launch and recovery.

- Data acquisition with provisions of real-time, quick-look and replay data from the modules and the payload subsystems (e.g. g-levels).
- Disassembly of payload and return of experiments.
- Post flight report.

3.3 Experimenter's Role

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

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

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

3.4 Project Planning

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

A general progress plan for REXUS flight projects is listed below. Detailed descriptions of reviews and tests are given in chapter 8.

3.4.1 Indicative Timetable

T-18 m	Call for experiment proposals
T-16 m	Proposal submission deadline
T-16 m	Proposal shortlisting
T-15.5 m	Selection workshop at ESTEC (ESA) / Bonn (DLR), presentation of proposals
T-15 m	Final experiment selection

T-13.5 m	SED v1-0 submitted
T-13 m	Student Training Week (STW) at SSC, Esrange Space Center or DLR, MORABA facilities. Preliminary Design Review (PDR)
T-9 m	SED v2-0 submitted
T-8.5 m	Critical Design Review (CDR) at ESTEC (ESA) / Oberpfaffenhofen (DLR) including soldering course
T-7.5 m	SED v3-0 submitted
T-7 m	IPR at experimenters' organisation
T-4.5 m	EAR at experimenters' organisation or a ZARM/SSC facility
T-4 m	Delivery of Experiments to Integration Week (ITW) at ZARM Bremen (experimenters required)
T-2.5 m	Bench Test at DLR Oberpfaffenhofen (experimenters required)
T-1 m	SED v4-0 submitted
T-0.5 m	Spin and Balance Test (experimenters not required)
T+0 m	Campaign at Esrange
T+0.5 m	Flight Report Documentation from experimenters submitted
T+1 m	Distribution of the REXUS post flight Report by EuroLaunch
T+3 m	SED v5-0 submitted including experiment results
T+4 m	Publication of Final Report/Results Seminar

3.5 Experimenter Documentation Requirements

3.5.1 Student Experiment Documentation (SED)

The SED provides EuroLaunch and other stakeholders from SNSB, ESA, DLR and ZARM with all the important information on a particular experiment. During the phases of experiment development, production and flight, the SED will be the main documentation for students to describe their experiment and 5 frozen versions will be provided (see 3.4.1). All documentation relating to the requirements of this document can be found at the REXUS/BEXUS Team Site, including the SED guidelines and SED template documents.

3.5.2 Campaign Requirements Plan/Flight Requirements Plan

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

3.5.3 Flight Report Documentation

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

4 REXUS SYSTEM

4.1 REXUS Vehicle

A typical REXUS vehicle consists of a one-stage rocket, an Improved Orion motor, and the payload. This rocket gives approximately three minutes of spaceflight with a payload mass of up to ~95 kg, including the service and recovery systems.

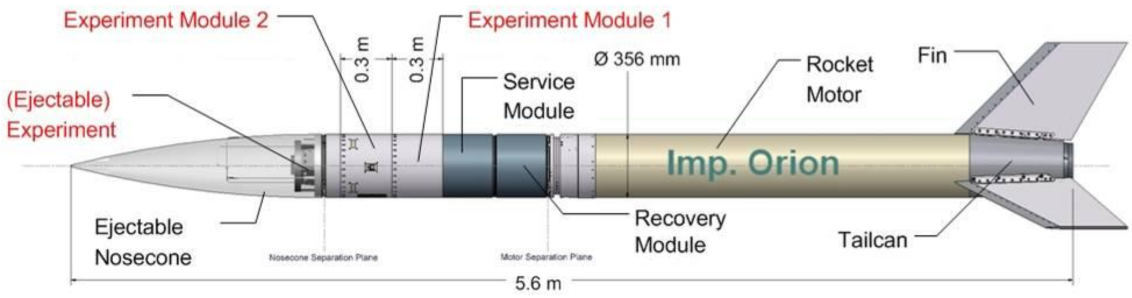


Figure 4-1: REXUS Standard Configuration

A typical configuration is shown in Figure 4-1. Each configuration is designed to optimise vehicle and experiment characteristics.

4.1.1 Service Module

The objectives of the Service Module are to establish the communication between the ground and the experiments, and to control the experiments. Furthermore, the Service Module monitors the quality of the ambient conditions, the flight parameters (acceleration, angular rates) and the housekeeping data. It also delivers power to the experiments.

The Service Module consists of two sections. The first one contains the electronic part of the Service Module (E-Box), while the other devices such as RF-parts, GPS, sensors and batteries are mounted on the bulkhead of this module.

The Service Module has four main electrical interfaces to its environment:

- to the EGSE via umbilical
- to the experiments, recovery, GPS system
- to the ignition unit, separation unit and yo-yo system
- to the ground via RF links by the PCM and the Video transmitter

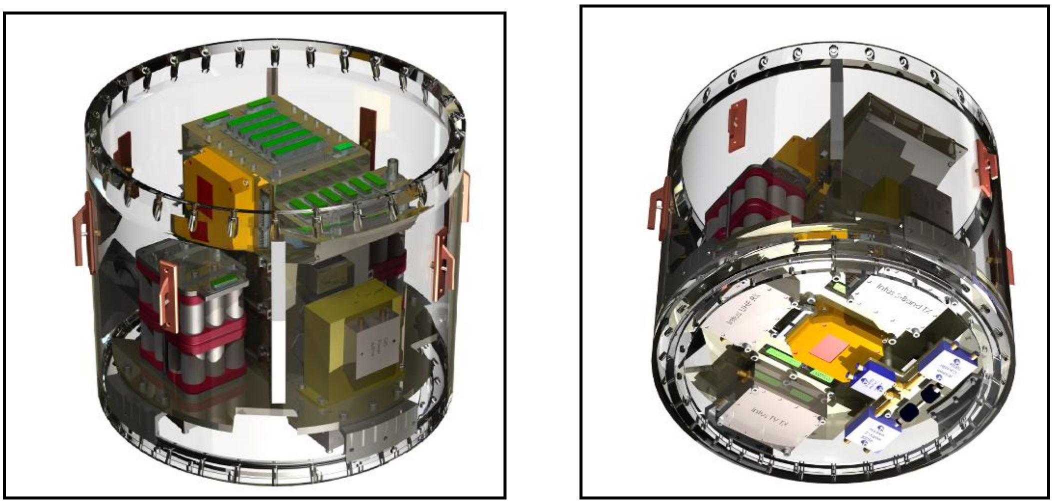


Figure 4-2: REXUS Service System (RXSM)

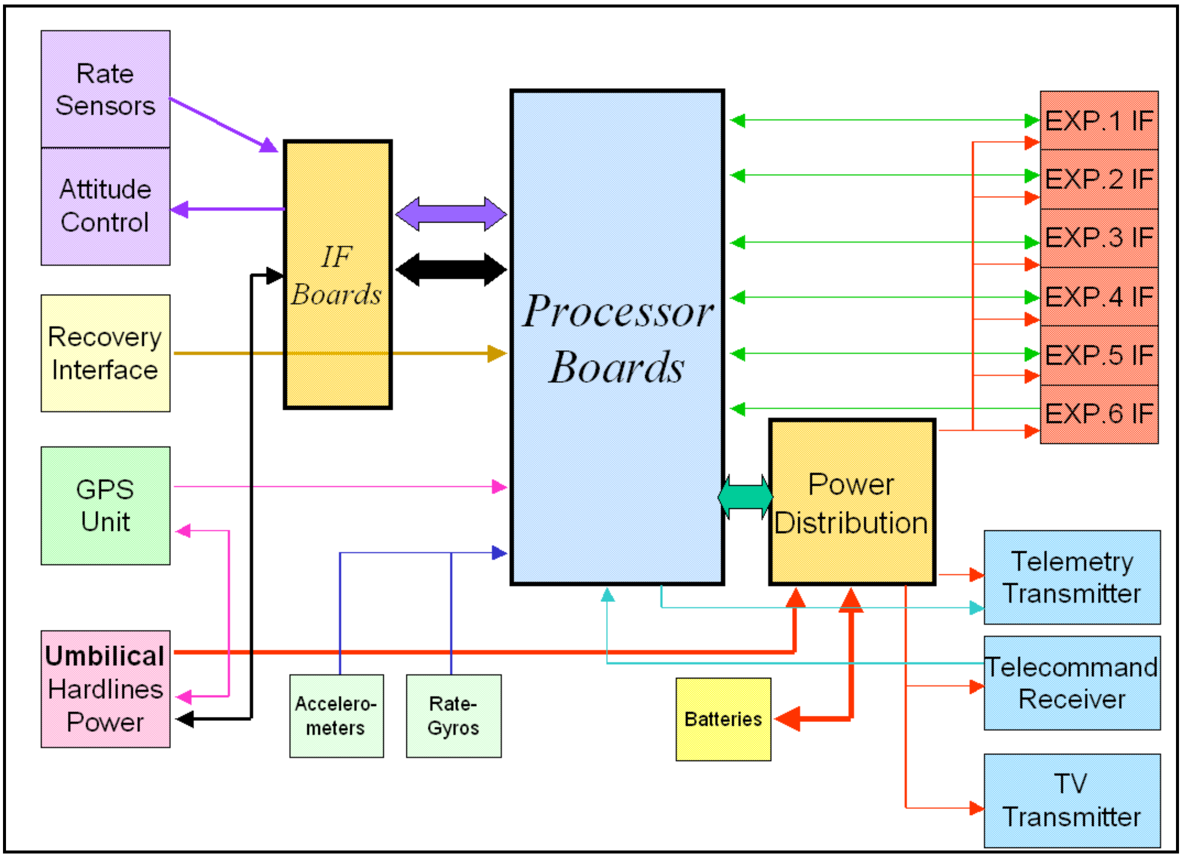


Figure 4-3: REXUS E-Box Block Diagram

4.1.2 Rate Control

A de-spin system (the Yo-Yo) can be used to reduce the stabilising spin after the launch phase. This is not part of the REXUS single stage standard configuration. The rocket will be de-spun from approximately 4 Hz to a maximum spin rate of 0.08 Hz (30°/s) in a clockwise direction when viewed from the rear.

4.1.3 Recovery Module

The recovery module is positioned in the back end of the payload and contains a drogue chute, which deploys the main chute. It also contains a heat shield, which protects the parachutes during re-entry. Barometric switches initiate the pyrotechnic sequence for ejecting the heat shield and releasing the parachutes.

The recovery system is capable of landing payloads with the designated payload mass from approximately 100 km apogee. The system is designed to decelerate from 150 m/s sink velocity to 8 m/s impact velocity.

4.1.4 Homing Aid

The vehicle is equipped with a GPS-receiver from which the service module can receive time and position information during flight. The GPS-position is transmitted via the telemetry stream. The recovery team in the helicopter can be equipped with a TM-receiver in order to acquire the GPS-position for quick and easy location of the payload. An autonomous homing beacon transmitter is also included in the recovery system. The payload is normally brought back to Esrange within a few hours of launch.

4.1.5 TV-Channel

One analogue TV channel is available for video transmission from one experiment.

The TV signal should be a standard PAL (B/G) with 1 Vss at 75 ohms. To connect this signal to the RXSM a BNC connector should be used.

4.2 Body Frame Coordinate System

For REXUS the Body Frame Coordinate system (BF) is used for the orientation of rocket components and experiments. Drawings of components and experiments should respect this axis definition. Accelerations are measured with the accelerometers referring to this coordinate system. The longitudinal axis is the roll-axis z_{BF}, which along with the pitch-axis x_{BF} and the yaw-axis y_{BF} build a right hand system.

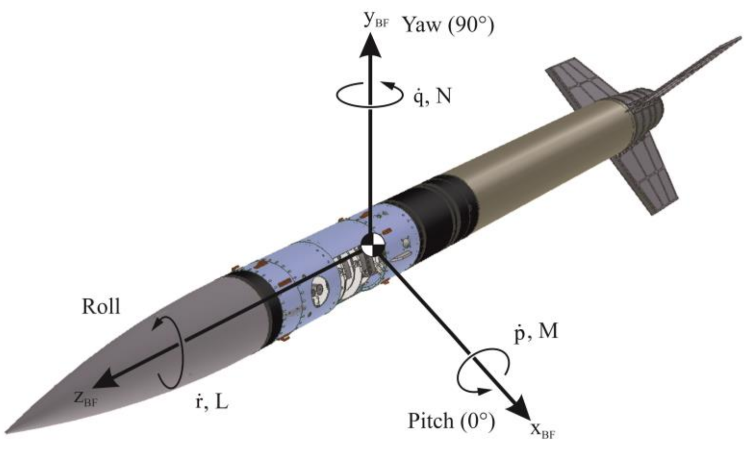


Figure 4-4: Definition of the REXUS BF-System

The BF angle velocities $\dot{q}$, $\dot{r}$ and $\dot{p}$ and the Roll-momentum L, the Pitch-Momentum M and the Yaw-momentum N are defined in Figure 4-4.

The origin of the system is located at the interface between the motor adapter and the payload on the longitudinal axis of the REXUS vehicle.

4.3 Performance and Flight Sequence

The performance of the REXUS rocket may be adapted to the respective mission requirements.

In the following tables, the flight sequence and g-levels from a typical REXUS flight with an Improved Orion motor are presented.

4.3.1 Nominal trajectory

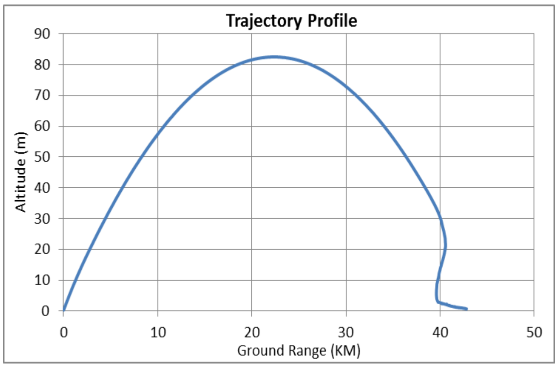
The nominal REXUS flight trajectory is dependent on payload mass and configuration as well as latest motor data. Please read the pre-flight version of the Flight Requirement Plan for valid flight events and nominal trajectory data. The following table gives an overview of the flight events during the REXUS-10 mission. The yo-yo release (Chapter 4.1.2) for de-spin of the rocket is not part of the standard configuration.

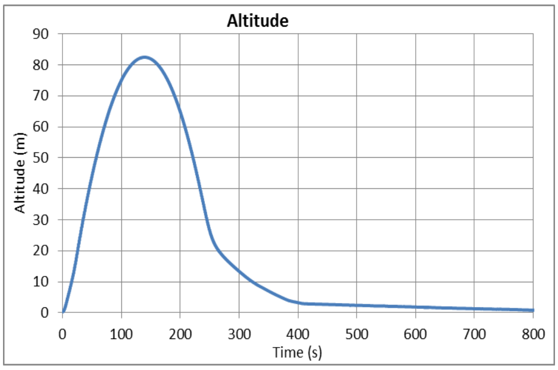
Table 4-1: REXUS-10 Approximate Flight Events

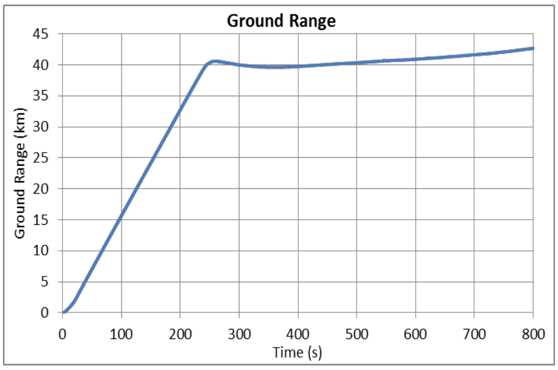
EVENT	Time (s)	Altitude (km)	Range (km)
Lift-off	0.00	0.332	0.00
Burn-Out	26.00	20.38	2.83
Nose Cone Ejection	61.00	52.73	8.89
Possible Yo-Yo Release	65.00	55.68	9.58
Motor Separation	66.00	56.39	9.76
Apogee	140.00	82.45	22.42
Payload Impact	~800	0.6	42.77

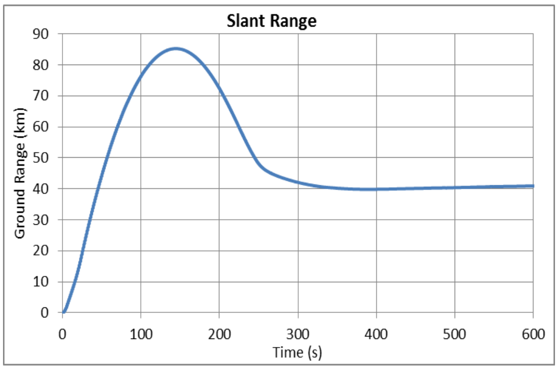
4.3.2 Graphs of typical trajectory

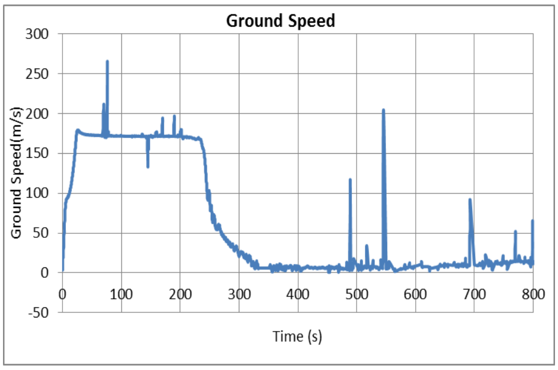
Graphs based on GPS data for the flight of REXUS-10. The valid nominal trajectory data of your mission will be part of the Flight Requirement Plan.

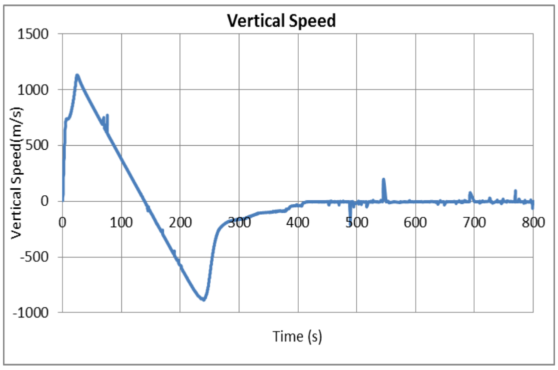


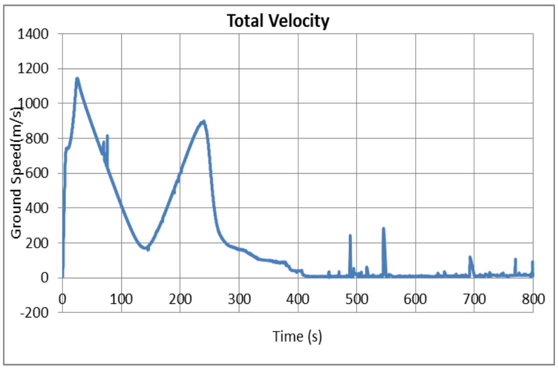


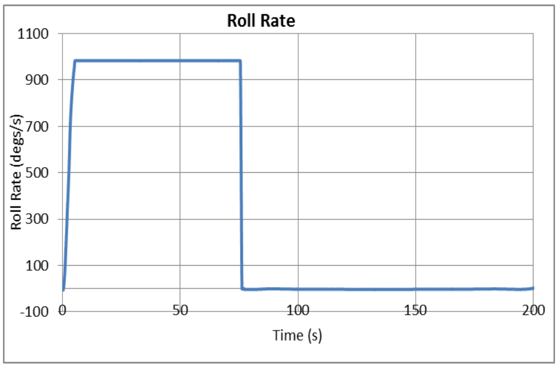


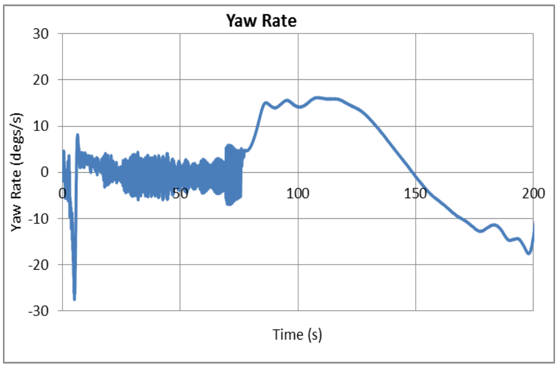


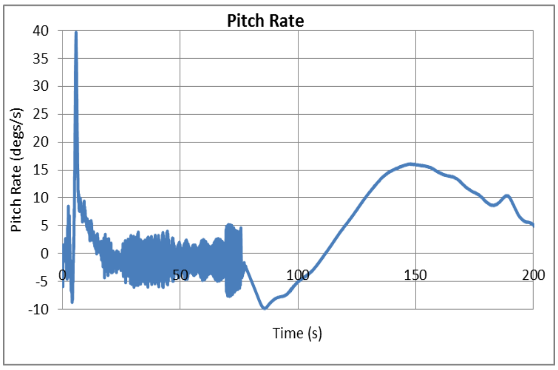


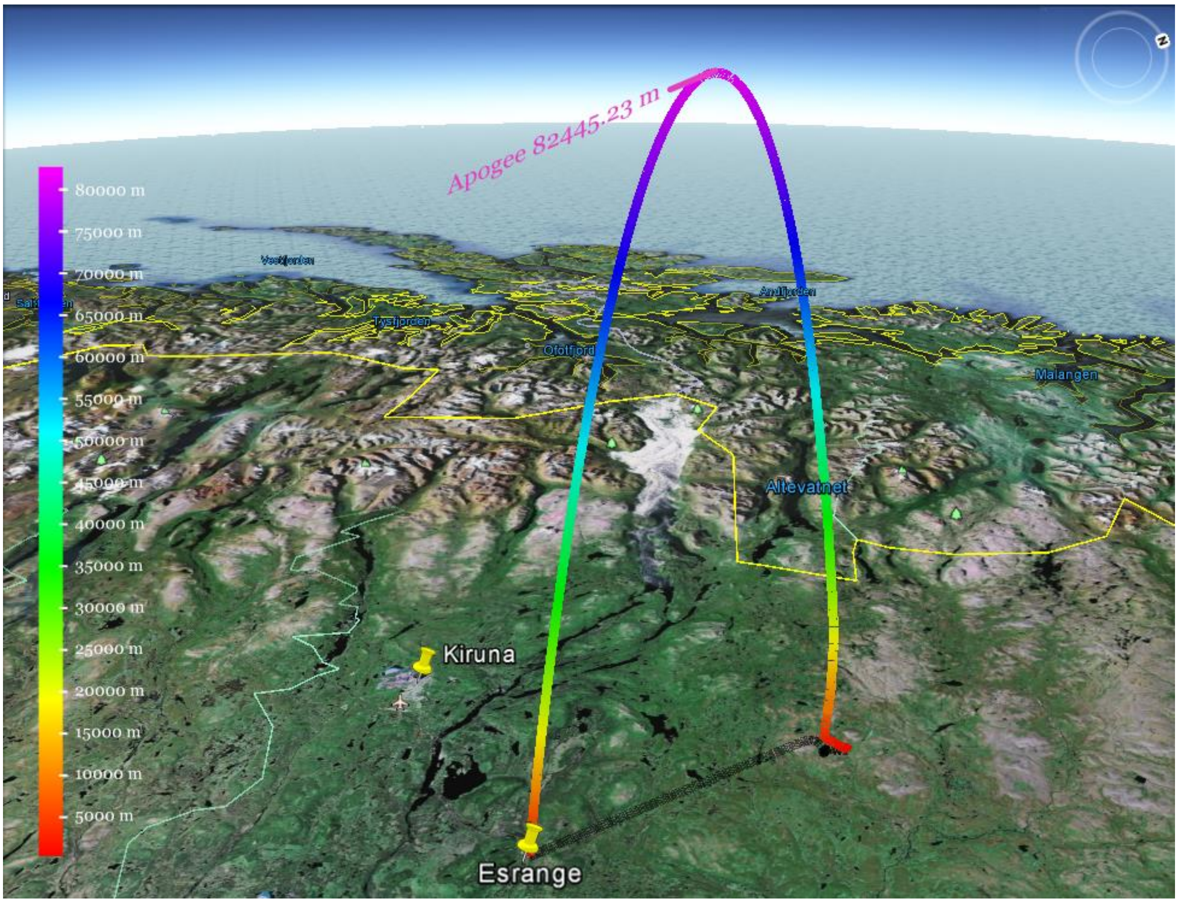



Total Velocity
Ground Speed(m/s)
1400
1200
1000
800
600
400
200
0
-200
0
100
200
300
400
500
600
700
800
Time (s)


Roll Rate
Roll Rate (degs/s)
1100
900
700
500
300
100
-100
0
50
100
150
200
Time (s)


Yaw Rate
Yaw Rate (degs/s)
30
20
10
0
-10
-20
-30
0
50
100
150
200
Time (s)


Pitch Rate
Pitch Rate (degs/s)
40
35
30
25
20
15
10
5
0
-5
-10
0
50
100
150
200
Time (s)


Apogee 82445.23 m
80000 m
75000 m
70000 m
65000 m
60000 m
55000 m
50000 m
45000 m
40000 m
35000 m
30000 m
25000 m
20000 m
15000 m
10000 m
5000 m
Ofotfjord
Malangen
Altevatnet
Kiruna
Esrange

As mentioned the total apogee is strongly dependant on the payload mass as demonstrated by the previous REXUS missions (note the designated ground range change for REXUS 5 and 6).

Note: dashed lines refer to predicted rather than recorded data, where data is missing or corrupt.

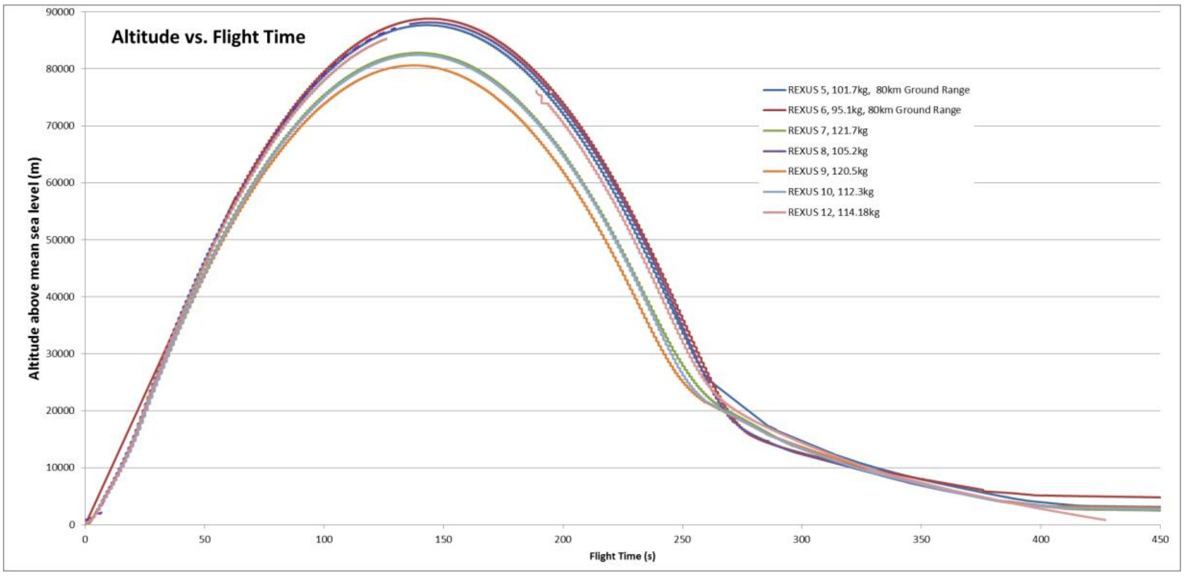


Figure 4-5: Altitude vs. Flight Fime for Previous REXUS Missions.

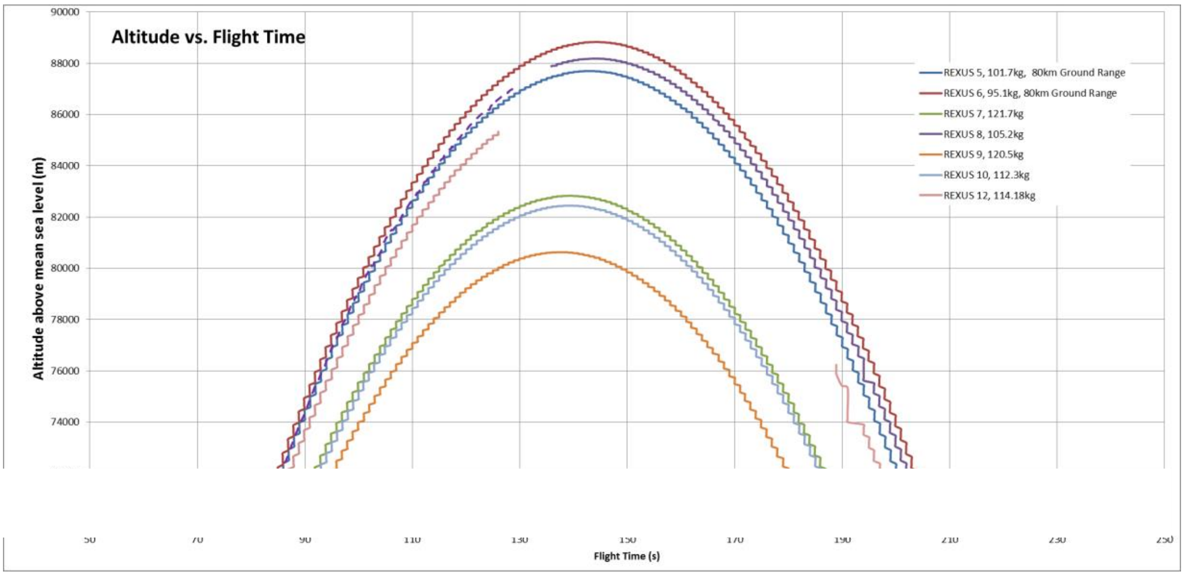


Figure 4-6: Apogee Focus for Altitude vs. Flight Time for Previous REXUS Missions

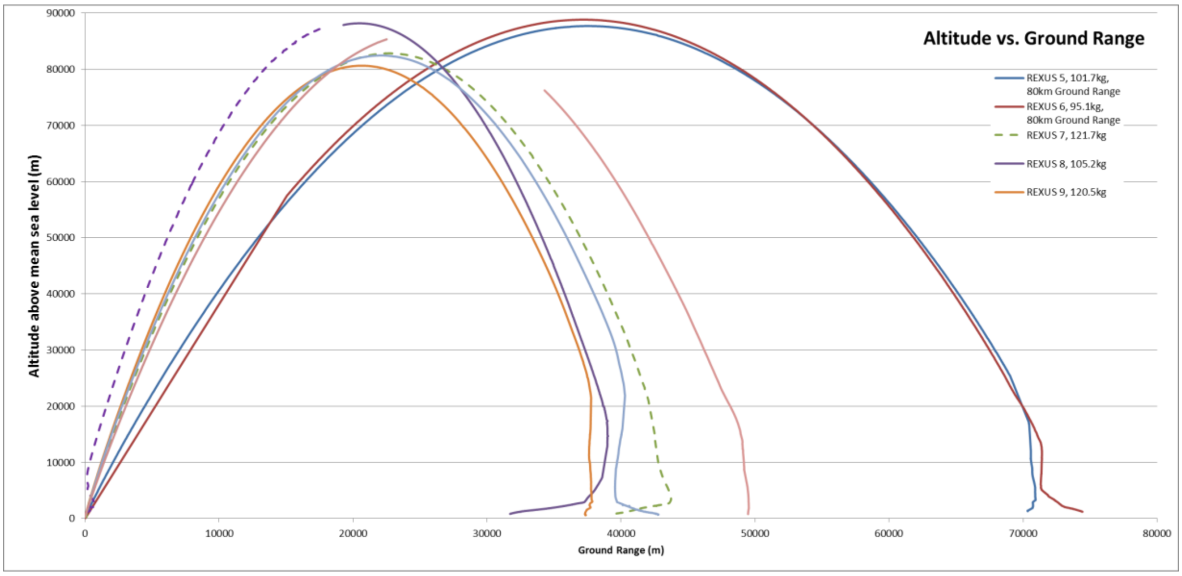


Figure 4-7: Altitude vs. Ground Range for Previous REXUS Missions

5 MECHANICAL DESIGN OF EXPERIMENTS

A typical configuration of an experiment module is shown in Figure 5-1 and Figure 5-2. Different types of mechanical interfaces between the experiment deck and the outer structure are possible. EuroLaunch will assist experiment teams to define suitable mounting positions, joints and screws.

It is a requirement that the experiment modules are either made gas tight or equipped with venting holes.

For experiments requiring late access, hatches in the outer structure are used. The integration of the samples must then be made prior to vehicle arming which starts at T-40 minutes.

External cooling liquid/gas may be supplied by gas umbilical up until launch.

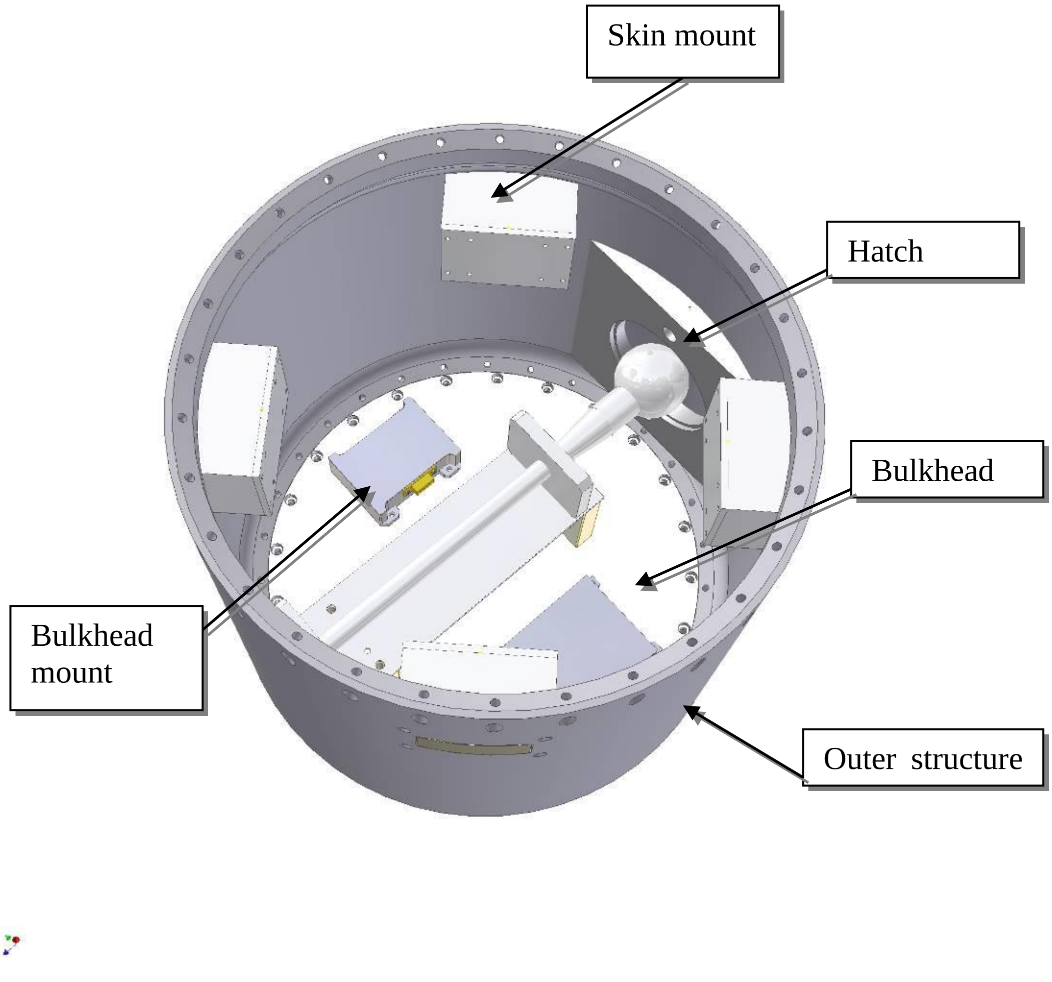


Figure 5-1: Experiment Module

Figure 5-2: REXUS Nose Cone Experiment (Underneath Ejectable Nose Cone)

5.1 Outer Structure

The baseline for the mechanical design is that the outer structure is made of 14” diameter (355.6 mm), 4 mm thick, 120, 220 or 300 mm long aluminium cylinder modules (**EN AW 7020-T6, blue anodisation)**. The mass of the modules vary depending on the exact configuration required. These modules are normally supplied by EuroLaunch, respectively ZARM. For experiments beneath the nosecone - it is a 14”, 4:1 Ogive nosecone - some of this space is taken by the nosecone recovery system, and care must be taken to avoid interference with this. Any deviations from the baseline must be agreed with EuroLaunch.

Note that it is in general not possible to use the full length of the module for the experiment. The experiment volume allowance begins 20 mm below the top of the module and ends 10 mm below the bottom surface. This ensures that there is no mechanical interference between experiments. Take care when designing experiments that connectors also do not need this space, so that assembly can be performed without any problems.

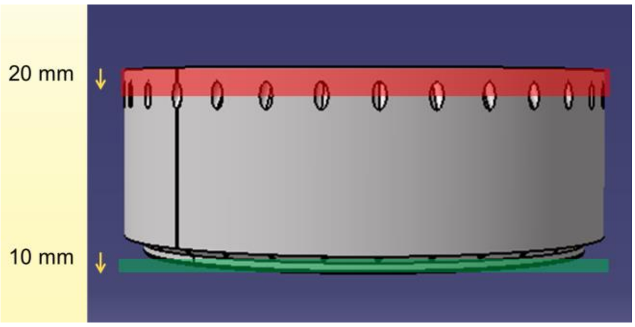


Figure 5-3: Experiment Module

The following figure shows the internal coordinate system. The MRL Launcher rail is at payload position 0°.

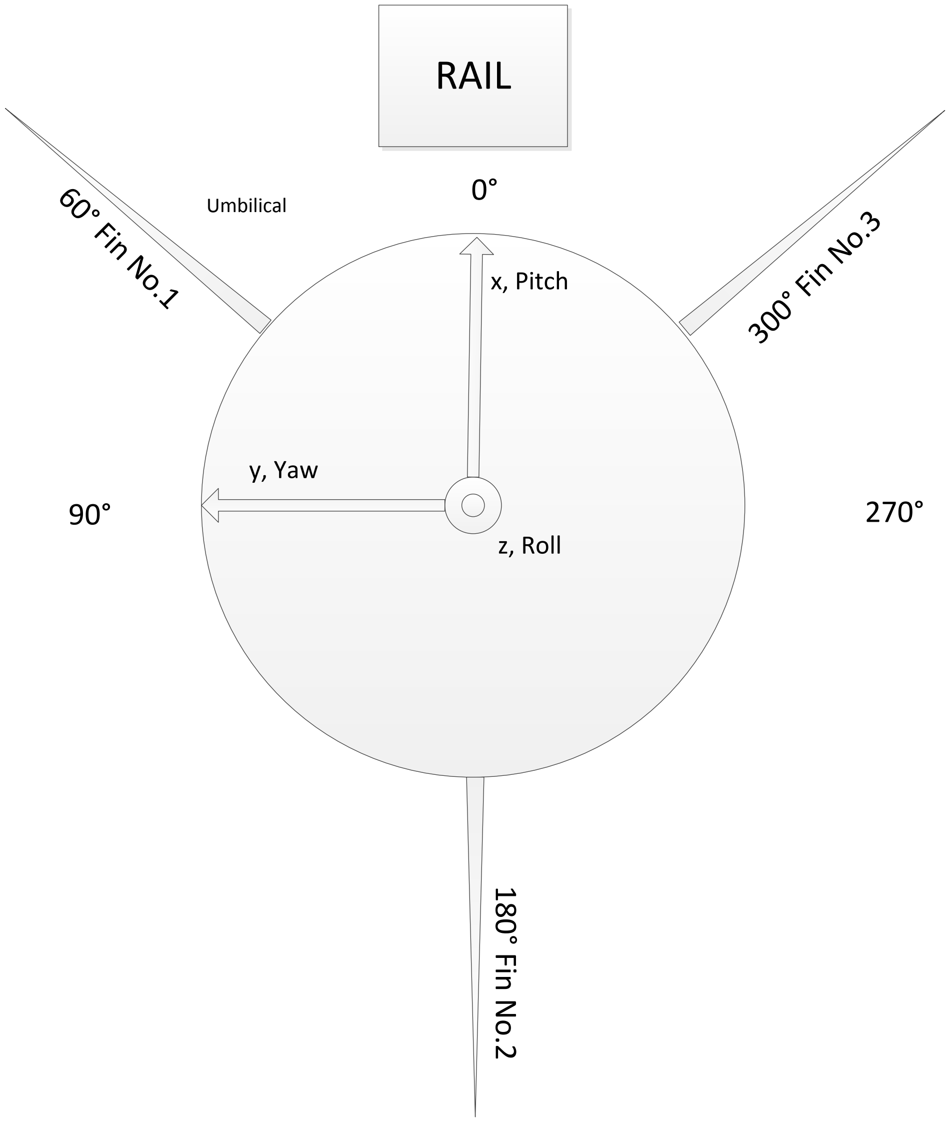
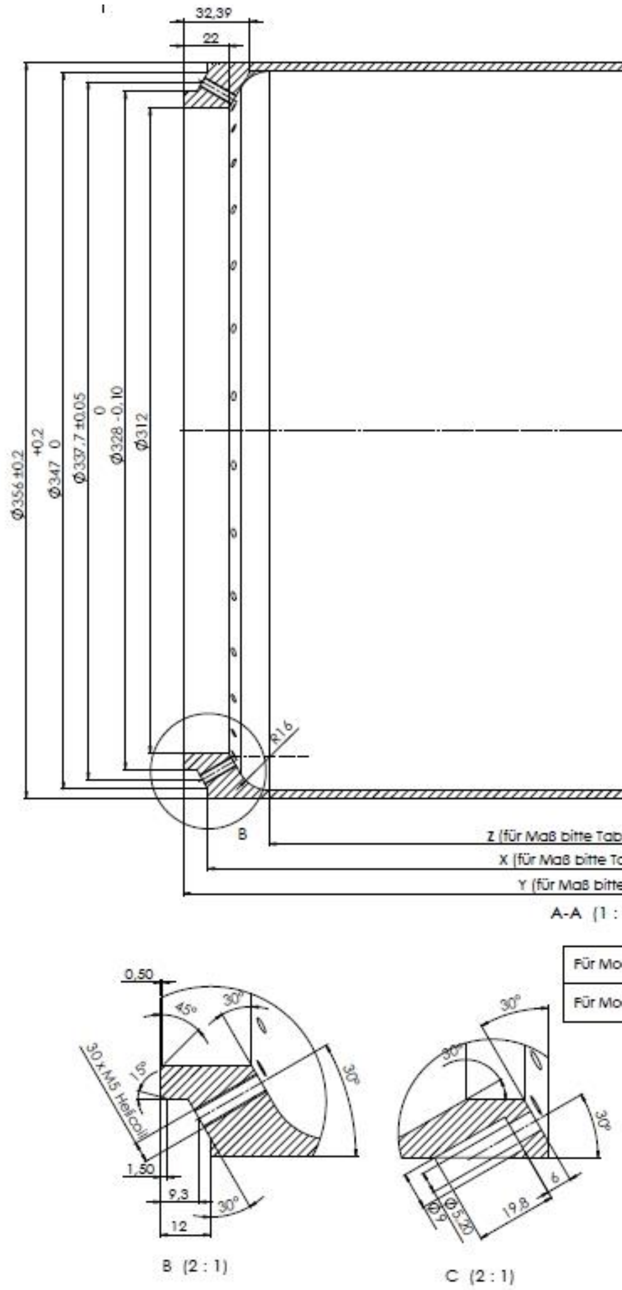


Figure 5-4: REXUS PL Coordinate System (positive z-Axis in flight direction)

The next figure shows the standard layout for a 14” module.



Für Modullänge 400mm	X=400mm	Y=412mm	Z=329mm
Für Modullänge 300mm	X=300mm	Y=312mm	Z=229mm

Figure 5-5: 14” Module geometry (contact DLR MORABA for details)

Two modules are connected by the so called RADAX joint. RADAX is an abbreviation for Radial-Axial. Helicoils are used in the aluminium modules. Following screws are used to connect the modules:

Hexagon Socket Head cap screw (ISO 4762, DIN 912), M5 X 16 mm, Material: Stainless A2

The torque moment for the M5 screws is 6.5 Nm.

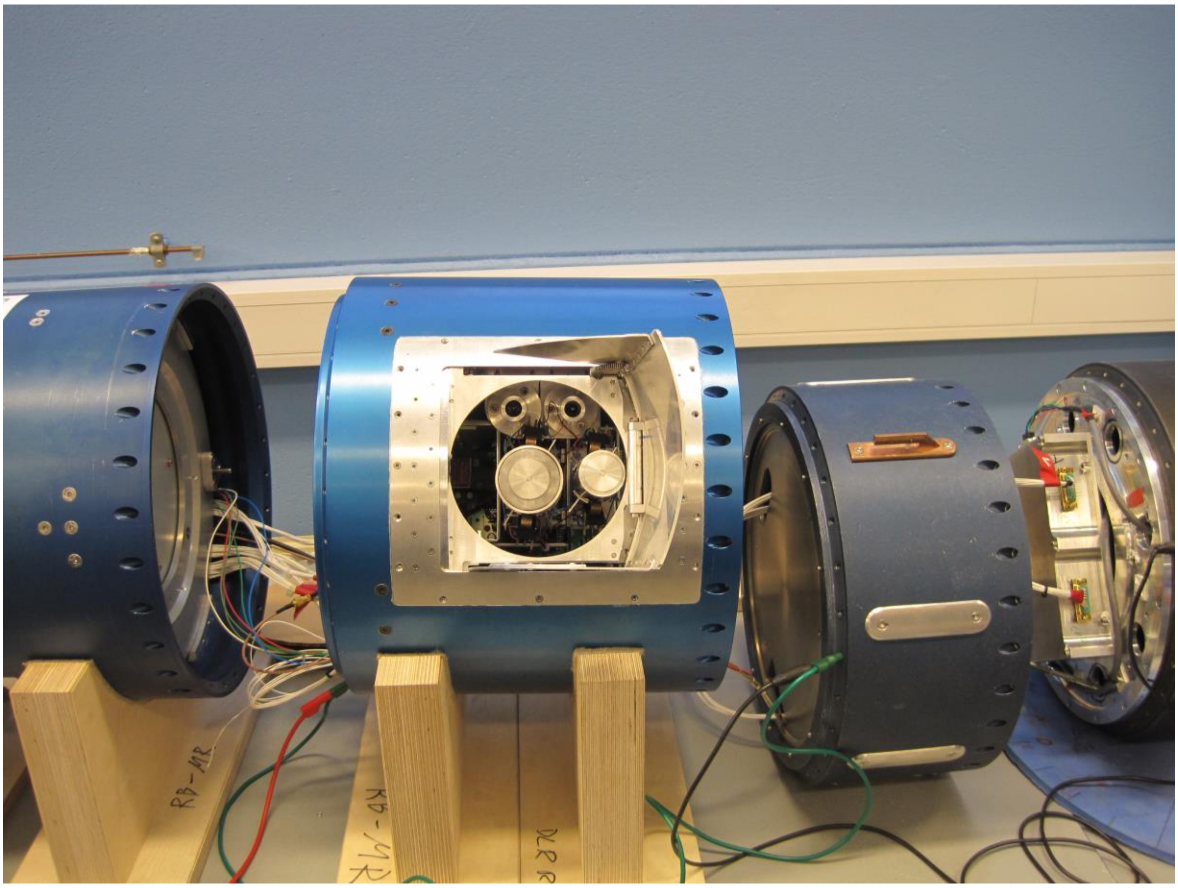


Figure 5-6: Experiment Modules

5.2 D-SUB Brackets

In each experiment a standard EuroLaunch D-SUB Bracket (see Figure 5-6: Experiment Module) should be mounted to enable assembly of scientific payloads.

It is to be located at 180 degrees in the module (this is opposite the groove cut in the module for the zero degree line which is represented in the CAD files found on the teamsite). It should sit 20 mm below the bottom of the RADAX flange at the top of the module. Above and below, the space should be left clear so that cables can be easily passed through and mounted to the walls.

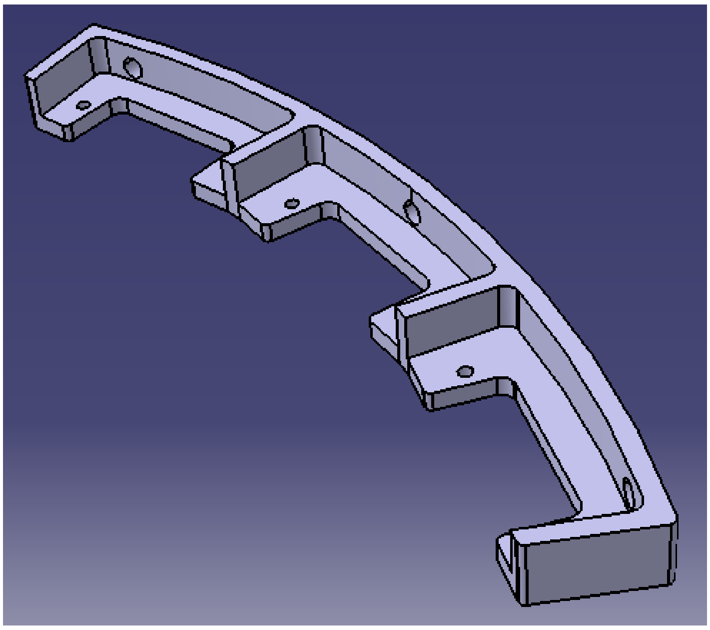


Figure 5-7: Standard EuroLaunch REXUS D-SUB Bracket

In addition a clear feed through should be left through the experiment, wide enough to pass through up to 4 D-SUB 15 connectors, this shall include a cable feed through hole cut through the module.

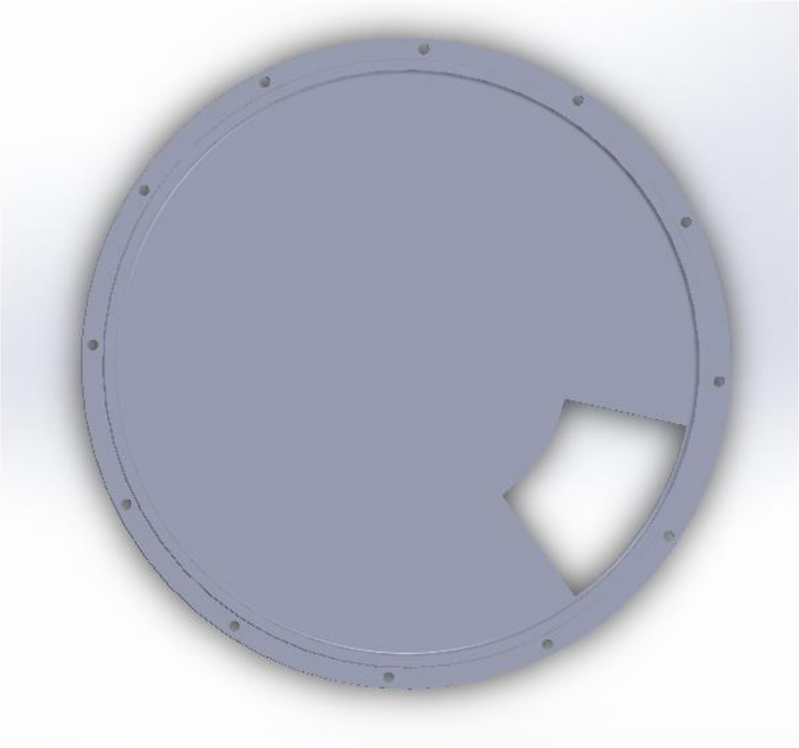


Figure 5-8: REXUS Bulkhead

5.3 Hatches

5.3.1 Late Access Hatches

Hatches for late access should be oriented so that access is possible when the payload is on the launcher. Hatches for late access should be oriented so that access is possible when the payload is on the launcher (i.e. well away from the 0 degree line). Hatches must be mounted before launch. The figure below shows a recommended design of a hatch. All hatches must follow the shape of the module.

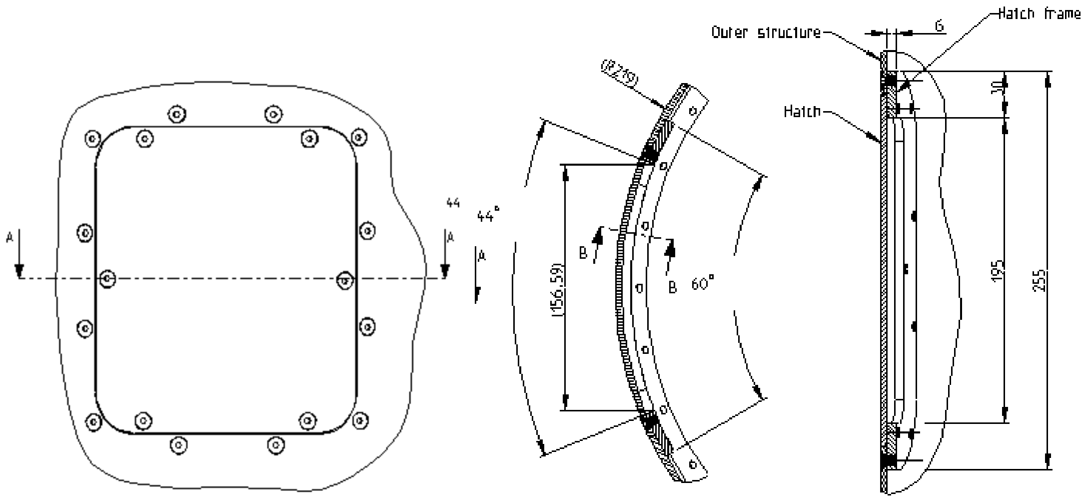


Figure 5-9: Hatch Example

5.3.2 Inflight Actuated Hatches

Inflight actuated hatches are beyond the standard scope of REXUS.

The use of any hatches requires a Request for Waiver (RFW) to be approved by DLR and SSC. Contact your ZARM/DLR or SSC/ESA supervisor for this document.

When such hatches are allowed, they must:

- Be curved and flush with the module skin (follow the shape of the module),
- Have no significant influence on flight dynamics.

The hatch retention systems must:

- Be at least single failure tolerant,
- Fully inside the experiment module ,
- Be verifiable for correct retention after assembly (i.e. verifying tension of retention cables).

The verification process must include

- A vibration test to the qualification levels with a model of the design,
- A long duration retention tests (minimum 7 days) to show that there is no significant deterioration of performance of the retention system.

The actuation process must:

- Leave no material hanging out from the module,
- Leave no unconstrained debris or material inside the payload.

5.4 Exhaust Openings

Reaction forces from exhaust openings shall be minimised by using at least two openings located symmetrically on the module.

5.5 Venting Holes

To avoid pressure build-up within the payload and to avoid gas-flow between modules, it is sometimes necessary to have venting holes in experiment modules.

One hole of 10 mm in diameter is recommended for each 15 dm^3 of evacuated air volume. A small cap such as the one shown in Figure 5-10 shall cover the holes.

During re-entry, hot air might enter the module through the venting holes and it is recommended to protect, or avoid placing heat sensitive equipment near these holes.

Figure 5-10: Venting Hole with Cap

5.6 Ejectables and Free Falling Units

It is possible to eject items from the modules but this requires an RFW as it is beyond the standard scope of REXUS. ***Contact your ZARM/DLR or SSC/ESA supervisor for this document.***

See section 5.10.1 regarding ejectables/free falling units and effects on flight dynamics.

The design of any hatch and release mechanism will be closely followed by EuroLaunch.

5.7 External Skin Mounts

It is possible to mount items on the exterior of the modules but this requires an RFW as it is beyond the standard scope of REXUS. ***Contact your ZARM/DLR or SSC/ESA supervisor for this document.***

Great care must be taken with the design of externally mounted objects due to the possibility of influencing flight dynamics. The size should be kept to a minimum and it should be designed to have a very small aerodynamic effect on the payload. External skin mounts must also be designed to ensure that they do not result in parachute line entanglement.

5.8 Use of Fluids within Modules

Use of fluids within REXUS modules is allowed but considerable care must be taken to ensure that the fluids stay within the module. All experiments wishing to include fluids (greater than 2 mL) in their experiments must use an absorbent material at the top and bottom of the module so that the possibility of fluid being transferred to other modules is eliminated. This material should have the capacity to absorb twenty times the quantity of the fluid used.

See section 5.10.1 regarding partially filled cavities and effects on flight dynamics.

5.9 Dimensioning Loads during Launch, Flight and Recovery

The experiments should be dimensioned to withstand the loads during a complete flight profile.

5.9.1 Acceleration

The typical longitudinal acceleration history (for an Improved Orion rocket motor) is shown in shown in chapter 4.3 with a peak acceleration of 20 g.

Centrifugal forces will also act on the experiments, since the rocket spins at 3-4 Hz.

5.9.2 Re-Entry Loads

The typical deceleration during re-entry is below 20 g and can occur in all axis.

5.9.3 Landing Velocity

The landing velocity is approximately 8 m/s. The shock at impact depends on the nature of the ground surface. Nominally, the landing is fairly gentle with no damage to the experiment modules.

5.10 Mechanical Retroaction Forces from Experiments on the Payload

An estimation or measurement of the induced acceleration or vibration levels of each experiment shall be presented to EuroLaunch at least four months before launch.

5.10.1 Vehicle Characteristics

Momentum wheels, cavities partially filled with liquids, ejectables/free flying units, etc. will only be accepted after a successful analysis of the impact on the vehicle performance.

5.10.2 Movements

Any movements of components or samples in the module can disturb the payload conditions.

These disturbances shall be kept to a minimum, for instance through counteracting mechanical devices or symmetrical gas exhaust openings.

5.10.3 Vibrations

Vibrations induced by movement of components in the payload will also cause disturbances to the flight conditions.

The vibration levels generated in the module shall be kept as low as possible. As a rule of thumb, the module-produced vibration levels should be lower than $5x10^{-5}$ (0-25 Hz). This level changes from flight to flight and depends on the experiment modules' sensitivity to vibrations.

5.11 Mass Balance and Mass Properties

The centre of gravity of each module shall be as close as possible to the longitudinal axis. It is not necessary to carry out mass balancing of each module, or to add ballast weights, since the total payload will be mass-balanced, thereby saving total ballast weight. This work is performed by EuroLaunch.

The accuracy should be as follows:

Total mass		± 0.5 kg
Moment of inertia	I_x	± 0.1 kg·m^2
	I_y	± 0.1 kg·m^2
	I_z	± 0.1 kg·m^2
Centre of gravity	X	± 20 mm
	Y	± 20 mm

The mass of the modules should be kept to a minimum to ensure the best possible performance of the rocket.

6 THERMAL DESIGN OF EXPERIMENTS

6.1 The REXUS Thermal Environment

6.1.1 Pre-Launch Phase

The integration of the modules and payload is done at normal room temperature 20 ± 5 °C. After integration, the payload is mounted to the motors before being transported to the launcher. The ambient temperature during transport can be low (-30 °C or lower), depending on the outdoor temperature, but the exposure time is short (5-10 minutes). The ambient temperature is highly dependent upon the time of year for launch; refer to Tu Tiempo [10] for some examples. Nominally the payload is shipped fully integrated from the Bench test to the Spin and balance and then on to campaign by unheated road transport. During this phase the temperature may be as low as -30 ºC for several hours.

6.1.2 Countdown Phase

Experience shows that during countdown, the experiment modules tend to see an increase in temperature over time, especially if long holds are required. Some actions can be taken in the launch tower to improve the situation, however it is recommended that temperature regulation is included in the design of heat sensitive experiment modules.

The thermal environment in the launcher housing will be controlled before launch. Normally, the vehicle will be in the housing with an air temperature of 17 ± 7 °C. Prior to launch, the housing is removed and the launcher is elevated ready for launch. This is the phase during which the rocket will see the coldest temperatures. This time period is nominally 20 minutes. However, in the case of a hold between T – 20 minutes and launch, this period can be extended indefinitely. Experimenters must be fully aware of how low temperature conditions can affect their experiments. The Service System can provide low levels of heating during this phase but this cannot guarantee specific temperatures. During other phases, the thermal environment can be controlled when required.

6.1.3 Flight Phase

The thermal environment of the outer structure of a front-end positioned parallel bay module on an Improved Orion motor flight can reach 110 ºC at 50 seconds after lift-off. Peak temperatures above 200 °C for the skin are expected during the re-entry phase. This will of course be transferred to internal parts, especially to items mounted onto the skin. For more detailed temperature information, please see previous flight temperature profiles.

6.1.4 Post-Flight Phase

After the impact, the payload will be subjected to snow and cold air in the impact area for a period of typically one to two hours. The temperature during the season when REXUS is launched is normally between 0 °C and -30 °C. Experiments with samples sensitive to low temperatures after the flight must be designed for these post flight conditions.

6.2 REXUS Thermal Requirements

In all phases (pre-flight, flight and post-flight) the following limits shall apply:

6.2.1 Heating of the Outer Structure

The modules' internal thermal dissipation must not heat up the outer structure more than 10 °C above the ambient temperature.

6.2.2 Temperature at the Feed-Through Cable

The modules' internal thermal dissipation must not heat up the parts close to or in contact with the feed-through cable to more than +70 °C.

6.2.3 Heat Radiation in the Module Interfaces

A module's internal thermal dissipation must not heat up parts facing other modules to more than +50 °C.

6.2.4 Convection between Connecting Modules

The heat transport by convection must be limited in such a way that the air temperature at the module interfaces does not exceed the ambient temperature by more than 10 °C.

An insulation deck, in both ends of the module, could be required to comply with these requirements.

7 ELECTRICAL DESIGN OF EXPERIMENTS

7.1 System Overview

As mentioned in 4.1.1 the RXSM works as a data interface between the onboard systems/experiments and the ground control.

There are 6 identical interface ports available for experiments, 5 of which are available for payload connection with each port providing the TM/TC, control wires and power. A further 2 ports are available for a TV channel connection.

The feed-through harness (i.e. the cabling that connects your experiment to the service system) will be designed and provided by EuroLaunch.

7.2 Radio Frequency Constraints

In general, for every transmitter that will be used at Esrange Space Center 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 therefore, special care must 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 experiment teams or give them the information needed to make such applications. Parameters such as transmitting frequency, radiated power, bandwidth of signal, antenna and antenna pattern, and modulation type are required information to have in advance.

The following frequencies are used in safety-, telemetry- and recovery systems and are therefore not allowed to be used in any experiment:
240.80 - 244.05 MHz
449 - 451 MHz
1575 MHz
2290 - 2295 MHz
2338.1 MHz

7.3 Durability

After integrating the payload, the whole rocket is mounted on the launcher. In this late phase before lift-off, experimenters do not have access to the payload any more.

During this phase there will be more tests of the whole system which means that the experiments are turned on and off several times. Finally, there will be one (or more) test countdown(s). Experiment teams should make sure that their experiments have enough battery, memory, chemicals, etc. to cope with this, in addition to the complete flight. During the test countdowns the testing signals (LO, SOE, SODS) may be given at any time in any order. Experimenters should be sure that they can cope with these signals, and if necessary implement a testing state (software or hardware) to avoid the need to access their experiment.

7.4 Telemetry System

The REXUS telemetry system consists of the TM master-board, located in the E-Box of the RXSM, and data sources distributed in the experiment part of the payload. All the data streams are multiplexed to a PCM data stream. The PCM/Biphase output from the main encoder modulates an S-band transmitter providing the ground link. The overall data rate of this PCM downlink is 500 kbit/s.

The interface between the TM master and each user in the TM system is implemented using an asynchronous serial link connection. The whole packed PCM downlink is equipped with a forward error correction (FEC) which minimizes data loss.

Data losses are expected during the launch and the re-entry phase. During the rest of the flight, the bit error rate is < 10^{-8} bit. If a bit error hits a frame's sync information, it could lose the whole frame which means that the serial data (up to 32 byte per data channel) contained in this frame is lost.

From past experiment experience, both short drops and long drops in the telemetry connection should be considered in the software. *Experimenters must consider that drops will occur and design their software accordingly*. Testing with the Service System Simulator can be conducted using simulated dropouts to verify that the experiment system can cope with potential telemetry situations. For details, please look at previous flights' data.

7.5 Telecommand System

The REXUS telecommand system consists of the TC master, located in the RXSM and TC users distributed in the experiment part of the payload. Each experiment module can be individually addressed by ground commands. The telecommand receiver operates in the L-band. Experiment data uplink during flight is not part of the standard scope of REXUS and requires an RFW. ***Contact your ZARM/DLR or SSC/ESA supervisor for this document.***

Experiment data uplink is possible during launch through the umbilical.

The telecommands and their characteristics must be specified and submitted in advance to EuroLaunch.

The interface between the TC master and each user in the TC system is implemented using an asynchronous serial link connection.

The overall data rate of this uplink is 19.2 kbit/s. This GMSK uplink uses CRC and CSM mechanisms to avoid executing corrupt commands.

7.6 REXUS Experiment Interface Description

Each experiment will be allocated its own standardised RXSM interface connector. On this connector, all communication, control, and power lines are implemented. A D-SUB 15 female connector is used to perform the interface on the RXSM side.

Up to 5 interface connectors are available to deliver power, to control the experiments and to exchange data in both directions.

There is a 6th interface available, but only with downlink capability (no uplink).

7.6.1 Experiment Interface Connector

The experiment interface connector should be a D-SUB 15 male type. This is the connector which is connected to the Service Module socket.

Table 7-1: Standardised REXUS Experiment Interface

Pin Nr	Name	Remarks
1	+28 V	Battery Power (24-36 V unregulated, I_{peak} < 3 A)
2	Charging (28 V/1 A)	
3	SODS	Start/Stop of data storage (open collector to GND or high impedance)
4	SOE	Start/Stop of experiment (open collector to GND or high impedance)
5	LO	Lift off (open collector to GND or high impedance)
6	EXP out+	Non inverted experiment data to Service Module (RS-422)
7	EXP out-	Inverted experiment data to Service Module (RS-422)
8	28 V Ground	Power Ground
9	+28 V	Battery Power (24-36 V unregulated, I_{peak} < 3 A)
10	n.c	
11	n.c	
12	Charging Return	Charging return (connected to 28V GND at the EGSE)
13	EXP in +	Non inverted Control data (commands) to Experiment (RS-422)
14	EXP in -	Inverted Control data (commands) to Experiment (RS-422)
15	28 V Ground	Power Ground

7.6.2 Telemetry Interface

A RS-422 interface is responsible for the transfer of the experiment data to the RXSM. The baud rate must not exceed 80% of the maximum data throughput. The formatting, failure recognizing and correction are the responsibility of the experiment teams.

Baud rate: 38.4 kbit/s standard

Format: 8 bits, 1 start and stop bit, no parity

Although this asynchronous downlink is fully transparent, the experiment teams should implement a data protocol as showed in Figure 7-1 below.

Figure 7-1: Downlink Protocol Example

To avoid channel bandwidth overload, it is recommended to add a **3 ms** pause between the data blocks (see Figure 7-5).

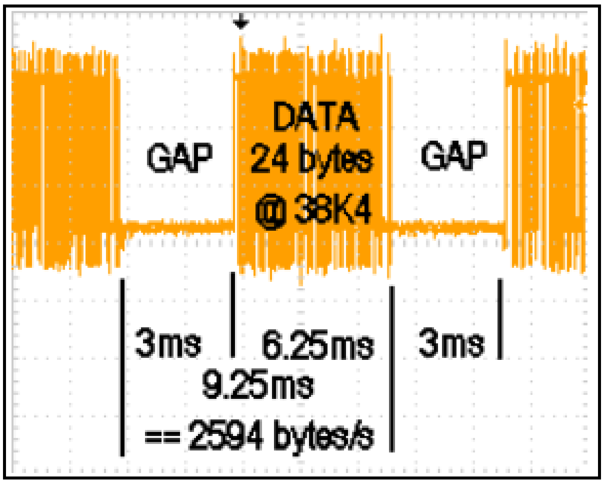


Figure 7-2: Downlink Channel Timing

REMARK: During the recent campaigns, a data loss could be monitored under certain circumstances. This "gap" solution eliminates the effect, but it is recommended that the experiment teams shall keep this part of their software flexible. Maybe higher data rates are possible depending of the data-frame structure. This has to be checked out in advance.

For more important TM/TC Information, please see the PCM Telemetry System document [9] from DLR MORABA. This is available on the Team Site in the "References" folder.

7.6.3 Telecommand Interface

A RS-422 interface supplies the appropriate commands to each experiment. The formatting, failure recognizing, and correction are also in the responsibility of the experiment teams.

Baud rate: 38.4 kbit/s standard

Format: 8 bits, 1 start and stop bit, no parity

The same parameters as on the downlink should be used.

Due to the fact that the uplink capacity is considerably low, the "gap" should be minimal **200 ms** wide (if 24 byte blocks are sent).

7.6.4 Power Interface

The power (standard 28 V DC) is delivered by the RXSM. The supply voltage varies between 24 V and 36 V depending on the condition of the onboard batteries. The experiment should be able to deal with voltage steps, which may occur when switching the RXSM from external (regulated) to internal (battery) power.

The peak power consumption should not step over 3 A (3 A per experiment line, not total consumption) during switching, while the mean value should not exceed 1 A mean (~30 Watts). The power for each experiment can be controlled by hard-line commands via umbilical or, if available, by telecommands during flight. If no telecommand after lift-off is available (which is standard), the power can be switched by a pre-programmed timeline.

The experiment must make provisions to limit voltage ripple fed back to the RXSM over the power line to a maximum of 100 mV.

If a user needs an extraordinary power system, the user is responsible for the monitoring and charging of his batteries via the umbilical lines.

It is absolutely recommended to use always both power pins for supplying the experiment (Pins 1 & 9 and 8 & 15).

7.6.5 Charging Interface

In the case of internal batteries within the individual experiment, there is a charging line to provide power (28-34 V, 1 A) to the experiment when the RXSM is switched off.

This line is only for charging purposes, not for operating the experiment when the RXSM is switched off (in case of radio silence). This line is protected with a diode to avoid reverse current and discharging.

7.6.6 Control Interface

The RXSM supplies 3 different control lines for each experiment.

They are implemented as open collector outputs with the capability to sink a current of maximum 50 mA (from ground) for each channel. The 28 V/GND is also structure ground.

An active signal means low impedance to ground, inactive means high impedance to ground.

The user should connect either an optocoupler device or a relay to make this signal available for his experiment. If using a relay, the user is responsible for including a clamp diode close to the coil of the relay.

Available control lines:

- **Start of Data Storage (SODS)**
  This control line can be issued by time line during flight or it can be initiated by the EGSE system via umbilical.
- **Start of Experiment / Stop of Experiment (SOE)**
  This control line can be issued by timeline or by command during flight.
- **Lift-Off (LO)**
  This signal is derived from the extraction of the umbilical connector from the Service Module when the rocket leaves the launcher.
  This is also a reset of the internal millisecond counter of the RXSM. All timeline events are correlated with this event (T+0s).
  During bench testing it is possible to simulate the lift-off condition, but not when the rocket is mounted on the launcher. Test countdowns will usually be stopped before the

lift-off event, so in this case SOE/SODS may be given but not LO.

As a result of the electric design, the LO signal is distributed to **all LO signal pins in parallel**. This means, all LO pins are electrically interconnected.
This requires a special treatment when connecting this signal (see below).

Waveform information for signals will be added to this document in the future. In the meantime, if it can be seen that this is required for an experiment. The experiment team should contact EuroLaunch to request this information.

7.6.7 Interface Suggestions

*Lift-Off Signal, **SOE, SODS signals***

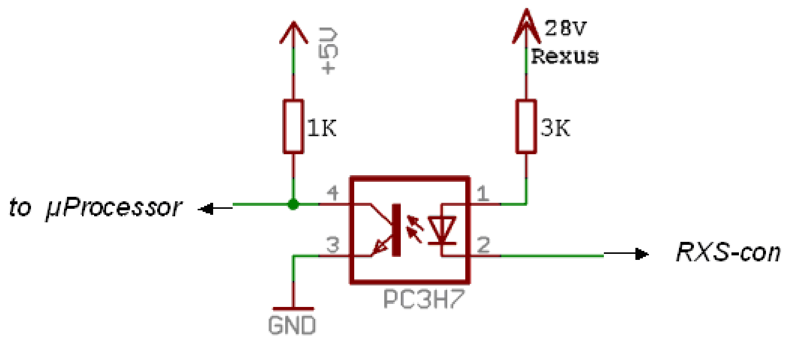


Figure 7-3: Interfacing Example

This example uses an optocoupler to establish the interface to RXSM. The important part is the relation of the primary part to the 28 V system power. You can use also a FET or a transistor, but always relate to the 28 V system power. Never connect this signal directly to your microprocessor input. Due to the fact that the LO signal is interconnected to other experiments, where it is also connected to +28 V (via a pull-up resistor), direct connection to a 5 V or 3 V device can cause damage or malfunction.

SOE and SODS signals are not shared with other experiments like the LO-signal, so precautions must not be taken there.

RS422 signals

On the RXSM (E-Box) end (downlink) there is a 1 kΩ resistor between the data lines. On the experiment side (uplink) a 1 kΩ resistor should also be implemented.

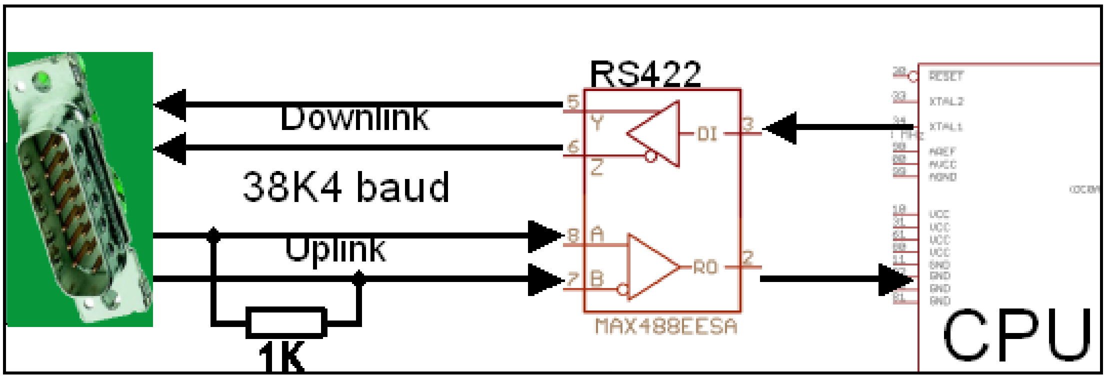


Figure 7-4: RS422 Interfacing Example

7.7 Interface Description on Ground

Space will be provided in the Scientific Office in the main building. The operator of an experiment receives his experiment data via a RS-232 interface, and he can control his experiment by sending commands via the same RS-232 interface over the umbilical.

If a recorder is onboard, it can be switched on just before lift-off. The SOE and the SODS can be defined by the user, and they are controlled by timelines on board.

If necessary, experiments can be switched off either by telecommands, or by timelines. This can be performed only by the payload engineer before Lift-Off.

Reception of experiment data:
Baudrate: 38.4 kbit/s
Format: 8 bits, 1 start and stop bit, no parity

Commanding of experiment:
Baudrate: 38.4 kbit/s
Format: 8 bits, 1 start bit and stop bit, no parity

A higher baudrate on ground than on board is no mistake; it ensures that all data can be distributed to the users in time. Of course the uplink data rate has to be the same as the downlink rate, but it is not possible to continuously send data at 57.6 kbit/s to the experiment (see 7.6.3).

7.8 TV Transmitter

If a TV downlink is requested by an experiment, the transmitter will be integrated in the RXSM in combination with a video multiplexer.

Three TV sources can currently be connected to the multiplexer. During the ascent- and free flight phase of the rocket, the TV channel is switched to the (one) experiment. On the descent or/and the re-entry phase the TV signal is switched to the recovery camera, which will monitor the chute openings. The switching time is determined by the pre-programmed timeline.

As one of the three sources must be connected to the recovery camera, this leaves only two connections available for an experiment. Due to the high demand from experimenters to use the TV transmitter, it is good to bring strong arguments as to why the camera is needed.

During transmission of the TV signal, all video is recorded. A copy of the tapes recordings can be made available to the team post-flight. It is also possible to arrange for the video to be converted into another more convenient format. This must be arranged with SSC staff and for timely delivery of the video, it is best to arrange this in advance.

7.9 Additional Batteries

EuroLaunch recommends using Ni-Metal Hydride (Ni-MH) batteries, and has a lot of experience in using the SAFT brand of batteries on sounding rockets. Other brands may be used, but it is wise to contact the project manager for advice. Lithium batteries should not be used if possible.

Recommended batteries:

Single use: SAFT LSH Series, (Lithium-thionyl chloride).

Rechargeable: SAFT Li-ION, Nickel Cadmium or Nickel Metal Hydride series.

7.10 Additional Umbilicals

7.10.1 Orientation

The orientation of the umbilical shall be in accordance with EuroLaunch instructions.

7.10.2 Electrical Umbilical Provided by Experiment Teams

The module-mounted connector will be mounted on a flange arrangement as shown below. The connector is male and the socket at the module is female.

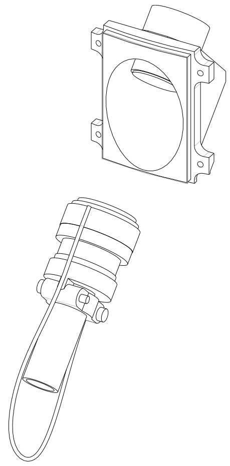


Figure 7-5: Umbilical Connection and Socket

7.10.3 High Power Connections

If a high power connection is required, the experiment designer is free to choose the type of connector. The connector is however subject to EuroLaunch approval. Furthermore EuroLaunch will decide, after discussions with the experiment designer, where and how the connector shall be mounted.

7.10.4 Ground Support Equipment-Umbilical Interface

Payloads are provided with Ground Support Equipment providing charging and hard-line communication. See the cyan EGSE box below.

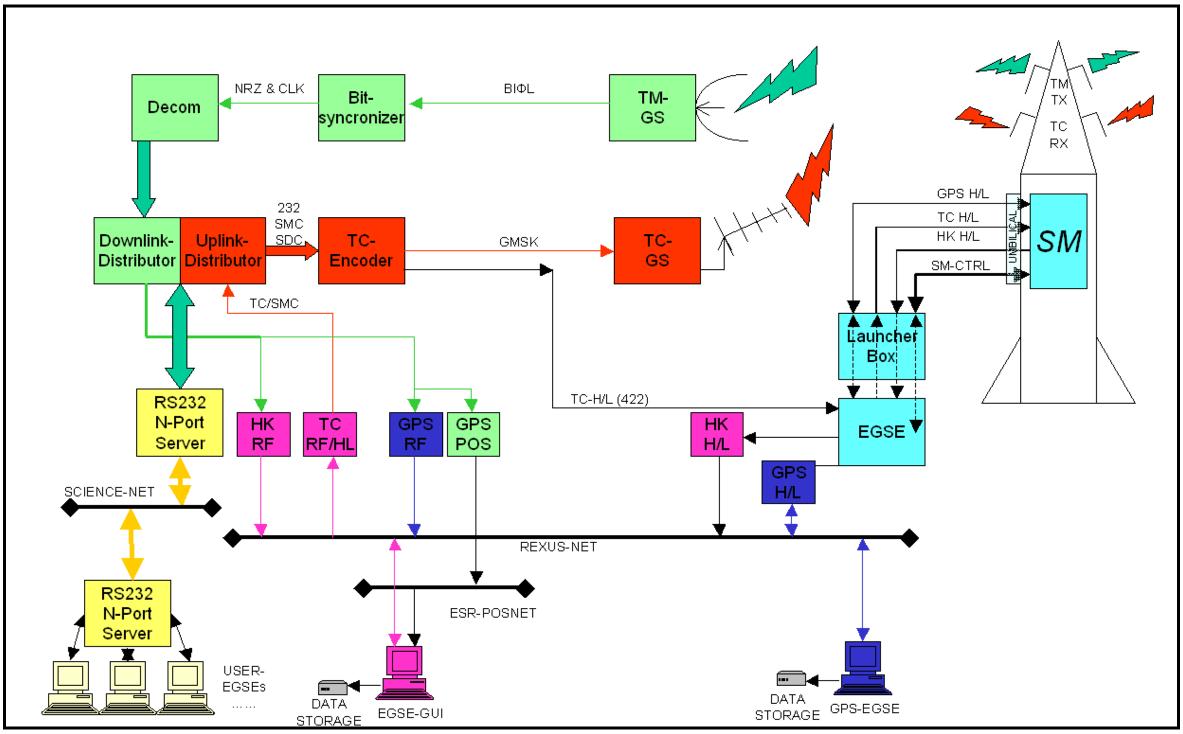


Figure 7-7: Communication Overview

The figure above shows the total data/signal paths of a REXUS rocket ground segment configuration.

7.11 Electro Magnetic Compatibility

The design shall be such that radiated Electromagnetic Interference (EMI) is kept as low as possible: it shall not interfere with other onboard systems. General guidelines of the design are as follows:

- All power supply cables shall be twisted.
- Data cables shall be twisted.
- In case of EMI problems, shielding of the cables shall be considered.

To assure reliable operation the input circuits of the experiment electronics must have filters as shown below.

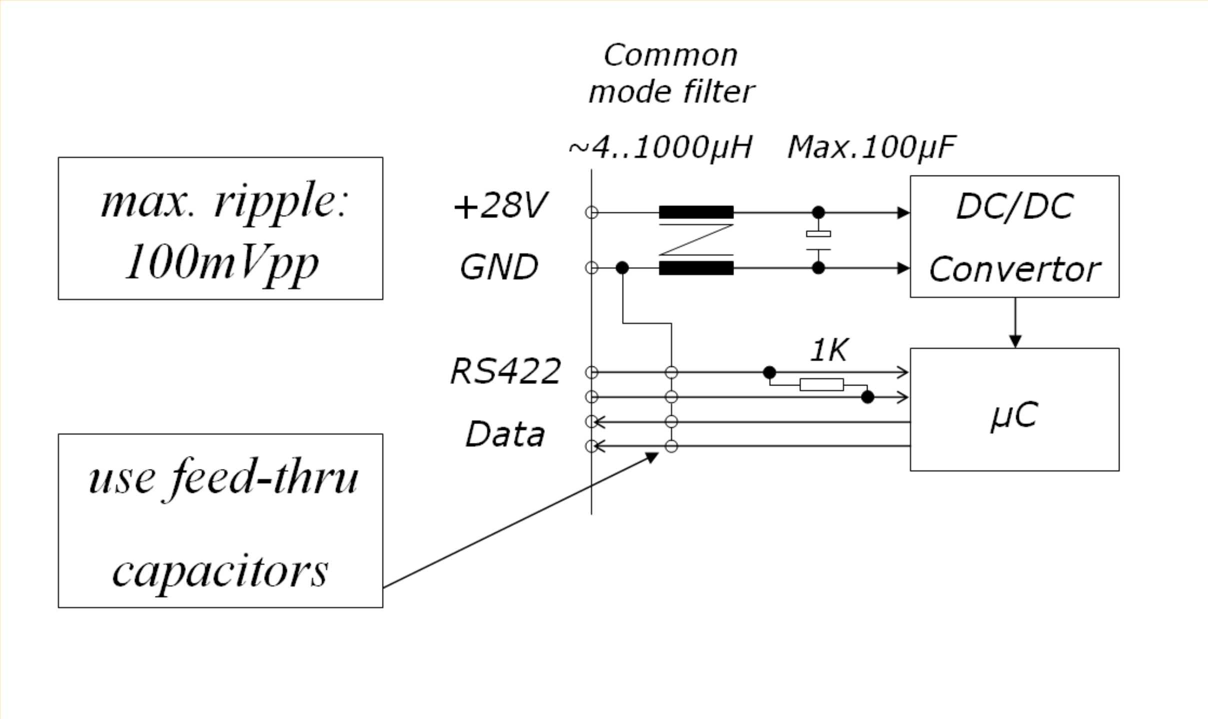


Figure 7-8: EMI Reduction

7.12 System Grounding

There is one “startpoint” inside the SM which connects the 28 V GND to the structure of the rocket.

The external power supply ground (PE) has no galvanic connection to the 28 V circuit.

Note: Avoid connecting the 28 V GND to a second protective earth (PE) terminal on the payload side, e.g. during bench testing.

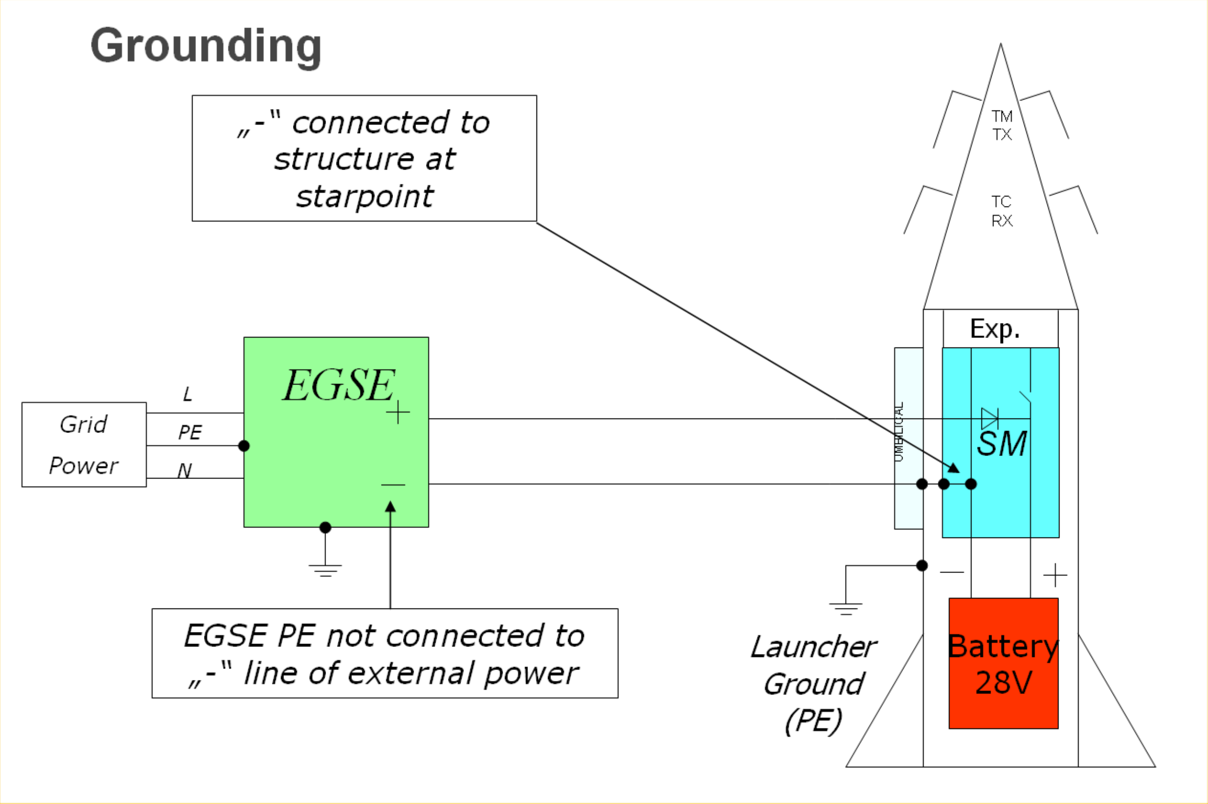


Figure 7-9: Grounding Concept

8 GENERAL DESIGN CONSIDERATIONS

8.1 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.

8.2 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.

8.3 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.

8.4 Redundancy

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

8.5 Mass and Size Considerations

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

8.6 Effectiveness of Testing

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

8.7 Safety

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

9 ENVIRONMENTAL TESTS PERFORMED BY THE EXPERIMENT TEAMS

Environmental tests are performed in order to verify a nominal function of the experiment during the ‘worst case’ environment during countdown, launch and flight.

9.1 Vacuum Test

This test is applicable not only for experiments which will be carried out under vacuum conditions, but also helps to verify that systems, mainly electrical, have nominal performance in the absence of convective cooling. It is the responsibility of the experiment team to perform this test.

Basic Procedure:

- The experiment shall be placed in a vacuum chamber (pressure below 0.5 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 module shall be in a similar mode as during the real ascent of the flight.
- After the functional test / flight sequence has been performed, it is recommended that the experiment is kept operating for an additional 15 minutes, in order to detect any leakages or overheating problems.
- When testing high voltage subsystems (U > 40 V), corona effects shall be searched for in the pressure interval 1-20 mbar.

9.2 Thermal Test

A thermal test is mainly performed in order to verify a nominal function of the experiment during the worst case temperatures that can be experienced during countdown, launch and flight. The heating of the outer structure during ascent is normally not included or tested. It is the responsibility of the experiment team to perform this test.

Basic Procedure:

- The experiment shall be placed in a thermal chamber. The Ground Support Equipment (GSE) shall be connected via the umbilical. The telemetry and telecommand checkout system shall be connected via the interface harness.
- Experiment data shall be supervised and recorded during the test.
- The temperature shall preferably be measured at several places in the experiment.
- Low temperature test:

  Adjust the temperature in the thermal chamber to -10 °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 at normal humidity.

- High temperature test:

  Adjust the temperature in the thermal chamber to +45 °C. When the measured temperatures in the experiment have stabilised, perform a functional test/flight sequence. During the transition from low to high temperature, the experiment shall be operating and data shall be recorded.

9.3 Vibration Test

A vibration test shall be performed to verify the individual experiment can withstand the vibration loads during the launch of REXUS. It is the responsibility of the experiment team to perform this test.

For REXUS, acceptance tests are nominally performed on all experiments. Where an experiment can influence the scientific payload, it is required to perform an acceptance test. Where an experiment can affect flight dynamics, it is required to perform a test on qualification level.

Basic Procedure:

- The experiment shall be mounted on the vibration table with a suitable fixture. Critical parts shall be equipped with accelerometers, in order to track the response curves.
- Functional tests and inspection shall be performed after each axis of vibration.
- Vibration in X, Y and Z-axis should be performed, as specified in below for the Improved Orion vehicle.
- Before and after each load-vibration test a resonance search run at low level (0.25 g, 5 Hz -2000 Hz, 2 octave per minute) shall be performed to evaluate the significant eigenfrequencies of the test items.

According to the NSROC [13] specification for the Improved Orion vehicle the levels for acceptance and qualification have been adapted for the REXUS-Programme as shown in the next two sections.

9.3.1 Acceptance Levels - Vibration

Acceptance levels must be performed on all flight equipment before the experiment will be accepted for flight.

Sinusoidal qualification test levels for axes X, Y and Z

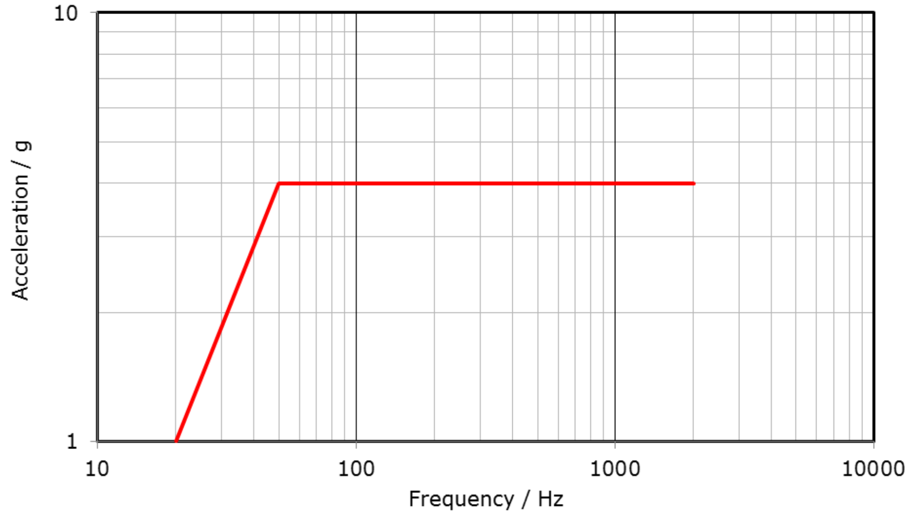


Figure 9-1: REXUS Sinusoidal acceptance test level for all axes

Table 9-1:

Frequency	Level	Sweep Rate	Remark
(10-50) Hz	0.124 m/s (4.87 in/s)	4 octave per minute	
(50-2000) Hz	4.0 g	4 octave per minute	

Random vibration acceptance test levels for axes X, Y and Z

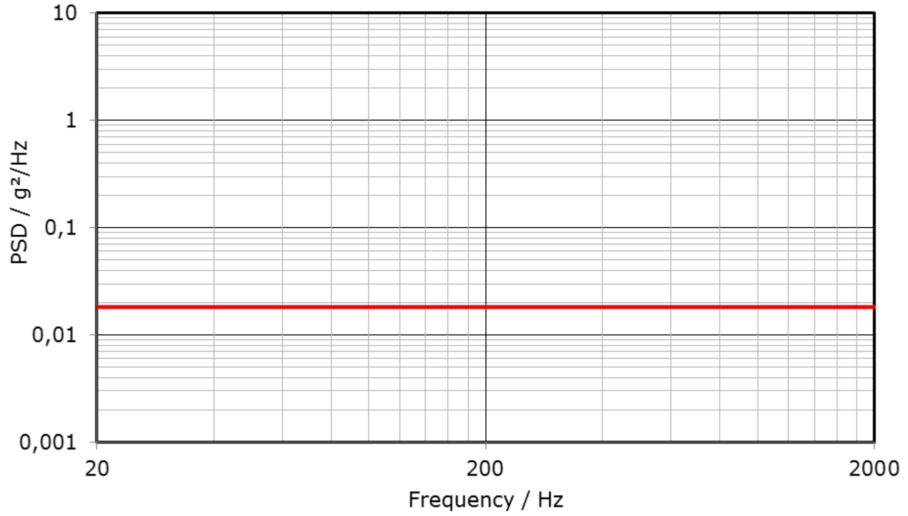


Figure 9-2: REXUS Random acceptance test level for all axes

Table 9-2:

Axes	Frequency	Level	PSD	Remark
Longitudinal (Z)	(20-2000) Hz	6.0 g_{RMS}	0.018 g^2/Hz	
Lateral (X,Y)	(20-2000) Hz	6.0 g_{RMS}	0.018 g^2/Hz	

Duration: 20 s/axis

Remark: For a flight model, EuroLaunch recommends a test for 60 s/axis at acceptance level.

9.3.2 Qualification Levels – Vibration

Take note that qualification levels are not normally performed with flight hardware (unless there is a possible influence on flight dynamics). The levels ensure that the design is adequate and give a high confidence that failure will not occur.

Sinusoidal qualification test levels for axes X, Y and Z

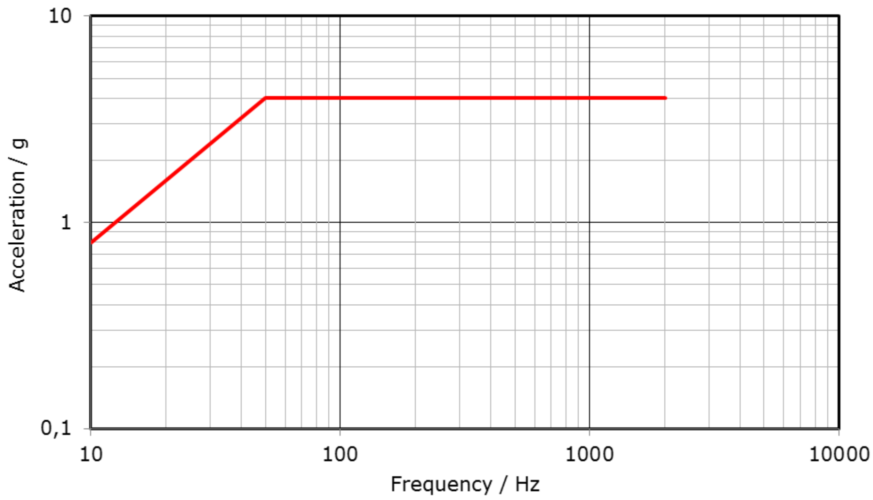


Figure 9-3: REXUS Sinusoidal qualification test level for all axes

Table 9-3:

Frequency	Level	Sweep Rate	Remark
(10-50) Hz	0.124 m/s (4.87 in/s)	4 octave per minute	
(50-2000) Hz	4.0 g	4 octave per minute	

Input to payload during lateral sinusoidal vibration must be limited during first bending mode via dual control accelerometer at CoG of the payload. This is done to avoid exceeding the maximum bending moment at the base of the payload.

Limited Bending Moment: 11300 Nm

Remark: Usually not performed by EuroLaunch

Random vibration qualification test levels for axes X, Y and Z

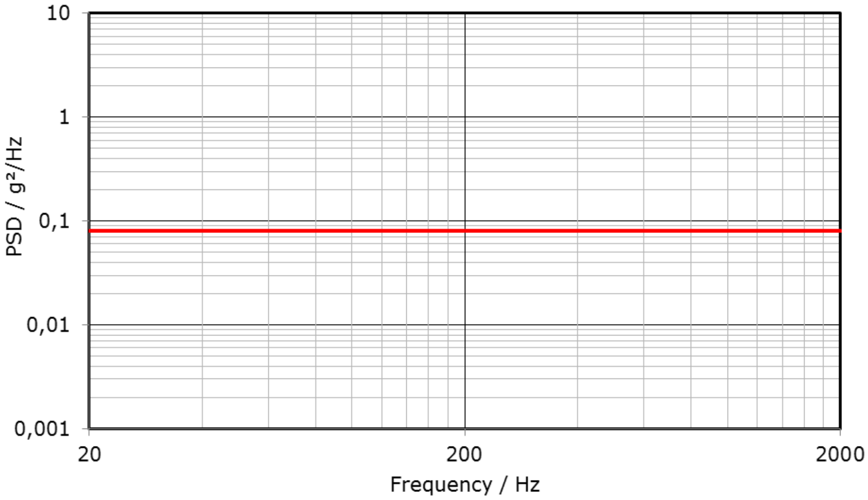


Figure 9-4: REXUS Random qualification test level for all axes

Table 9-4:

Axes	Frequency	Level	PSD	Remark
Longitudinal (Z)	(20-2000) Hz	12.7 g_{RMS}	0.081 g^2/Hz	
Lateral (X,Y)	(20-2000) Hz	12.7 g_{RMS}	0.081 g^2/Hz	

Duration: 20 s/axis

Remark: For a flight model, EuroLaunch recommends a test for 60 s/axis at acceptance level.

10 PRE CAMPAIGN ACTIVITIES

10.1 Esrange Safety Board (ESB)

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

10.2 Campaign Requirements Plan (CRP) Flight Requirements Plan (FRP)

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

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

10.3 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.

10.3.1 Experiment Status by Delivery

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

- Electrical/functional tests
- Vibration tests
- Environmental 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.

10.3.2 Experiment Incoming Inspection

All the mechanical and electrical interfaces of the experiment will be inspected at delivery to the scientific payload integration week, bench test and launch campaign. In general the scientific payload integration week includes only the experiment modules, whereas the bench test includes the experiment modules, the service system, and where required for payload operation, the recovery system. The tests performed are very similar, but after the bench test no further corrections can be made to the experiment modules.

10.4 Payload Assembly and Integration Tests

This chapter deals with the assembly of the payload and the tests conducted on the whole integrated payload. It also defines the requirements regarding the status of the experiment modules upon delivery to the payload Assembly and Integration Tests (AIT).

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

At the start of the payload integration tests, all experiments comprising the REXUS payload must be made available to EuroLaunch. During some of the tests being performed, technical personnel trained to handle the experiment and ground support equipment shall accompany the experiment. During the AIT, the experiment must be in flight configuration. If the use of dummies is required, this must be agreed by EuroLaunch.

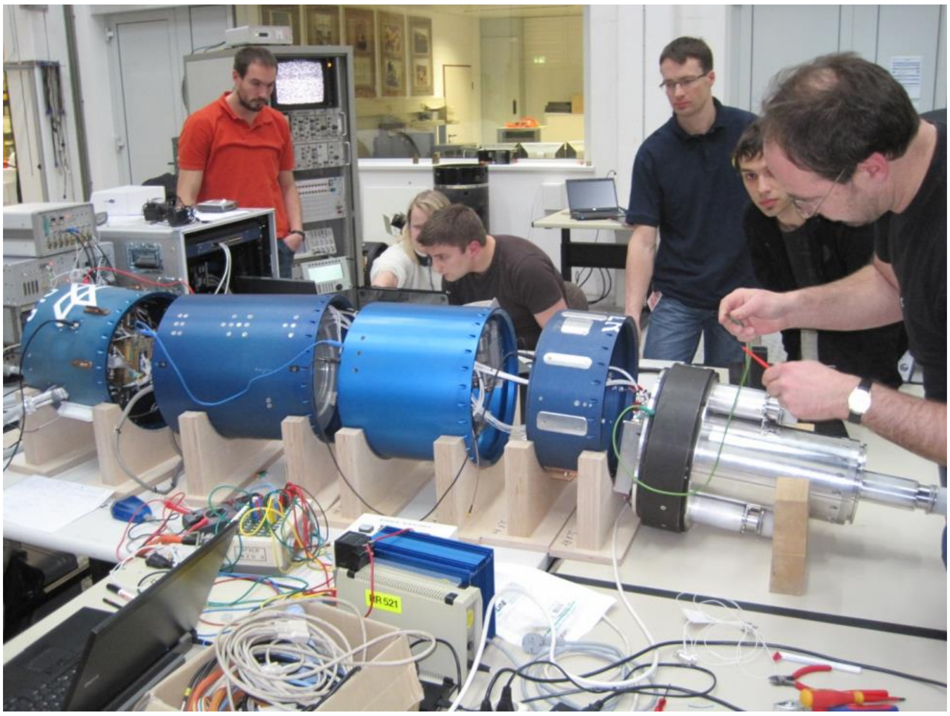


Figure 10-1: System Bench Test (REXUS-7 at DLR MORABA)

10.4.1 Payload Assembly

The experiments, other modules and subsystems will be mated to the payload in due order. All the mechanical and electrical interfaces will be checked and tested systematically during the assembly.

10.4.2 Electrical Interface Test

The electrical interface test will verify the compatibility of the interfaces and the functioning of the hardware concerned. Interface compatibility for critical signals, protection automatisms and voltage regulations will be checked systematically during assembly. Detailed procedures must be defined for each individual module or subsystem.

This test is performed by EuroLaunch.

10.4.3 System Electrical Test 1 and EMI-Check

These tests shall be performed with all flight hardware electrically operational and as far as possible, operating in flight configuration.

Telemetry transmission will be done first via cable and then via the telemetry transmitter. All signals will be verified at the telemetry ground station. All subsystems shall be monitored via the dedicated Ground Support Equipment (GSE).

These tests are performed by EuroLaunch together with a representative from each student experiment team.

10.4.4 Flight Simulation Test

This test shall be performed with the payload in flight configuration, as far as possible. The test procedure shall include the countdown procedure list and follow the nominal countdown timetable.

This test is performed by EuroLaunch together with a representative from each student experiment team.

It is important that any modifications made to hardware or software, 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. All corrections after the FST shall be documented and reported to EuroLaunch.

Basic Procedure

- The experiment payload shall be integrated and in flight configuration. The Ground Support Equipment (GSE) shall be connected via the umbilical. The telemetry and telecommand checkout system shall be connected via the interface harness.
- Module data shall be supervised and recorded during the test.
- A nominal realistic countdown procedure shall be followed, including at least one payload checkout. Switching between external and internal power shall be done at the nominal time (T-2 minutes).

- At lift-off, the umbilical shall be disconnected and the payload shall be controlled via TM/TC. The experiment sequence shall be as close as possible to the flight sequence.

It is also useful to perform a test with "unexpected" performance and to practise possible countermeasures.

Examples of abnormal occurrences are:

- Interruption in internal power supply.
- Reset of onboard processor.
- Malfunction of subsystems e.g. illumination is suddenly switched off.

10.4.5 Mass Properties Measurement and Balancing

Following the above testing the integrated payload is shipped to Kista, Sweden for the mass properties and balancing where the mass properties of the payload are measured and aligned. The following measurements are performed by EuroLaunch before sending the payload to Esrange:

- Payload Mass
- Centre of gravity
- Spin (Tip Indicator Run-Out, Static and Dynamic Imbalance
- Moments of inertia

During the balancing, the payload is subject to ~3 Hz spin for several minutes. Experiment teams are not required at the spin and balance.

10.4.6 Bend Test

A bend test is normally not performed. However, if such a test is necessary, the payload will be attached at the payload/rocket motor interface and a force will be applied perpendicular to the structure, giving rise to a torque on the payload/rocket motor interface. The deflection will be measured at three positions along the payload body.

These tests are performed by EuroLaunch, if needed.

10.4.7 Payload Vibration Test

A vibration test of the complete REXUS payload is normally not performed.

11 LAUNCH CAMPAIGN

The duration of a REXUS launch campaign is approximately 12 days in spring. This does not allow any time for errors or delays, so it is important to be well prepared.

Each morning, there is a status meeting in one of the Esrange conference rooms, where the upcoming activities are discussed. An example campaign schedule is shown below.

Table 11-1: Example campaign schedule

Date	**Action**
Day 1	Start of campaign Safety briefing
Day 1-3	Preparation of experiment modules, service systems and recovery systems
Day 4-6	Payload assembly Flight Simulation Tests (FST) Mating payloads with motors
Day 6	Flight Readiness Review (FRR)
Day 7	Rocket 1 roll out to launcher and test countdown
Day 8	Pre-flight meeting Rocket 1 Hot countdown
Day 9	Rocket 2 roll out to launcher and test countdown
Day 10	Pre-flight meeting Rocket 2 Hot countdown
Day 11-12	Reserve days

11.1 Description of Esrange Space Center

All the necessary information for a user of Esrange can be found at: http://www.sscspace.com/products-services/rocket-balloon-services/launch-services-esc.

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

11.2 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.

11.2.1 Additional Esrange Safety Board Meetings

If a safety issue arises during a campaign, there might be a need for an extra Safety Board meeting before a launch is possible.

11.2.2 Radio Silence

During arming of the rocket motors, it is strictly forbidden to transmit or to do any power-switching of an experiment or its subsystems.

11.3 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, they should make a detailed plan of how they will work, who should do what (team member, Esrange staff, etc.) and how much time is needed to do everything.

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

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

11.3.1 Equipment

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

11.4 Assembly of Rockets and Payloads

11.4.1 Assembly of Rockets

All assembly and preparation activities for the rockets are the responsibility of the EuroLaunch launch team.

11.4.2 Assembly and Checkout of Payloads

Payload assembly and preparations are conducted by the REXUS project manager, together with EuroLaunch staff. Working space in the launching area will be allocated by Esrange.

11.5 Flight Simulation Tests (FST)

The payload will be ready for the final Flight Simulation Tests (FST) after successful results in the checkouts. Umbilicals shall be connected and the payload shall preferably be in a vertical position. Each module shall be monitored and controlled by the module ground support equipment.

When all modules are operating nominally, a short countdown and flight sequence will be performed. This test can be repeated many times if found necessary or desirable to do so.

All telemetry and telecommand signals will be recorded in the telemetry ground station during the test.

At a minimum, two tests will be performed in preparation for the countdowns. One with lift-off signal and one without the lift-off signal will be given by removing the umbilical.

During these tests, the experiment operators will be in the Science Centre and should treat the tests as not only a test of the experiment but also of the procedures and behaviour that should be conducted during countdowns. Not only does this help in preparing for launch but also makes the testing easier and less stressful for everyone involved.

Consider for your design that this test can be operated with ease (and without access) and will not have a negative effect on your experiment. In particular, think about how the signals given to your experiment (Lift-off, SOE etc.) will affect your performance during the test and before flight.

11.6 Flight Acceptance Review (FAR)

Upon completion of payload integration tests described in chapter 10.4, the Flight Acceptance Review (FAR) shall be held.

The results from the tests shall be reviewed and problems will be discussed.

The objective of the FAR is to obtain system acceptance and to authorise the start of the campaign. If the FAR is unsuccessful due to failure of any experiment or subsystem, an agreement shall be reached, whether or not to proceed on schedule.

11.7 Flight Readiness Review (FRR)

The Flight Readiness Review (FRR) is conducted by the EuroLaunch co-ordinator of the campaign, after completion of experiment module preparation, payload integration and test, payload integration on launcher, GSE installation in the blockhouse, payload checkout, ground support stations checkout and test countdown.

The purpose of the meeting is:

- to authorise the start of the countdown phase, i.e. the launch.
- to ensure that all ground and payload service systems essential for a successful launch, flight and recovery are operating nominally. For this, the person responsible for each system shall give a status report at the meeting.
- to ensure that all experiments are ready for the flight. For this, each appointed experiment module manager shall give a status report at the meeting. In addition, the experiment team leaders are requested to state the operative status of the experiments.
- 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 applicable during the countdown phase (canteen hours, information systems etc.).

11.8 Test Countdown

After the Flight Readiness Review, the rocket and payload will be rolled out to the launcher and mounted. Except for extraordinary cases (time constraints coupled with confidence in experiment performance), a test-countdown will be performed.

For the experimenter, the test countdown will be run in much the same way as the Flight Simulation Tests. However, there are two important differences. Please take note and consider how they may affect your experiment.

- no lift-off signal will be given (umbilical remains connected)
- this is normally a full-countdown test

Think about how your experiment will respond to being given other signals without the lift-off signal.

As this will be as close to a full countdown as is possible without launching the rocket, this is perhaps the most important opportunity to determine that the full experiment operation procedure is satisfactory. The countdown procedure should be finalized during the flight simulation tests (in fact the best way to do this is before via practice (without signals), procedure review and if possible simulation).

At this stage in the campaign, experimenters often find themselves stressed, but it is important to remain calm. Due to the length of the test-countdown, it is important to treat it as closely as possible to a serious launch. Please see below in the countdown section for the experimenters’ roles in this and consider your actions during all tests.

12 COUNTDOWN AND LAUNCH

12.1 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 days allocated during the campaign week. Experiment teams should be prepared to hand over the operation of their experiment to someone else if the launch is postponed to a later opportunity.

12.2 Launch Conditions

Launch period:	Usually first two weeks in March
Launch window:	Usually 05.00 – 16.00 LT
Visibility:	Sufficient for helicopter flight

12.3 Safety in the Launch Area

Esrange has the overall responsibility for safety and has the Veto right in all safety issues during all activities within the Esrange base area.

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

No one is allowed on the launch pad during countdown without the permission of the Operations officer.

12.4 Personnel during the Launch

12.4.1 Esrange Project Manager - PM

Esrange appoints a Project Manager for every project that is planned to be carried out from Esrange. The Project Manager is the Esrange contact for the range user. The user is responsible for coordination and delegation of responsibilities of campaign activities, safety matters, campaign planning, co-ordination, countdown procedure, and operations at the range.

12.4.2 Payload Engineer - PE

The Payload Engineer handles the rocket service system and switches the experiments on and off.

12.4.3 Project Scientist - SCI

The Project Scientist:

- Acts as a focal point for the experiment teams during countdown.

- Relays questions between the experiment teams and the Operations Officer, via WT or telephone.
- Informs the Operations Officer and the Payload Manager about the status of the experiments.
- Sends a Go or NoGo signal to the Operations Officer.

12.4.4 Operations Officer - OP

The Operations Officer handles the countdown and is the focal point for all activities. Communication take places over the com loop voice link, the Go / NoGo-system and the PA system. During the countdown phase, important countdown information is displayed on PA video monitors at various locations around Esrange.

12.4.5 Telemetry personnel - TM

Together the Esrange and DLR telemetry personnel handle the receiving, transmitting and recording equipment during preparation and launch.

12.4.6 Launch Officer / Vehicle - VEH

The Launch Officer, whose call sign is ‘Vehicle’, handles all personnel and equipment related to the launch. He is also responsible for safety on the launch pad.

12.4.7 Safety Officer - SAF

The safety for third parties is the major concern of the safety officer. He issues permission for individuals to visit the launching area during CD. This is shown by the wearing of a dedicated badge: red badges for temporary visits and green badges for permanent personnel in the blockhouse during CD.

12.5 Countdown and Launch

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

The nominal lift off time is planned for between 0500 and 1600 LT. The launch window is determined by the payload preparation time, hold requirements and the time of daylight. The maximum launch window duration is 11 hours.

The decision to start the countdown is taken at a weather briefing immediately before the planned start of countdown. This decision is based on dedicated weather forecasts and wind data obtained by a meteorological balloon released from Esrange shortly before the flight. 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. Experiments should be designed to handle not only the flight but also 3 hours of CD plus some possible holds.

The experiment teams’ ground equipment will be situated in the scientific office in the main building.

12.5.1 CD List

The schedule below indicates standard countdown actions relative to launch (T = 0). The final CD list will be issued during the pre-flight meeting.

Time (H:M)	Action
-2H30	FIRST HIGH ALTITUDE BALLOON
-1H35	DECISION TO START COUNTDOWN
-1H20	START OF COUNTDOWN
	CHECK LIGHTS AND COMMUNICATION
-1H15	END OF RADIO SILENCE
	SWITCH ON PAYLOAD TRANSMITTER AND TRANSPONDER
	AND START HORIZONTAL P/L CHECK
-1H	PAYLOAD TEST COMPLETED
	PAYLOAD TRANSMITTER OFF
	RADIO SILENCE IN THE LAUNCH AREA
	CHECK FIRING LINE LEDEX SYSTEM, ARM AND ELEVATE VEHICLE, CLEAR PAD
-45M	SIREN ON
-20M	LEDEX SYSTEM CHECKED, VEHICLE IS ARMED AND ELEVATED, PAD IS CLEAR
-15M	END OF RADIO SILENCE
	SWITCH ON PAYLOAD
-10M	PAYLOAD TEST COMPLETED
	PAYLOAD TRANSMITTER OFF, RADIO SILENCE IN THE LAUNCH AREA
	END OF RADIO SILENCE
	AUTHORIZATION TO SWITCH ON PAYLOAD
-5M	ARM LEDEX FIRING LINE
-3M30	SEND QUESTION LIGHTS
-3M	VOICE COUNT EVERY MINUTE
	FIRING LINE LEDEX ARMED
	PAYLOAD ON INTERNAL
-1M45	TAPE RECORDERS ON
-1M	VOICE COUNT EVERY 10 SECONDS
-40S	SEND ANSWER LIGHT
-25S	AUTHORIZE LAUNCHING
-10S	VOICE COUNT EVERY SECOND
0	***** LIFT-OFF *****
+10S	VOICE COUNT EVERY 10 SECONDS
+1M	VOICE COUNT EVERY MINUTE UNTIL +6 M

12.6 Communication Discipline

Observe the following regarding all communication.

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

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

Call sign during preparation

Functional names	Function in the rocket processes
Operation	Operations Officer
Launch Officer	Launch Officer on launch pad
Vehicle	Responsible for all rocket systems
Safety	Safety Officer
TM	Telemetry station - Esrange or DLR
Scientist	Responsible for Scientific Payload
Payload	Payload Manager

12.7 Science Center Operations and Communication

Please note, this information is subject to change depending on launch requirements and operational decisions.

Experiment teams will be located in the Science Center during the Flight Simulation Test, Test Countdown and Hot Countdown (Launch). Their point of communication will be the Project Scientist (SCI) [call-sign: Scientist or Science]. All communications from the experimenter will go through this focal point (see above descriptions for more information). This requires that one member from each team is the communication point for the Project Scientist. It must be clear which person from each experiment fulfils this role. They must be located where they can always attract the attention of the Project Scientist (line-of-sight is a requirement) but also where they can receive information non-disruptively from team members operating experiment ground-stations.

The communication between the point of contact team members and the Project Scientist will be arranged during the launch week. If you have queries or would like to review practices, this can be done before-hand. A good time to consider your arrangements is during the bench tests of the payload where you will first trial the experiment with the service system.

During countdown, all team members (and any observing personnel) must keep noise-levels to a reasonable level that neither distracts nor disrupts experiment team operations. This includes not breaking line-of-sight between the project scientist and the point of communication for teams, not blocking anyone’s vision of the countdown clock, minimizing movement within the science centre, and no horse-play (being silly).

At -20 minutes, the doors will be closed and people will no longer be able to enter or leave the building, make sure your team is prepared for this eventuality. At this point, experimenters must “sit down, be quiet and be still”.

Experimenters must keep a careful eye on their own experiments and consider any risks that could affect their experiments. If something occurs that endangers the success of their experiments, contact the Scientific Officer quickly and clearly so that the issue can be resolved. If issues can be foreseen, please inform the Project Scientist before but do not forget to maintain a vigilant watch over any actions that may affect your experiment in a negative way as it may not always be possible for the Project Scientist to monitor every experiment.

Please see the Communication Discipline section above for “pro-words” that can be used to maintain professionalism and clarity in communication. The Project Scientist will ensure during campaign that teams are communicating clearly but it helps greatly when the experiment teams are prepared and ready to work on improving communication.

After the launch of the rocket, many teams still have work to do and must monitor their experiments. Although the urge to celebrate will be strong, everyone in the science center must consider possible other work and how their actions can affect possible events (the unforeseen included).

12.8 Recovery

The helicopters are equipped with direction finders for the payload beacon signal and can also be equipped with a payload TM receiver for data reception of the payload’s GPS position.

During the flight, the payload trajectory will be tracked by means of the transmitted GPS-data and by use of a slant range system in the TM ground stations.

During the descent of the payload, the prediction on the impact point co-ordinates is reported to the helicopters from Esrange. The helicopters start their operation to locate the payload immediately after the impact. At the impact site, the helicopter crew disassembles time critical samples from the payload for the quickest possible return to the Esrange laboratories. The recovery crew can also interact with the experiment modules (e.g. inserting disarm plugs), if this is required it should be clearly included in the SED and again on an illustrated recovery sheet as well as discussed with the crew during the campaign. If early recovery is required, a second helicopter is acquired to carry the payload back to the range.

The whole operation is normally completed within two hours of the launch.

Only personnel crucial for the mission are permitted to join the recovery operation and must have permission from Operations Officer to do so.

13 POST LAUNCH ACTIVITIES

13.1 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.

13.2 Disassembly of the payload

The day after launch, disassembly and packing will start. It is up to the owner of the experiment to decide about transportation of their experiment and equipment. All items left at Esrange will be thrown away, and destruction costs for hazardous items may be charged to the experiment teams. All materials left behind should be clearly labelled to determine the best disposal method.

13.3 Campaign report

Esrange will issue a campaign report within one month.

14 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 REXUS 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 these concerns.

14.1 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.

14.2 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.

14.3 Additional Quality Topics

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

14.3.1 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.

14.3.2 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.

14.3.3 Re-used Items

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

14.3.4 Availability and Maintainability

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

14.3.5 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.

14.4 Personnel Safety

The REXUS 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 www.av.se/inenglish/lawandjustice/workact

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

14.5 Safety at Esrange Space Center

The safety regulations that apply at Esrange may be found in the Esrange Space Center Safety Manual [4]. It is a requirement that all personnel participating in the campaign shall have read the safety regulations prior to their arrival at Esrange Space Center.

A COORDINATE SYSTEM DEFINITION

This chapter will give an overview of the coordinate systems that are used for the REXUS 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 coordinate systems used.

Table A-1: Coordinate Systems

ECI	Earth Centred Inertial
ECEF	Earth Centred, Earth Fixed
WGS84	World Geodetic System 1984
LTC	Local Tangent Coordinate System
VCVF	Vehicle Carried Vertical Frame

A.1 Earth Centered Inertial System (ECI)

This system originates at the centre of the Earth, as the name implies, and is designated with the letters x_{ECI}, y_{ECI} and z_{ECI}. The fundamental plane is the Earth equator. The x_{ECI}-axis points towards the vernal equinox. The y_{ECI}-axis points to the North Pole. This coordinate system is not rotating. It is assumed to be inertially fixed in space, see Figure A-14-1.

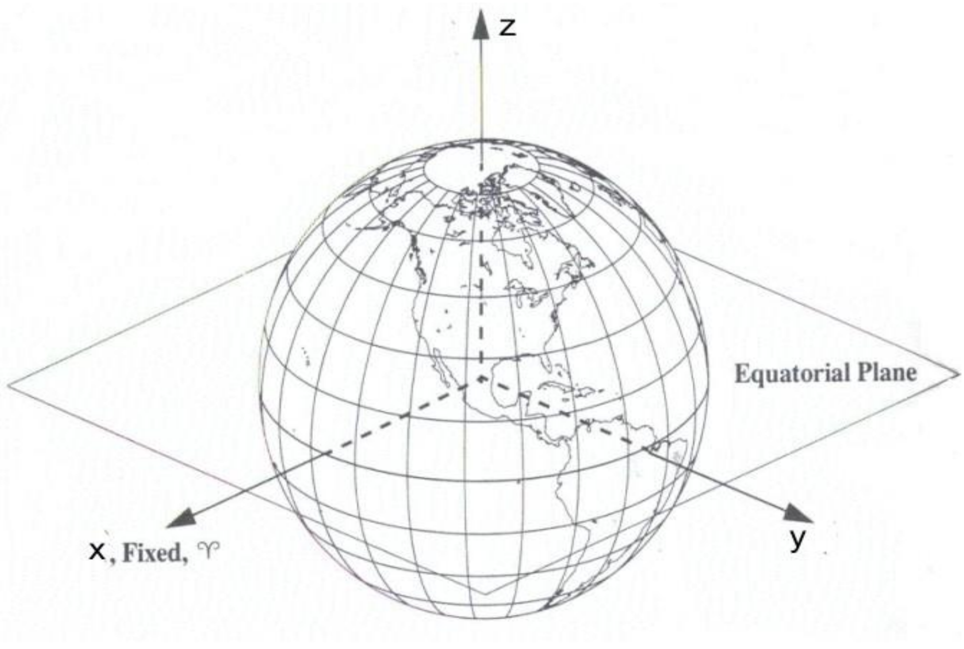


Figure A-14-1: Earth-Centered Inertial System (ECI) [Ref. [12]]

A position in the ECI-System can be defined in **Cartesian coordinates** (x_{ECI}, y_{ECI}, z_{ECI}) or in polar coordinates (Right Ascension α, Declination δ, geocentric distance r) [Ref. [11]].

The transformation between the coordinates is done with following equation:

$$\vec{r} = \begin{pmatrix} x \\ y \\ z \end{pmatrix} = r \cdot \begin{pmatrix} \cos\delta \cdot \cos\alpha \\ \cos\delta \cdot \sin\alpha \\ \sin\delta \end{pmatrix}$$ Eq. A-1 [Ref. [11]]

$$\alpha = \arctan\frac{y}{x}$$ Eq. A-2 [Ref. [11]]

$$\delta = \arctan\frac{z}{\sqrt{x^2 + y^2}}$$ Eq. A-3 [Ref. [11]]

$$r = \sqrt{x^2 + y^2 + z^2}$$ Eq. A-4 [Ref. [11]]

As with the heliocentric coordinate system, the equinox and plane of the equator move very slightly over time, so a truly inertial reference frame for the Earth is impossible to realize. An inertial coordinate system can almost be achieved, if it refers to a particular epoch and it is specified how the vectors are transformed to and from this time. Calculations that transform vectors to and from this epoch are usually called Reduction Formulas.

The **ECI reference system** for the REXUS data is the J2000.0 system. This has been used since 1984. The x_{ECI}-axis points in the direction of the mean vernal equinox and the z_{ECI}-axis points in the direction of the mean rotation axis of the Earth on January 1, 2000 at 12:00:00:00 TDB which corresponds to a Julian date JD 2451545.0.

A.2 Earth Centered, Earth Fixed (ECEF)

If the geocentric coordinate system rotates with the Earth, it results in the **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 is rotating.

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

$$\vec{r}_{ECEF} = \begin{pmatrix} x_{ECEF} \\ y_{ECEF} \\ z_{ECEF} \end{pmatrix} = d \cdot \begin{pmatrix} \cos\varphi_{gc} \cdot \cos\theta \\ \cos\varphi_{gc} \cdot \sin\theta \\ \sin\varphi_{gc} \end{pmatrix}$$ Eq. A-5

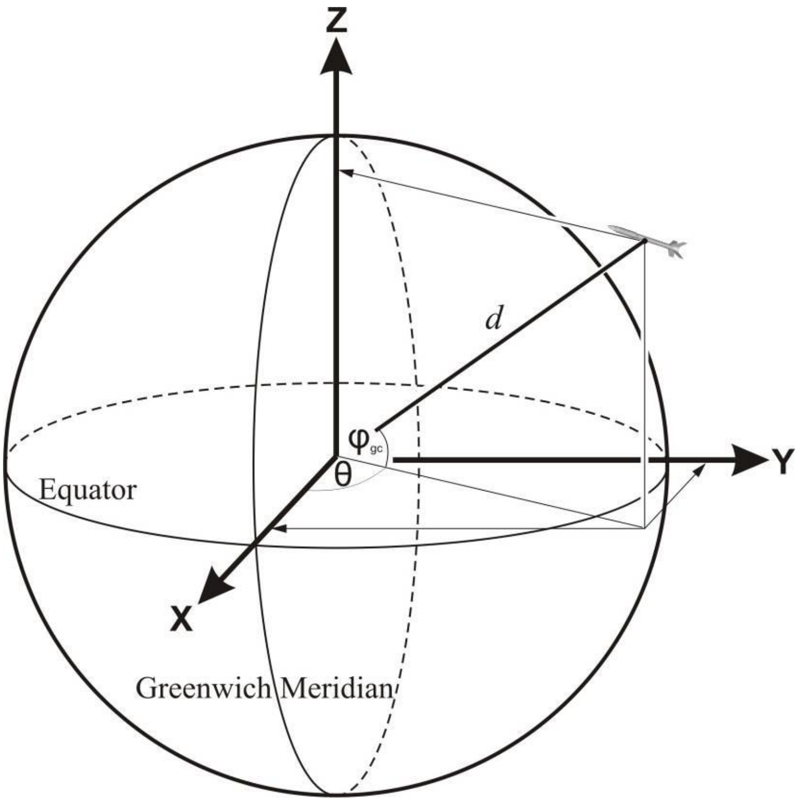


Figure A-14-2: ECEF Coordinate System

A.3 World Geodetic System 1984 (WGS84)

The global reference system **World Geodetic System 1984** (WGS84) is used for the REXUS GPS position data.

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

$$f_\oplus = \frac{R_\oplus - R_{Pole}}{R_\oplus}$$ Eq. A-6 [Ref. [11]]

The WGS84 Ellipsoid has a flattening of $f_\oplus = 1/_{298.257223563}$ and the equator radius $R_\oplus$ is 6378137 m [Ref. [11]]. The Earth's eccentricity $e_\oplus$ can be calculated with the following equation.

$$e_\oplus = \sqrt{1-(1-f_\oplus)^2}$$ Eq. A-7 [Ref. [11]]

The position of the Rocket is given in geodetic coordinates relative to the reference ellipsoid. The **geodetic longitude θ** corresponds to the geocentric longitude. Unlike the geocentric latitude φ_{gc}, which is the inclination of the position vector to the equatorial plane, the geodetic latitude φ_{gd} describes the angle between the equatorial plane and the normal to the reference ellipsoid. It is positive to the North and negative to the South.

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

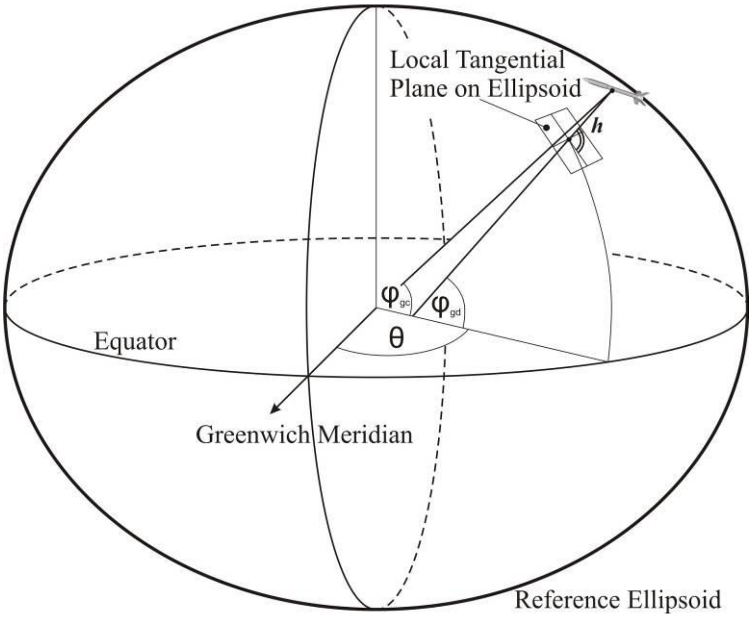


Figure A-14-3: WGS84 Reference Ellipsoid

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

A.4 Local Tangential Coordinate System (LTC)

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

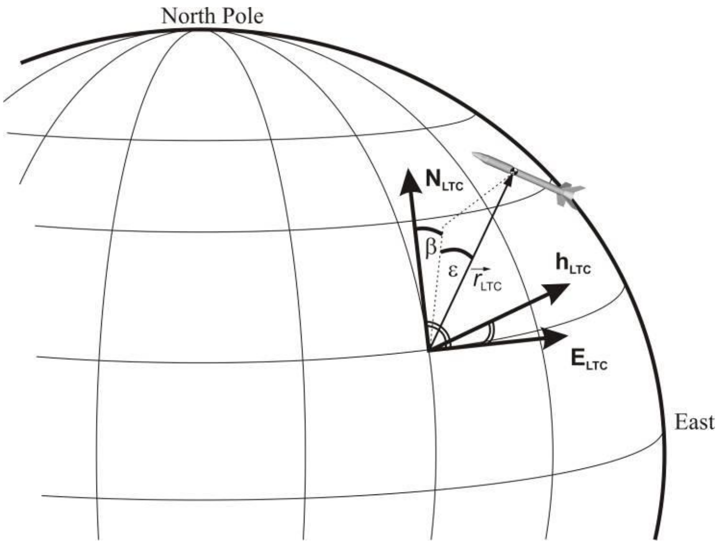


Figure A-14-4: Local Tangent Coordinate System (LTC)

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

$$\beta = \arctan\left(\frac{east_{LTC}}{north_{LTC}}\right) \qquad \text{Eq. A-8}$$

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

$$\varepsilon = \arctan\left(\frac{h_{LTC}}{\sqrt{east_{LTC}^2 + north_{LTC}^2}}\right) \qquad \text{Eq. A-9}$$

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

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

The distance d between the rocket and the observation location is also called slant range.

A.5 Vehicle Carried Vertical Frame (VCVF)

This system moves with the rocket and the origin is the centre of gravity of the rocket. The velocity and acceleration that are calculated with the GPS data are usually also given in this coordinate system.

The N_{VCVF}-axis points to the local North and the E_{VCVF}-axis to the local East. The Z_{VCVF}-axis builds a right hand system and is perpendicular to the local plane. Only the equator it is oriented exactly to the Earth's centre.

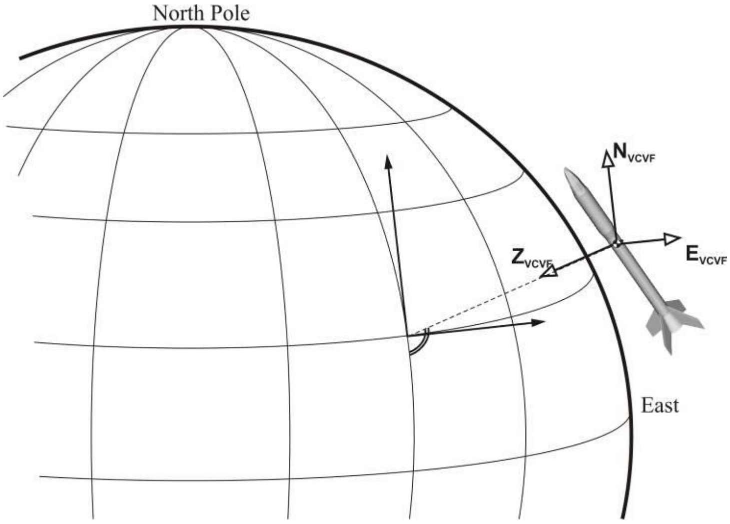


Figure A-14-5: Vehicle Carried Vertical Frame

As already mentioned, velocity is given in this coordinate system and the Flight Path Angle γ and the Heading Angle β can directly calculated with the following equations.

$$\gamma = atn\left(\frac{-v_z}{\sqrt{v_{north}^2 + v_{east}^2}}\right)$$ Eq. 14-11

$$\beta = atn\left(\frac{v_{east}}{v_{north}}\right)$$ Eq. 14-12

The next figure shows the orientation of the angles:

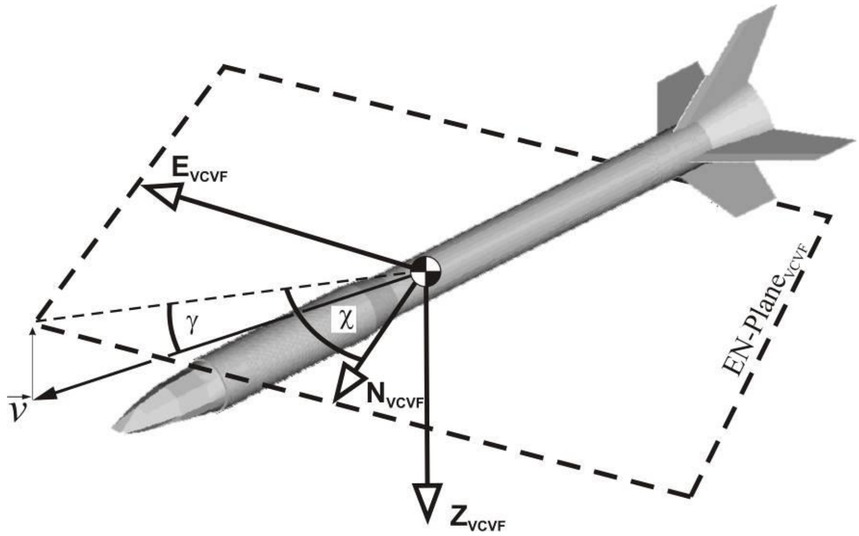


Figure A-14-6: Flight Path Angle and Heading Angle

B APPENDIX B

Esrange Safety and Security Compliance Confirmation - Rocket

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, EUA00-E538) 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.

Project Scientist is appointed by the customer and responsible for the scientific mission.

Payload Engineer is appointed by the customer and responsible for the technical function of the payload.

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 Swedish and foreign authorities during **countdown, flight and recovery**.
Safety Officer (SO) is responsible for flight safety during **countdown and flight**. He/she will also control access to the launch areas and issue access permit badges where applicable.
Launch Officer (LO) is responsible for the ground safety in the launch areas during **countdown** and also all work with explosives at Esrange.
Flight Control Officer (FCO) is appointed when a flight includes a flight termination system. He/she decides to **abort a flight** if the vehicle deviates from a safe trajectory.

We accept the content of the text above. Date ……………………………………

………………………..…………………..	…………………………………………..
Customer Mission Manager/Project Manager	Esrange Project Manager