Guidelines for Student Experiment Documentation

SED Guidelines

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The REXUS/BEXUS programme is realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Agency (SNSA). The Swedish share of the payload has been made available to students from other European countries through a collaboration with the European Space Agency (ESA).

EuroLaunch, a cooperation between the Swedish Space Corporation (SSC) and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operations of the launch vehicles. Experts from DLR, ZARM, SSC and ESA provide technical support to the student teams throughout the project.

CHANGE RECORD

Version	Date	Changed chapters	Remarks
0	18-12-2008	New Version	
0.1	11-02-2009	Chap.2,3,4,6	J. Heinemann
0.2	12-02-2009	Chap. 6,7	H. Hellmann
2.0	17-11-2009	All chapters	H. Page, M. Siegl
2.1	19-11-2009	Chap. 6.1	M. Pinzer
2.2	24-11-2009	All chapters	H. Hellmann
2.3	02-12-2009	Front page PREFACE Chap.1,3,4,7,8 Appendix A	M. Fittock A Stamminger
2.4	09-12-2009	All chapters	H. Page, M. Siegl, K. Debeule
2.5	09-12-2009	All chapters	M. Fittock
3.0	14-12-2010	All chapters	M. Siegl, M. Fittock, H. Page, A. Lambert
4.0	06-12-2012	All chapters	A. Kinnaird, N. Callens, M. Fittock
5.0	12-11-2013	Minor changes in all chapters, Preface, 1.5.1, 2.6, 2.7, 3.3.1, 3.4, 4.3, 5.2, 6.4, 7, 8, A,	N. Newie
5.1	11-06-2014	List of figures A list of all figures included in the document shall be provided. **LIST OF TABLES** A list of all tables included in the document shall be provided. Preface, 2.3, 3.5.1, 4.2.2, 4.5, 5.1, 6.1.5, 6.1.6, 8.1, Appendix A – Experiment Reviews	A. Kinnaird N. Newie
5.2	14-12-2015	Minor changes in all chapters, 2, 3, 4.6, 6.4, Appendix D	A. Kinnaird, M. Nürmberger K. Debeule

			S. Mawn
6-0	08-10-2018	Minor changes in all chapters, File naming, SED Version, 2, 2.5, 3.4, 3.5.1, 3.5.2, 4.3, 4.5, 4.6, 4.7, 5.1, 5.3, 6.1.1, 6.2, 6.3, 6.4.1 deleted, 6.4.2 deleted, 6.4.3 deleted, 7.4 added, Appendix A – Experiment Reviews	A. Kinnaird, V. Botti
6-1	05-06-2019	Include Table 6-4 Flight Req.	K. Schüttauf, R. Avila
6-2	22-04-2020	Minor changes in chapter 1, 2, 3, 6. Appendix A – Experiment Reviews	A. Frenea-Schmidt, A. Kinnaird, K. Schüttauf A. Lacombe
6-3	25-08-2023	*Fixed broken and missing cross-references for images and tables. *General spelling error and readability corrections and changes for sections; Preface, Experiment Phases, 2, 3.1, 3.2, 3.5.1, 4, 4.1, 4.2, 4.2.1, 4.2.2, 4.4, 4.5, 5.1, 5.2, 5.3, 6.1, 6.1.2, 6.1.3, 6.1.4, 6.1.6, 6.3, 7.2, 8.3, Appendix A *Updated Sections; Cover page: Dates & Cycle numbers Removed Abstract under change record 2.3: Clarification added 5.1: Note Added 5.2: More examples and elaborations added 6.1: Making clear that EuroLaunch refers to SSC/MORABA 6.1.4: Added a table to replace a list of examples. 6.3: Added a table for the BEXUS timeline 8.2: Reworked with working links and IEEE structure. Updated the outdated references.	J. Gorissen M. Nürmberger A. Frenea-Schmidt M. Snäll

6-4	14-10-2024	1.4, 3.2, 3.3, 3.4, 3.5, 4.1, 4.7, 4.10, 6.1.5 Added List of Figures, List of Tables *Updated Sections: 1.4: Minor updates 3.2: Minor updates 3.3: Changed name in “Workforce” instead of “Manpower” Added Figure 3-3 and further details 3.4: Added table to include teams social media links 3.5: Added explanatory Section 3.5.2 4.1: Minor updates 4.7: Added specification and columns related to Peak and Average Power and Current; highlighted sentence below the table 4.10: Enriched and detailed the expected contents of the section 6.1.5: Clarified that “If the experiment requires reduced gravity, the rocket needs to be de-spun.”	M. Nürmberger G. Gelosa

Keywords: REXUS, BEXUS, SED - Student Experiment Documentation

TABLE OF CONTENTS

LIST OF FIGURES

A list of all figures included in the document shall be provided.

LIST OF TABLES

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PREFACE

One of the most important facets of the REXUS/BEXUS educational programme is to give students experience of documenting all the required information for a space-related project. Therefore the purpose of this document is to give guidelines for the structure and content of the experiment documentation. The guidelines include references to the standards provided by ECSS (European Cooperation for Space Standardization) [1].

The objectives of the SED are:

- To ensure that experiment design can be checked in advance by experts, thereby giving the experiment the highest chance of success
- To educate students on document and report writing, which is of high importance in the aerospace sector
- To train students in certain skills for their future careers (e.g. requirement writing and classification, project management, risk analysis, etc.)

Associated with this document, there is an SED template with a given structure. It will be distributed as a docx-file to be used as a starting point for each selected student group to describe all aspects of their experiment. There is no limit to the number of pages used for this SED, but clarity and conciseness are strongly encouraged. The required documentation is dependent on the complexity of the individual experiment. The SED should be well-structured and appendices should be used for detailed information to ***keep the main body of the SED as short as possible***. This detailed information may be e.g. details of scientific background, technical drawings or component datasheets. The documentation should be written in a ***clear and concise*** manner that allows a person who does not know the experiment to understand its purpose and design.

The SED should provide EuroLaunch (SSC/MORABA) and the experts from DLR, SNSA, ESA and ZARM with all important information on the experiment. During all experiment phases the SED is the only documentation for describing the experiment in detail.

Experiment Phases

The SED reflects a space project lifecycle. It is a living document with five different frozen versions to be delivered by the experiment teams at certain times:

- Version 1 at least 2 weeks before the Preliminary Design Review (PDR)
- Version 2 at least 2 weeks before the Critical Design Review (CDR)
- Version 3 at least 1 week before the Integration Progress Review (IPR)
- Version 4 At least 1 week before the Experiment Acceptance Review (EAR)
- Version 5 as a final report with flight performance and experiment results to be delivered approximately 3 months after the launch campaign

At these instances, the SED should be submitted as a single PDF file and will be reviewed by the organisers. **PDFs shall be printed with converted word bookmarks enabling navigation using the bookmarks tab.** It is possible to make more than one issue of each version. If such additional revisions are necessary will be judged by the organisers.

Any changes in the SED should be clearly listed in the change record list on the second page of the document; the “Remarks” column should summarise what has been changed (e.g. updated components list, updated design requirements, added new risks, etc.). In addition to this, **a separate highlighted version** must be provided in which all changes are highlighted to aid the review process.

File Naming

The naming convention for the SED is as follows:

1. Platform indication plus number of flight:
    a. If the platform has been already defined, BX for BEXUS or RX for REXUS, plus the number of the flight (e.g. BX34, RX33)
    b. If the flight number has **not** been defined yet, BX or RX plus the number of both flights (e.g. BX3435, RX3334)
2. Experiment name
3. SED, plus version (e.g. 3 for CDR) and issue number (beginning with 0 and increasing number when a new issue is sent), more about this in the next section.
4. Date of issue in format ddMmmyy e.g., 12Jul23

e.g. BX32_HERCCULES_SED_v4-0_22Jun23.pdf

More information about the naming of files for the REXUS/BEXUS programme can be found in the “Filename Convention”. This should be used for all files submitted (e.g. CAD files, presentations, Gantt Charts etc.).

The title should always be updated in the “Document ID”, in the SED footer and also in “document properties” for every issue.

SED Versions: Which chapter to update when

During the different phases of the experiment, the content of the SED document will grow in length and increase in detail. Pictures, tables, schematics, diagrams and datasheets should all be included.

A detailed description of the level of detail required before each review can be found in Appendix A.

Before submitting the SED, the team should always check the document for consistency and ask to an outside colleague for a review. It is highly recommended to use a spelling and grammar checker to correct language mistakes and to *ask for feedback on how comprehensible the document is.*

When filling in the SED, the team should:

1. Keep in mind that the person who submits the document and the person who approves it must be different. Ideally, the approver should be a supervisor, professor etc.
2. Keep the format of the SED as shown in the SED Guidelines (e.g. number of the chapters, order and name of the appendices, etc.).
3. Keep the measurement units indicated in the document (e.g. bit and not Bytes).
4. Be consistent with the nomenclature and the measurement units along the entire document and between different issues and versions.

Version 1

Before the PDR, the experiment objectives are already fixed. In the first version of the SED, the main emphasis is on carefully defining the requirements and producing a complete preliminary design. The team shall:

1. Write a good Introduction in Chapter 1 (Introduction to the experiment, team organisation)
2. Define the Experiment Requirements in Chapter 2.
3. Provide details of the project planning in Chapter 3 (sections 3.1 to 3.4)
4. Make a first estimation of the risks related to the project in Section 3.5
5. Describe the complete preliminary design in Chapter 4. Major components must be defined and their numerical values must be properly estimated in particular:
    - Experiment setup, expected mass, volume, power consumption
        - Mechanical - layout diagrams, materials selected
        - Electrical – Schematics, early bread boarding
        - Thermal - basic thermal calculations (i.e. worst hot and cold cases in steady state and possibly also a transient phase) should be provided.
        - Power - Basic Power Calculations
        - Software – Concept and ground station evaluated, principle testing with electronics
6. Give a brief overview of the planned tests in Chapter 5.
7. Provide tables and preliminary information in section 6.1.
8. Provide preliminary information in section 7.1 and some lessons learned in section 7.5.

Important: All the chapters/sections should have content when the SED is submitted for the first time, even if the information is preliminary. The team should not leave any part of the document blank (exception are made for optional chapters such as “Radio Frequency Interfaces – 4.2.3” and “Thermal Interfaces – 4.2.4”, which may be deleted if not used).

For more information on the PDR see Appendix A – Experiment Reviews.

Version 2

Before the CDR, the experiment objectives and requirements are already fixed. Briefly review the corresponding chapters (Chapter 1 and 2) to improve clarity and accuracy. Requirements and risks should **not** be renumbered from version 1. Any changes made following comments at the PDR should be clearly indicated. In version 2 of the SED, the main emphasis is on the detailed design and the verification plan. The team shall:

1. Complete the introduction to the experiment, the team organisation section in chapter 1, the experiment requirements in chapter 2 and project planning in sections from 3.1 to 3.4 . Minor changes can be done, if necessary.
2. Provide a detailed Risk register in section 3.5.
3. Complete the experiment design in chapter 4. Numerical values of the major components must be well calculated or measured. The design must be completely defined:
   - Mechanical – Detailed mechanical description, information about assembly and manufacturing, stress analysis and load calculations where applicable (Finite Element Analysis – FEA). CAD models and datasheets must be included in Appendix C.
   - Electrical – Power distribution and interfaces finalised, complete PCBs design and electronics schematics.
   - Thermal - a detailed multi-nodes thermal analysis is recommended, considering as possible nodes hot spots and components exposed to extreme hot/cold conditions. The use of a software package is recommended.
   - Power – Definitive and complete power budget
   - Software – PC software overview, software program flow, On-Board Data Handling, code for programmable logic (programs, availability during mission) and code verification coverage
4. Give a detailed verification plan in Chapter 5.
5. Give a detailed description of the campaign preparation activities in Chapter 6.2.
6. Update the lessons learned during designing the experiment in Chapter 7.5.

It’s important to note that after the CDR, the design is frozen so that the experiment can be built and verified. Every detail of the experiment should be covered in Chapter 4. This should include all detailed drawings/schematics for mechanics, software and electronics.

For more information on the CDR see Appendix A – Experiment Reviews.

Version 3

About 6 weeks after the CDR, an expert will visit each experiment team to perform the IPR and ensure that integration is progressing well. The IPR will be arranged at the students' university. The final experiment design should be adjusted according to the comments received during the CDR.

The SED version 3 should be delivered about one week prior to the meeting with the main content corrections listed below.

1. Introduction to the experiment, team organisation, experiment requirements and project planning should be updated to reflect the current status, including the incorporation of the test plan. (Chapter 1 and 2 and Sections from 3.1 to 3.4).
2. The risk register should be defined but the risk magnitude should decrease in time due to design decisions and testing (Section 3.5)
3. If necessary, any adjustments to the finished design in Chapter 4.
4. Updates of the component list in Section 4.3, including the status of component orders.
5. Updates and finalisation of the verification plan in Chapter 5.
6. Updates of the campaign preparation information in Chapter 6.
7. A draft of the data analysis plan in Chapter 7.1 as well as updates on the lessons learned.

For more information on the IPR see Appendix A – Experiment Reviews.

Version 4

Prior to shipping the experiment, the Experiment Acceptance Review (EAR) will be performed. Version 4 of the SED should be submitted at least one week before the EAR. This version should include all necessary information needed by EuroLaunch for campaign operations.

1. Chapter 3 should be updated to reflect the current status.
2. If difficulties were encountered during testing, an update may be necessary. Chapter 4 should describe the whole experiment as-built, in detail.
3. All information in Chapter 6 should be finalised, in particular the input for the Campaign / Flight Requirement Plans and details of the experiment time events.
4. A detailed data analysis plan should be given in Chapter 7.1 as well as updated Lessons Learned from the testing in Chapter 7.5.

For more information on the EAR see Appendix A – Experiment Reviews.

Version 5

The completion of a final report is required for the members of the experiment team to receive certification of participation in the REXUS/BEXUS programme. This report is submitted as the final version of the SED. A complete account of the whole project should be presented (including as-built design documentation). The emphasis of the changes/additions is on the launch campaign, experiment results and outreach actions.

1. All TBD items must be closed (e.g. components, tests, Gantt chart, post-flight actions, etc.).
2. The team shall provide details of the experiment results and data analysis in Chapter 7.
3. Special emphasis should be placed on a summary of all Lessons Learned during the whole experiment project, in section 7.5.
4. If needed, other Chapters of the SED should be updated to reflect the status of the experiment (e.g. abstract must be updated): it should be clear throughout the document that the experiment has flown. That means that the experimenters should be careful with the use of future tense and should update the abstract and the preface.

In addition to the general not-highlighted and highlighted versions of the document, a third version of the SED version 5 should be produced. This version will be non-highlighted and **shall exclude all team members' names, pictures, and personal contact details, except for the team email.** This specific version will be intended for publication on the REXUS/BEXUS website.

Access to SED by various parties

The SED in all its versions will be circulated to EuroLaunch (SSC/MORABA) engineers and experts from DLR, SNSA, ESA and ZARM. It will also be archived in a secure shared server (called the TeamSite), to which other students participating in the programme will have access. Version 5 will be published on rexusbexus.net, with permission of the team.

If there is information related to the experiment and/or personal information which should be kept confidential outside of the REXUS/BEXUS programme, the team should discuss this with one of the organisers and mention this clearly in the SED in an opening section before the Abstract.

ABSTRACT

The abstract is a concise overview of the document, comprising a maximum of half a page. It tells the reader *what* the experiment team wants to measure/test/investigate, *why* they want to do this, and *how* they want to do it (the underlying scientific method, on a sounding rocket or balloon). It will mention concisely the key feature(s) of the experiment design, for example its novelty, robustness, or accuracy and how to achieve these key feature(s). Finally, the abstract gives expected or potential results and their expected accuracy.

For the final report, the abstract is complemented with the obtained results and describes (if applicable) their importance in the scientific context.

An Abstract should not contain any formulas, figures, tables or references but may contain numbers.

1 INTRODUCTION

1.1 Scientific/Technical Background

Here the team should briefly describe the scientific or technical field relevant to the experiment, the questions addressed, and assumptions made.

Key papers in the field should be referenced, where applicable.

Any projects that have synergies with the experiment shall be mentioned.

1.2 Mission Statement

Here the overall purpose of the experiment shall be described. This should be one or maximum two short paragraphs outlining the current *problem* and a *qualitative solution* to that problem*.* This statement should draw on the scientific/technical background and will briefly explain why this experiment should be performed and what it will do, forming the basis for the experiment definition.

From the mission statement the qualitative experiment objectives can be defined in section 1.3 from which the experiment requirements in section 2 can be defined.

1.3 Experiment Objectives

Here, all objectives of the experiment shall be listed, specifying what shall be measured, tested, or investigated.

Hint: Think about what the 'end user' wants from this experiment.

If applicable, it is recommended to distinguish between scientific and technical objectives and, if appropriate, to number the objectives or use tables.

It should be clear which objectives should be reached in order for the experiment to be considered successful (primary experiment objectives). These objectives make up the key performance parameters of the experiment.

Then, it should be defined which objectives are 'additional' objectives (secondary experiment objectives).

The primary objectives will define the minimum mission success if they are reached. The combined primary and secondary objectives should reflect the total mission success.

Objectives should be broad statements of what the experiment must do, they should not be quantitative (with the exception of broad financial constraints). The verifiability of the objectives should be considered but does not need to be included specifically.

If necessary, what is <u>not</u> in the scope of the experiment should be clarified.

Example: Obj.1: To test a system for real time forest fire detection from a high-altitude balloon.

1.4 Experiment Concept

This section should include an overview of the concept of the experiment which will be carried out and the key elements of the experiment (e.g. sensors, cameras, particle detectors) should be identified.
In addition, the functional and/or physical blocks of the experiment should be named (e.g. data taking unit, sensor unit).
It should be described in general terms how these elements interact, without providing any technical detail but with the use of a high level diagram, if applicable.
The experiment overview should not describe any design choices. This section should be general and may need updating following the design considerations.

It is recommended to include illustrations. Furthermore, a block diagram or similar to explain the different functional and/or physical blocks of the experiment shall be included.

1.5 Team Details

1.5.1 Contact Point

An address, email and phone number should be given here not only to facilitate REXUS/BEXUS contact but also for people interested to be able to contact the team. It is recommended to have a named contact person at the team's university/institute to ensure continuity after the project.

The team shall also have a team email address to which the entire team has access.

1.5.2 Team Members

In this section, the team members and their respective roles in the team should be presented, including:

- Educational background and relevant interests (e.g. physics, computer science, mechanical engineering, etc.).
- Field of work within the team (without giving details of tasks – this belongs in Chapter 3)
- Expected workload within the team (in general terms)
- Academic credit that is expected to be awarded for work related to the experiment

If the REXUS/BEXUS programme participation is part of coursework at the university, the title of the course and the number of ECTS points awarded should be specified. Students are encouraged to carry out at least part of the work for their REXUS/BEXUS experiment within the scope of a university course, to ensure sufficient time allocation and academic support.

If the REXUS/BEXUS programme participation is part of thesis work, for each student there should also be a note indicating how much time is needed for the actual implementation of the experiment.

2 EXPERIMENT REQUIREMENTS AND CONTRAINTS

In order to achieve the Experiment Objectives that are listed in section 1.3, the experiment has to have certain functionalities, which will be performed to the desired standard by means of a good technical design.

Requirements can be divided in several categories. In order to keep it simple only four categories will be considered here: functional, performance, design and operational requirements. Before starting the detailed experiment design, these requirements need to be determined.

A good requirement set begins to define the design space and tells you what the system shall/should/may do. Thus, writing requirements with a negative sentence shall be avoided.

In Figure 2-1 the general flow for creating requirements can be seen.

Typical characteristics of a good requirement are:

1. Justifiable (i.e. it should ‘come from’ somewhere).
2. Unique (i.e. not covered by other requirements)
3. Unambiguous
4. Verifiable
5. Identifiable (i.e. it should be numbered)
6. Traceable (i.e. you should know where it comes from)

First the experiment objectives and the requirements of the vehicle should be analysed and then all the experiment requirements should be defined.

An appropriate numbering scheme and/or a table should be used.

Normally on a project, throughout the design and fabrication of the experiment, all the requirements are constantly monitored to make sure that they are indeed fulfilled. This process is called verification and is detailed further in Chapter 5.

Whilst defining the requirements one should keep in mind how they will be verified once a detailed design is complete.

In the following sections some specific examples are given to facilitate the process of requirement definition.

Further details of definition and classification of requirements are given in the ECSS technical requirements specification document ECSS-E-ST-10-06C [2] which is available on the REXUS/BEXUS TeamSite.

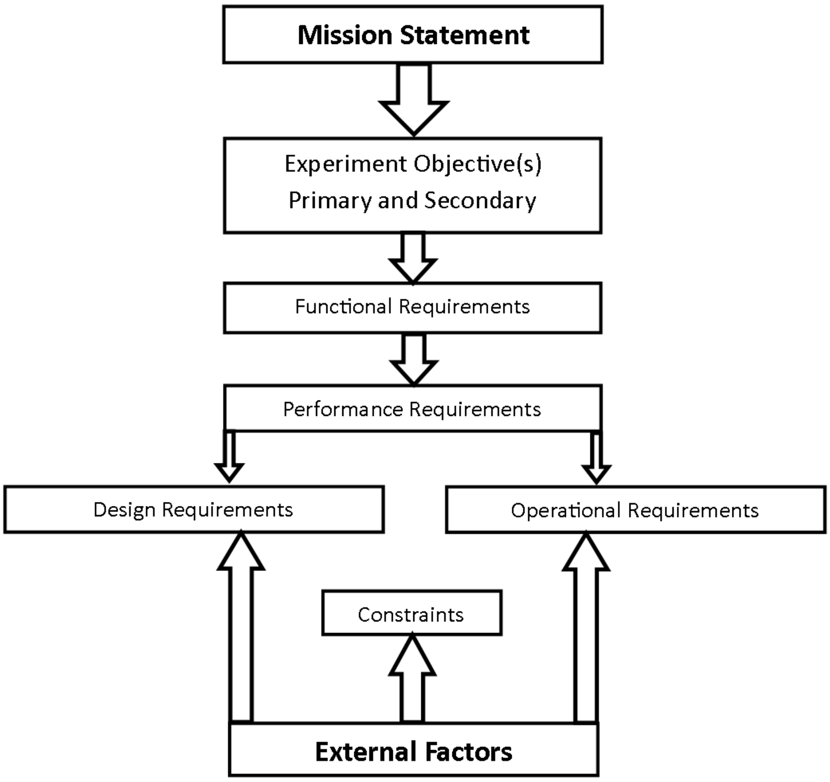


Figure 2-1: Idealised requirements flow chart.

2.1 Functional Requirements

Functional Requirements define the functionality that the experiment needs to have or the tasks it needs to fulfil in order to achieve the experiment objectives.

Assuming a hypothetical simple balloon experiment with the goal of measuring temperature in the stratosphere, functional requirements could be (simplified): F.1.: The experiment shall measure the temperature outside the BEXUS gondola F.2.: The experiment shall measure the temperature inside the BEXUS gondola

It is important to note that it is not mentioned which sensor is used, how many there are, how fast it will measure, how precisely it will measure, etc. This information belongs to the next section.

One should also note that these functions are the functions of the experiment which lead to the accomplishment of the scientific/technical objectives, **not** secondary or consequential functions, such as the correct distribution of power by the Power Distribution Unit.

2.2 Performance Requirements

Performance requirements quantify to what level the functional requirements will be fulfilled. In the case of measurements, they typically define:

- the range;
- the precision;
- the frequency.

Performance requirements define the quality of the experiment.

The performance requirements for the example above could be (simplified):

P.1.: The temperature measurement's range outside the balloon shall be between -100 and +50 degrees centigrade.

P.2.: The temperature measurements outside the balloon shall be made with an accuracy of +/- 1 degree centigrade.

P.3.: The temperature measurement outside the balloon shall be made at a rate of 1 measurement every second.

It is interesting to note that the functional requirement F.1. has led to 3 performance requirements.

2.3 Design Requirements

Design requirements define all design (system engineering) aspects that the experiment needs to fulfil. While functional requirements and performance requirements originate from the experiment team and the experiment objectives, design requirements mainly come from other sources, such as:

- the flight environment (e.g. the need to withstand mechanical and thermal stress)
- the launch vehicle (e.g. certain components may be forbidden, certain interfaces are defined by the launch vehicle, mass or power budget restrictions)
- legal limitations (e.g. frequency allocation)
- safety restrictions (e.g. high voltage or ionisation)

An important subset of design requirements are the interface requirements, which determine that the mechanical and electrical interfaces to the launch vehicle are correct. Many of these requirements are listed in the REXUS/BEXUS User Manuals and some of them are directly imposed by EuroLaunch.

Design Requirements should only describe design solutions if those are imposed from external sources (such as the ones described above) and cannot be decided by the experiment team.

For the example above, some design requirements are (list not complete):

D.1.: The experiment shall operate in the temperature profile of the BEXUS vehicle flight and launch.

D.2.: The experiment shall operate in the vibration profile of the BEXUS vehicle flight and launch.

D.3.: The experiment power connector shall be an Amphenol PT02E8-4P, Code A.

D.4.: The experiment shall not disturb or harm the launch vehicle.

The following requirements are compulsory if the experiment uses its own batteries on a BEXUS balloon:

D.X.: The experiment batteries shall be qualified for use on a BEXUS balloon.

D.X.: The experiment batteries shall either be rechargeable or shall have sufficient capacity to run the experiment during pre-flight tests, flight preparation and flight.

D.X.: The batteries in the gondola-mounted experiment shall be accessible from the outside within 1 minute.

2.4 Operational Requirements

Operational requirements are requirements that the experiment has to fulfil to be handled and operated safely and reliably. Operation not only refers to operation during flight but also to the handling of the experiment immediately prior and after flight (i.e. data extraction). Some of the operational requirements are related to experiment safety.

Examples of possible operational requirements are:

O.1.: The experiment shall accept control of the camera function from the ground segment.

O.2: The experiment shall accept a request for radio silence at any time while on the launch pad.

O.3: The experiment shall be able to conduct measurements autonomously in case connection with the ground segment is lost.

O.4: The experiment shall be able to enter a secure mode after landing (pyros and sensitive equipment shall be disabled).

Whenever dangerous elements are included (e.g. chemicals, ionisation, radiation, lasers, pyrotechnical devices) a dedicated handling requirement must be introduced.

2.5 Constraints

Constraints are those factors which limit cost, schedule, and implementation techniques available to the team and that cannot be overcome.

In general, cost is considered a constraint for most of the space missions since it is defined and fixed from the beginning of the mission, and it is difficult to modify it. However, for many REXUS/BEXUS experiments, cost is not a constraint as the cost is often not fixed and new funding sources may be acquired throughout the project.

Examples of possible constraints are:

C.1.: The laboratory is closed for the entire August.

C.2. The thermal chamber of the university cannot provide temperatures below -40ºC.

Typically, constraints are things imposed on the team by outside factors.

3 PROJECT PLANNING

Project planning is key to experiment success and should be considered as important as the technical design. This section will help the team identify insufficiencies in resources and time.

It is strongly recommended that at least one team member focuses on project planning. It is also recommended to make use of a piece of dedicated project management software which can build up and manage the Work Breakdown Structure (WBS), project schedule and resource allocation. For a more detailed description, the Project planning and implementation standard by ECSS can be consulted [3].

3.1 Work Breakdown Structure (WBS)

A Work Breakdown Structure (WBS) provides a framework for managing cost, schedule and technical content. It divides the project into manageable work packages (WPs), organised according to the nature of the work by breaking down the total work to be performed into increasing levels of detail. [4]

The WBS (E.g. Figure 3-1) can be made by project phase, by subsystem or by some other logic. The lowest level boxes show the tasks that can be allocated to either individual team members or working groups (i.e. mechanical). It is recommended to include in the WBS a clear numbering system and indication of who (either team members or working groups within the team) is responsible for each WP. It may be helpful to include verbs in the description of tasks (design, build, integrate, etc.).

No scheduling information or sequencing of tasks is implied in the WBS, but it may be helpful to think through the experiment process in a logical order.

Assembly, **testing**, **post-flight activities** and other fundamental phases of the project shall also be included.

Since the WBS should include 100% of the work for the project (not more, not less), **project management**, **documentation** and **outreach shall also be included**!

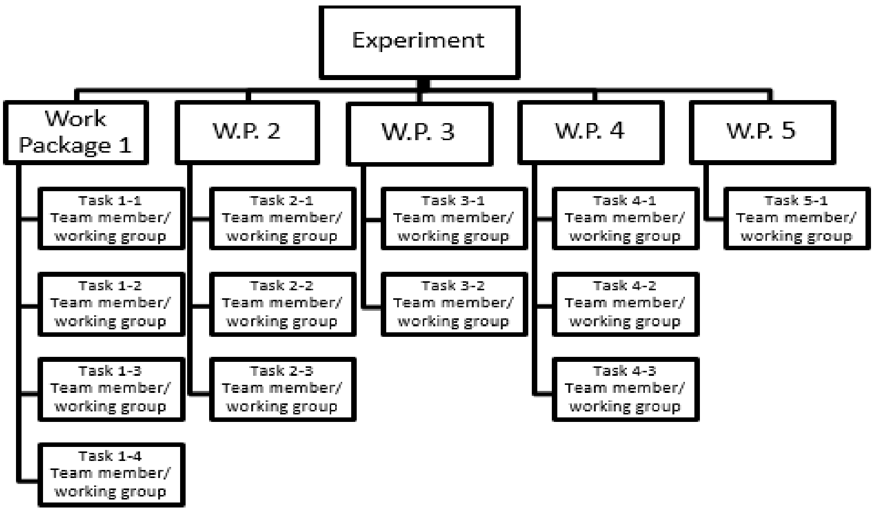


Figure 3-1: Example Work Breakdown Structure (WBS)

3.2 Schedule

Once the WPs and tasks have been defined in the WBS, their interdependencies can be analysed to plan them in a logical time sequence. In this section, a schedule (Gantt chart or similar alternative) should be presented, showing the duration, order and interdependencies of all tasks and indicating key project milestones (e.g. reviews, tests, experiment delivery). The schedule may be divided into phases or work packages.

The schedule should include **all** tasks and WPs defined in the Work Breakdown structure. This also includes assembly, testing (with tests defined in the verification plan in Chapter 5), post-flight activities (e.g. data analysis and reporting), project management, outreach and documentation.

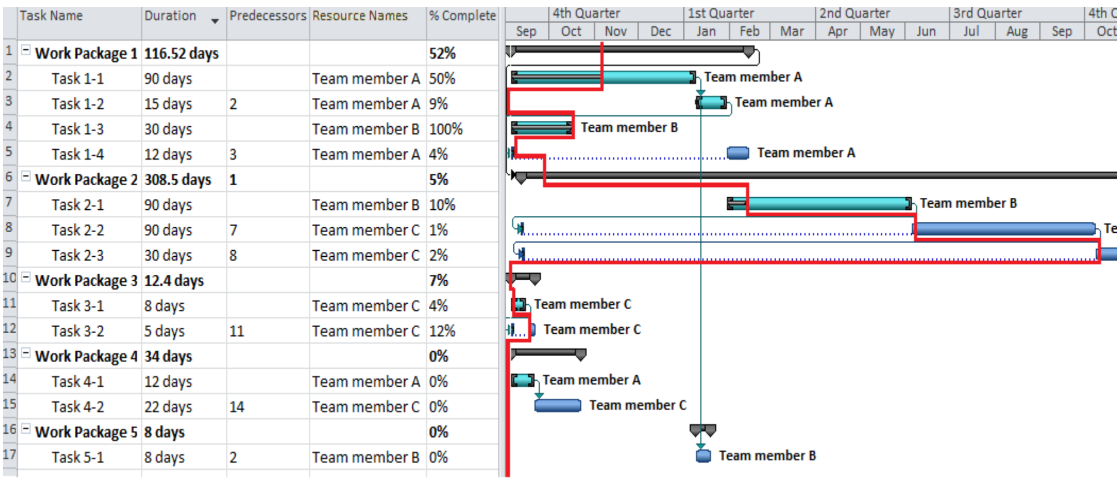
It is important to block periods of time when team members will not be available (e.g. for holidays or exams) and plan some buffer time, in case of unexpected problems, delays or test failures.

It is recommended to carefully check the delivery time of critical components, especially long lead items, and ensure that these are ordered as soon as possible.

The schedule should be presented in draft form at PDR and finalised by CDR. Subsequent updates should **show the up-to-date project status** with respect to the original planning, e.g. by marking a progress line on a Gantt chart (see below) and showing % complete for each task. Milestones should not be moved in time! In case of delays, their reason should be specified in the document (e.g. delayed part delivery, test repetition required…).

It is recommended to include a top-level schedule within the SED, and to provide a detailed one in the appendix or as an attachment.

Clear allocation of task interdependencies and scheduling will aid the team in identifying the project's Critical Path, (which is the list of tasks which takes the longest and thus drives the project completion) and help them in allocating resources in the next section.



	Task Name	Duration	Predecessors	Resource Names	% Complete
1	**Work Package 1**	**116.52 days**			**52%**
2	Task 1-1	90 days		Team member A	50%
3	Task 1-2	15 days	2	Team member A	9%
4	Task 1-3	30 days		Team member B	100%
5	Task 1-4	12 days	3	Team member A	4%
6	**Work Package 2**	**308.5 days**	**1**		**5%**
7	Task 2-1	90 days		Team member B	10%
8	Task 2-2	90 days	7	Team member C	1%
9	Task 2-3	30 days	8	Team member C	2%
10	**Work Package 3**	**12.4 days**			**7%**
11	Task 3-1	8 days		Team member C	4%
12	Task 3-2	5 days	11	Team member C	12%
13	**Work Package 4**	**34 days**			**0%**
14	Task 4-1	12 days		Team member A	0%
15	Task 4-2	22 days	14	Team member C	0%
16	**Work Package 5**	**8 days**			**0%**
17	Task 5-1	8 days	2	Team member B	0%

Figure 3-2: Example Gantt Chart with progress line, critical path and resource allocation

It is permissible to use a landscape page and colour code to create a clearer and more effective schedule. The status of structural components (designed, ordered, delivered, assembled, tested), as well as electrical boards, sensors and software should be included in the schedule. If there are several units using different software, their status should be indicated in different sub-sections.

3.3 Resources

3.3.1 Workforce

In this section, the work distribution within the team should be described but this should **not** be a repetition of section 1.5.2.

When assigning team members, their skills, experience, and availability should be taken into account.

It is recommended to think of what measures are necessary if a team member suddenly becomes unavailable, possibly recruiting members that can back-up another member for critical tasks.

Here, there should be a detailed description of the workforce required to fulfil all tasks that must be carried out in order to deliver, fly, and analyse the experiment. This should be built up from the tasks that are presented in the Work Breakdown Structure.

The workforce available should be estimated, as the number of hours (or days) during each week that are available. This should be calculated as a sum of the hours available of each team member. Holidays and exam periods should be also taken into account. Ideally, this would be compared to the tasks and their scheduling to ensure that the manpower is available when the work is required to be completed. It is also important to keep in mind that throughout the programme-related events (e.g. training week, CDR, launch campaign etc.) the team will spend several full days (working/traveling) only on this project and those hours should be taken into account as well.

The team should map the workforce required during each phase to the workforce available. It should be shown that there is more workforce available than workforce required as otherwise any delays will mean a failure to meet deadlines.

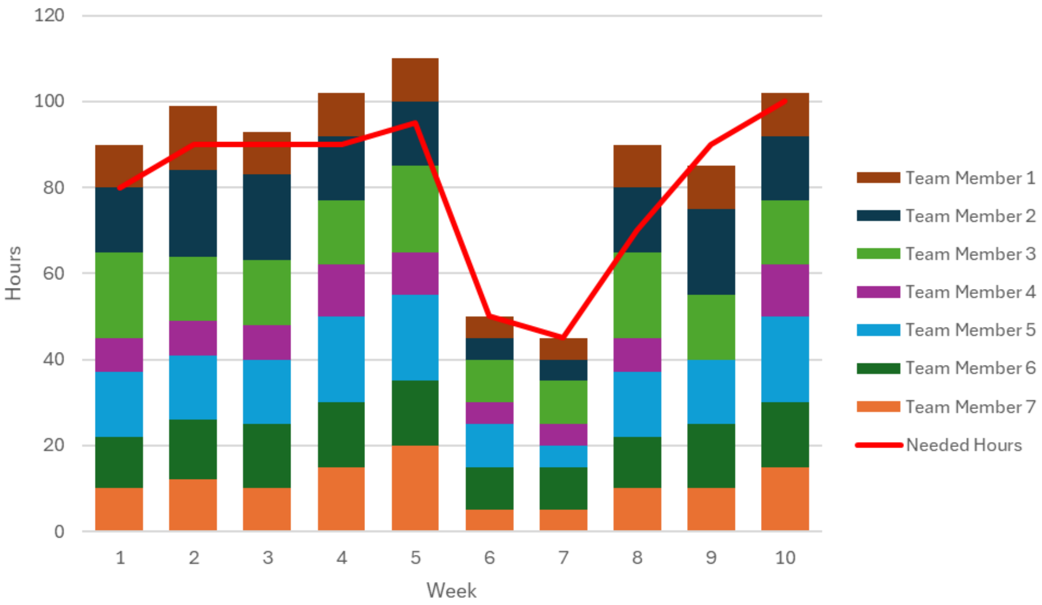


Figure 3-3 Example graph comparing available workforce (in hours per week) to the workforce needed for completing all scheduled tasks.

If it can be seen that the manpower is not sufficient, steps should be taken to find different approaches such as de-scoping, recruiting more team members, or changes to the scheduling of the project.

3.3.2 Budget

This section should contain a detailed table with costs (including margins) and funding estimations.

This should be a summary of the experiment budget where deficit and surplus must be indicated with a description of which strategy would be adopted in order to address any deficit.

Preferably, the currency used should be the EURO. In case of a different currency, an estimation of the values in EURO shall also be added.

3.3.3 External Support

Here, all the organisations, departments or companies that provide sponsorship or in-kind support should be listed. For example, professors of a university or institute, local companies or nearby research laboratories, facilities to which access is possible, etc. It is also important to mention any support or expertise which is lacking.

3.4 Outreach Approach

Outreach is a fundamental part of a project to promote it, to ensure knowledge transmission but especially to attract sponsors. It is directed to multiple stakeholders (scientific community, general public, press, etc.) and it can be done using different approaches such as press release, university presentations, crowdfunding, promotional material, etc.).

In this section there should be an outreach plan containing a detailed schedule of all the activities designed to publicising and communicating about the experiment and a description of the chosen strategy to promote it and fundraise it.

It is recommended to add a list of the interviews and presentations planned, including dates (when already scheduled) and interested stakeholders. Any website or blog should be described, including the link, specifying how it is planned to evolve and, mentioning, in particular, any contact with local or national media representatives.

In this chapter, the team shall also fill a table such as the one shown below, with information about all the team social media along with the proper links:

Table 3-1: Team social media links

Team	Facebook	Instagram	LinkedIn	Website	Etc.
REXUS/BEXUS	Rexus/Bexus	@rexus_bexus	rexus-bexus	https://rexusbexus.net/	…

See Appendix B – Outreach and Media Coverage for further suggestions.

3.5 Risk Register

Risks exist with every project, and they must be identified and dealt with.

In order to manage the risks within the project, the following steps must be used:

- Identification of the risks in certain relevant categories
- Estimation of the probability (P) and severity (S) of each risk
- Calculation of the risk index (P x S) and risk magnitude
- Decision whether these risks are acceptable or not
- Identification of actions to perform to mitigate or remove the risks, or reduce them to an acceptable level
- Monitoring and communicating the risks
- Record of all of the above in a risk register (see template below)

The risk register should be updated in each new SED version.

Details of principles and requirements for risk management on space projects are given in the ECSS document ECSS-M-ST-80C [5] which is available on the REXUS/BEXUS TeamSite.

3.5.1 Explanation of Columns in Risk Register template

Risk ID

TC – technical/implementation

MS – mission (operational performance)

SF – safety

VE – vehicle

PE – personnel

EN – environmental

These categories should be adapted to the experiment and, if needed, new categories may be added.

Not only risks to the experiment, to the vehicle and to personnel should be considered, but also organisational and management risks.

Probability (P)

A. Minimum – Almost impossible to occur

B. Low – Small chance to occur

C. Medium – Reasonable chance to occur

D. High – Quite likely to occur

E. Maximum – Certain to occur, maybe more than once

Severity (S)

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

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

Table 3-2: Risk index and magnitude scheme

Probability (P)	1	2	3	4	5
E	low	medium	high	very high	very high
D	low	low	medium	high	very high
C	very low	low	low	medium	high
B	very low	very low	low	low	medium
A	very low	very low	very low	very low	low
	Severity (S)				

Table 3-3: Risk magnitude designations and proposed actions for Individual risks

Risk index (P x S)	Risk magnitude	Proposed actions
E4, E5, D5	Very High risk	Unacceptable risk: implement new process or change baseline – seek attention at appropriate high level.
E3, D4, C5	High risk	Unacceptable risk: see above.
E2, D3, C4, B5	Medium risk	Unacceptable risk: must be managed. Consider alternative process or baseline – seek attention at appropriate level
E1, D1, D2, C2, C3, B3, B4, A5	Low risk	Acceptable risk: control, monitor, consider options
C1, B1, A1, B2, A2, A3, A4	Very Low risk	Acceptable risk: control, monitor

In general, after calculating the risk magnitude, it should be assessed if the risk is acceptable or unacceptable and, according to that, an action should be proposed in order to mitigate it.

A risk is commonly considered acceptable or unacceptable according to the following philosophy:

- Acceptable risk:
  - Can be tolerated in the project
  - Doesn’t require any pro-active preventative or mitigation actions
  - If occurs, it can be “worked-around”
- Unacceptable:
  - Cannot be tolerated in the project
  - Requires pro-active mitigation actions
  - If occurs despite the prevention or mitigation may still require a “work-around”

The SED template contains an embedded excel file which automatically calculates the Risk Index and correctly formats the cell, but another automatic or manual method may be used.

3.5.2 Completing the Risk Register Template

Each risk should have a unique risk ID number. Risks should never be renumbered or removed from the risk register.

As the project proceeds, some new risks may arise, some other risks can be eliminated but, in general, the magnitude of most of the risks will decrease by:

- Prevention (reducing the probability, P)
- Mitigation (reducing the severity, S)

It is to be expected that at the beginning of a project, the risk magnitude of most identified risks is unacceptable (medium risk or higher). Only throughout the development of the experiment, by implementation of prevention and mitigation measures, the risk magnitude will be lowered to acceptable levels.

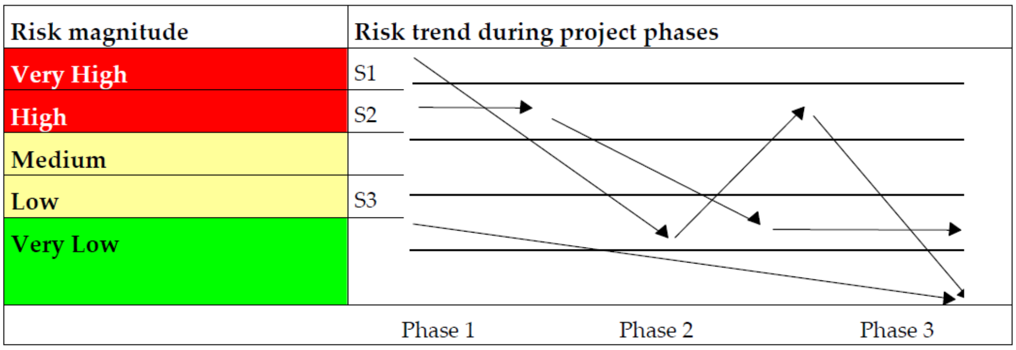


Figure 3-4 Example of a risk trend [5]

If a risk is reduced, the probability and the severity must be updated. For this, a new entry is made in the risk register, below the original risk, showing the residual risk and its new classification.

To facilitate logical numbering, it is recommended to start by numbering risks in increments of 10, so that additional or residual risks can subsequently be entered between the original entries.

Table 3-4: Risk Register Template with examples

ID	Risk & consequence	P	S	P x S	Prevention and/or Mitigation Action
TC10	Critical (irreplaceable) component is destroyed in testing	B	4	Low	No test is performed on the critical component, component performance verified by analysis and review only.
TC11	Residual of TC10 after implementation of the mitigation action.	A	4	Very Low	Acceptable risk: no action
SF10	Part of experiment placed externally to the gondola falls from balloon gondola over a populated area during flight	C	5	High	Secure the experiment on the gondola using a safety cable.
MS10	Battery fails to recharge before flight, limiting experiment lifetime	A	2	Very low	Acceptable risk: no action
MS20	Software programme in microcontroller fails during flight	C	3	Low	Watchdog checks for crashes and resets if necessary. 'Power-on-reset' sequence brings system to safe state

4 EXPERIMENT DESCRIPTION

The following sections should contain the detailed description of the design of the experiment. Every aspect (subsystem) of the experiment must be covered. The experts in the review boards (PDR, CDR) can only give advice based on the provided information in these sections. The more details and information given here, the more recommendations there will be from the review board. **It is recommended to give most of the information in diagrams, graphics or tables, keeping the text to a minimum and inserting any details that are not essential to understand the experiment in the appendix.**

The experiment shall be designed to fulfil all the requirements that are listed in Section 2.

The following sections outline the level of detail that should be provided. However, this chapter should be adapted to the respective experiment and more sections can be added if necessary.

4.1 Experiment Setup

The aim of this section is to describe the different subsystems of the experiment and how they interact with each other.

The team shall use schematics and a block diagram to explain the interfaces between the different blocks.

This section shall be a more detailed extension of the experiment overview (Section 1.4).

4.2 Experiment Interfaces

The experiment has a mechanical and an electrical interface to the vehicle. They represent the footprint of the experiment and not the detailed experiment description. These shall be described in the following subsections within a maximum of 3 pages in total.

Before defining and describing these interfaces, the team shall consult the REXUS/BEXUS User Manuals [6] [7].

4.2.1 Mechanical

This section should contain only a description of the fixation and mounting of the experiment and its different components to the vehicle, indicating the mounting pattern of the experiment and specifying the amount and the size of bolts, nuts, washers, etc. (in a table).

Any other special requirements should be also indicated and justified.

This section shouldn't contain the full description of the mechanical design of the experiment since it will be required in section 4.4.

For REXUS:

The attachment to the experiment module and the bulkhead must be clearly shown and described, including diagrams of any modifications.

For BEXUS:

The attachment to the gondola must be clearly shown and described, including a diagram of this interface.

4.2.2 Electrical

This part should contain only the description of the electrical interface to the vehicle.

For REXUS:

If applicable, the usage of the REXUS service module should be described and the use of:

- Signals
- Power
- Up- and downlink
- Grounding

It is recommended to include a table summarising which pins are connected.

Example:

Table 4-1: REXUS connector pin out usage

Pin No.	**Name.**	**Use**
1	+28 V	Experiment Power
2	Charging (28 V/1 A)	Not connected – not used
3	SODS	Not connected – not used
4	SOE	Used
5	LO	Used
6	EXP out+	Downlink (non-inverted)
7	EXP out-	Downlink (inverted)
8	28 V Ground	Ground
9	+28 V	Experiment Power
10	n.c.	Not connected
11	n.c.	Not connected
12	Charging Return	Not connected – not used
13	EXP in +	Uplink (non-inverted)
14	EXP in -	Uplink (inverted)
15	28 V Ground	Ground

For BEXUS:

If applicable, the usage of the E-Link should be also described, in terms of:

- data rate of uplink
- data rate of downlink
- protocol
- connector type.

Also, the usage of BEXUS batteries (Gondola Power) should be described, if applicable, which means:

- number of connections (if multiple batteries are used, it should be stated if they will be connected together with a single connection or if they will be connected separately with multiple connections)
- type of connector
- expected average and max current
- protection (both for the experiment and for the power supply).
- grounding.

4.2.3 Radio Frequencies (optional)

If radio frequencies are transmitted beyond the casing of the experiment, either intentionally or unintentionally, it is mandatory to give their details and reference the frequency table provided by Swedish PTS (Post & Telestyrelsen). If the experiment will transmit, it must be certain that it will not interfere with the rocket/balloon systems. Therefore, following data should be measured:

- frequency
- bandwidth
- power level
- modulation.

4.2.4 Thermal (optional)

This section only needs to be included if the experiment heats or cools the vehicle (gondola, rocket experiment module) to a non-negligible extent.

In this case, the amount of energy exchanged with the vehicle or the neighbouring experiments should be calculated.

4.3 Experiment Components

All the major components of the experiment (e.g. sensors, micro-controllers, cameras, etc.) should be listed in a table(s), specifying:

- Availability, cost and supplier
- Number of items
- Specifications (e.g. dimension, weight)
- Brief reasons for choosing each component
- Current status ('designed/to be ordered', 'ordered', 'confirmed/in production', 'delayed', 'delivered').

For extensive component lists, the use of split tables and the appendix is encouraged. Relevant datasheet should be provided in the corresponding appendix.

The following table should be filled in as a summary (**this table, which is the same as in section 6.1.1, is compulsory, and the measurement units and the coordinate system shall not be changed**):

Table 4-2: Experiment summary table

Experiment mass (in kg):	
Experiment dimensions (for BEXUS) or module size (for REXUS) (in m):	
Experiment expected COG (centre of gravity) position:	

<u>For BEXUS</u>

If the experiment consists of several separate boxes or units, the dimensions, mass and COG of each component should be indicated.

<u>For REXUS:</u>

It should be stated whether the mass includes the experiment module.

The mass of the system should be specified at the following stages:

- Mass at lift-off (with module).
- Mass at de-spin (with module).
- Mass at re-entry (with module).

4.4 Mechanical Design

This section shall describe the mechanical design, the material used for the structure/boxes and how every component is mounted to the structure/boxes. The use of figures is highly recommended.

It is recommended to pay particular attention to any moving parts inside the experiment.

Additionally, it is highly recommended to perform FEM (Finite Element Method) analysis, especially for critical components and complex designs, to verify the structural integrity and ensure that the system can withstand the operational loads. More information on vibration, shocks and experiment mounting is available in the appropriate User Manual [6] [7].

Some consideration should be given to design justification, especially when design choices are not obvious, however presentation of design trade-offs is not required.

4.5 Electronics Design

This section should give an overview of the electronics system layout, first describing the electronics (and selected components) of the experiment with the use of a block diagram (e.g. Figure 4.1-1), and then inserting the electronics schematics of each subsystem and component. Usually, the schematics follow the sub-functions of the block diagram. It is important to indicate, in particular:

- the Voltage Level
- the power dissipation
- how power is distributed in the system
- the data usage
- grounding.

In addition, it should be clearly indicated how many PCB(s) are used and where they are located.

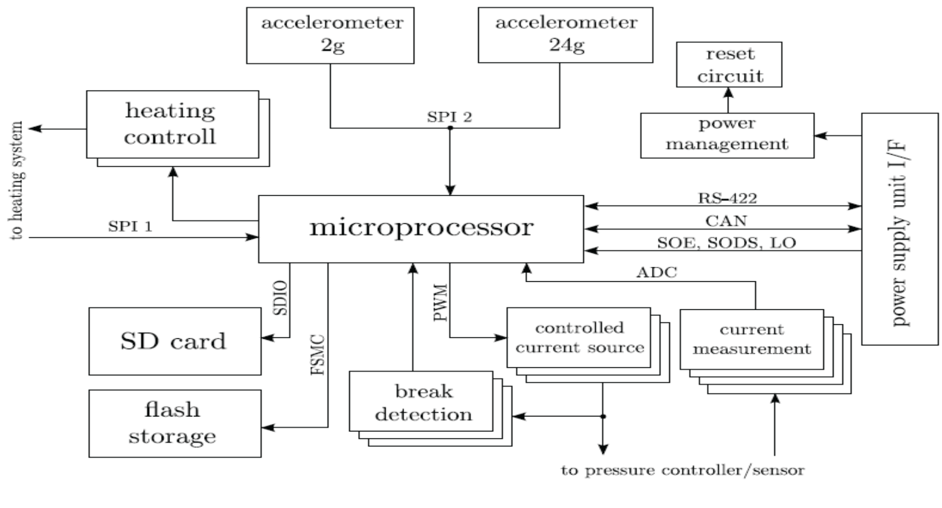


Figure 4-1-1: Electronics schematics and PCB(s) layout example, Team CEMIOS RX20

Electronics schematics and PCB(s) layout shall be provided, and the power distribution and interfacing shall be defined.

Then, in later stages, also a list of all interconnecting cabling used in the experiment shall be provided and the circuits should be tested on a breadboard.

4.6 Thermal Design

In this section, the environmental conditions for the experiment (transport, preparation, pre-launch, flight and recovery), the temperature range in which the experiment shall operate, and the heat production of the experiment components should be determined.

A table of components and their operating/survivable ranges shall be included. Where any components lie outside of the design range, it should be explained how this is handled.

In addition, a thermal analysis is recommended, and the boundary conditions and the results of the analysis should be presented in the SED.

Example:

Minimum/Maximum Expected Operating Temperature: -10ºC/+65ºC

Minimum/Maximum Expected Survivable Temperature: -30ºC/+65ºC

Table 4-3: Example component thermal ranges table

Component	**Operating T (ºC)**		**Survivable T (ºC)**		**Power Dissipated (W)**		**Comments**
	Min	Max	Min	Max	Average	Max	
Camera	0	70	Unknown	Unknown	0.35	0.5	Operating temperature as stated in the camera data sheet. Thorough testing shows continued good operation at -20ºC – see test report.
Processor	-40	85	-55	85	0.5	0.8	-
Power Unit	-40	85	-55	85	0.4	0.6	-

This section should describe the design of the active and/or passive thermal control required to keep the experiment in its thermal operating range at all times prior, during and after flight.

4.7 Power System

It is recommended to fill in the table below, calculating the power budget of the experiment and considering, if applicable, the power consumption during different duty cycles and phases (before launch, during flight, after landing), with a good safety factor. This calculation shall show whether the experiment is well designed or whether additional provisions (low power function, different batteries) have to be made. The use of a I vs. t graph for the launch phases (the integral of which is the Ah) is strongly encouraged.

Table 4-4 – Example of Power Budget Table

Phase	**Duration [h]**	**Component**	**Duty Cycle**	**Peak Current [A]**	**Average Current [A]**	**Voltage [V]**	**Peak Power [W]**	**Average Power [W]**	**Total Power [Wh]**
Before Launch		Camera							
		Processor							
		…							
	Sub Total								
During Flight		Camera							
		Processor							
		…							
	Sub Total								
After Landing		Camera							
		Processor							
		…							
	Sub Total								
Complete Flight	**TOTAL**								

If batteries are used, their type and amount should be specified, and their datasheet shall be attached in the appendix. Otherwise, it should be clearly indicated that the power supply provided by the launch vehicle is required.

4.8 Software Design

Here the software of the on-board experiment and the ground station should be described. This paragraph should be used as an aid to design the experiment's software, not only documenting it.

The following topics should be covered:

1. Purpose
   A short introduction of the software purpose is required. Example: "*Experiment control and data handling of the experiment "centrifuge". A servo motor control loop has to be designed and environmental experiment data shall be stored and transmitted to a ground station."*

2. Design
   a) Process Overview
      A brief description of the process overview is required, including a block diagram which includes the technical process field (e.g. actuators and sensors), the process control unit (e.g. microcontroller), external storage, interfaces (e.g. I/O, Bus, …) and ground control in form of blocks which are combined with arrows.

   b) General and safety related concepts
      It is important to make considerations about possible error behaviours and describe safety related concepts like redundancy or watchdog if applicable.

   c) Interfaces
      Here the setup interfaces should be described, in particular the communication interface (e.g. UART, Ethernet, and Rocket Signals). The team shall indicate the minimum bandwidth requirement, the normal bandwidth requirement, and the maximum bandwidth requirement, and design the transmission packets, considering fail-safe data transmission possibilities. Also, the process field interfaces (e.g. USB sensors, CAN bus, etc.) and the user interface should be considered.

   d) Data acquisition and storage
      The amount of data gathered and its storage on-board the experiment should be estimated. In particular, storage package architecture should be described, calculating buffer sizes and data transmission rates to permanent storage devices, if applicable.

   e) Process Flow
      The process flow of the experiment should be described. It could be useful to use process-flowcharts, sequential-function-charts or state-machine-diagrams if applicable.

   f) Modularisation and pseudo code
      It is recommended to break down the functionality of the system into independent modules, such that each can be solved separately, and to describe the different modules and their interfaces. Pseudo code or UML-diagrams can be used for the description if applicable.

3. Implementation
   The team should decide about the programming language and development tools they want to use and address the need of an operating system or the usage of programming libraries if applicable. Elementary parts of the source codes (e.g. interrupt service routines) should be also described.

4.9 Ground Support Equipment

In this section, there should be a description of all the equipment that is part of the experiment but that does not fly on the rocket/balloon. Usually, this is the ground segment, one or several computers that receive data from the experiment through E-Link (BEXUS) or through the service module (REXUS).

Also, the software design of the ground segment should be described and the handling of received data shall be detailed.

The programming language(s) and the development environments used should be indicated. Pictures of the developed GUI (Graphic User Interface) may be included.

A description of any mechanical or electrical systems that are needed for the experiment to be prepared should be inserted (think especially on campaign preparations). In particular, any custom solutions such as loading, fluid filling, verification, calibration, or assembly equipment should be described in detail.

4.10 Changes from Former Flight (for Re-Flights only)

If the experiment will fly on the REXUS or BEXUS for a second time, or is inherits major components of an experiment that flew before, the team shall explain this clearly in the SED, as follows:

In section 4.1, the team shall indicate which subsystems are used without any modifications and which ones are modified or re-designed.

In section 4.3, the team shall specify which components are pre-flown (components that already flew as part of the previous experiment) and which ones will be newly manufactured or procured.

In section 4.4 to 4.9 the team shall describe the experiment as it will fly, but it shall be comprehensible which subsystems or components are inherited from the initial flight and which ones are new designed. This could be achieved by splitting the sections into differed subsections, for example:

- 4.4 Mechanical Design
    - 4.4.X Ejection System
        - 4.4.X.1 System Overview
        - 4.4.X.2 Inherited Components
        - 4.4.X.3 New Components

In this section (section 4.10), the team shall provide a summary of all changes form the initial flight configuration. For each redesigned component or subsystem, it shall be described:

- What the initial flight configuration looked like.
- Why the initial design had to be changed.
- What the new design is, with a link to the appropriate section in this SED.

This should not be more than one page per component.

5 EXPERIMENT VERIFICATION AND TESTING

After the design and implementation of the experiment according to the experiment requirements (Chapter 2), it must be determined whether these requirements are actually fulfilled. The process of checking the experiment (or parts of it) against the requirements is called verification.

The overall objective of verification is to demonstrate, through a dedicated process, that the deliverable experiment meets the specified requirements. See ECSS-E-ST-10-02C [8].

In reality requirements verification is a continual process and should be considered throughout the design in a concurrent design scenario – the final review, inspection and test should be a formality of verification.

Example:

The example requirement D.1 ('The experiment shall be designed to operate in the temperature profile of the BEXUS balloon') can be verified by performing an appropriate thermal test of the whole experiment.

5.1 Verification Matrix

In this section, all the requirements defined in chapter 2 should be copied, or crossed reference, into a verification matrix where it will be defined how to verify them.

There are four established verification methods. For more details see: ECSS-E-ST-10-02C [8]:

- Verification by test (T), see the example above.
  Verification by test is performed by subjecting the experiment to a physical test.
- Verification by inspection (I).
  Verification by inspection is performed by simply inspecting/looking at the experiment.
- Verification by analysis or similarity (A).[1]
  Verification by analysis is performed by e.g. running a computer simulation on some parts of the experiment.
- Verification by review-of-design (R).
  Verification by review-of-design uses design documents (schematics, engineering drawings, etc.) to show that the experiment will perform as expected.

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[1] Verification by similarity is performed by proving that a part of the experiment is similar to a part that has already been flown successfully and will be flown in the same conditions. If the conditions are different, it must be proven that the conditions in which the previous experiment has been flown are still applicable.

All the requirements should be listed in a table similar to the following:

Table 5-1: Example of a verification table with a column for the verification method

ID	Requirement text	Method	Reference	Status	Verification Result
D.1	The experiment shall operate in the temperature profile of the BEXUS balloon.	A,T	Test 1	A – Verified T – To be done (Spring 2018)	**Pending**
O.X	The experiment shall be equipped with an arm plug that can be removed easily prior to launch.	I, T	Test 2	I – Done (See Inspection report - 15 September 2018) T – Done and failed (See test report - October 2018)	**Not verified**
D.X1	If the experiment uses its own batteries: The experiment batteries shall be qualified for use on a BEXUS balloon / REXUS rocket.	A	Analysis 1	A – Verified (See Analysis report - 10 April 2018)	**Verified**
D.X2	If the experiment uses its own batteries: The batteries shall either be rechargeable or shall have sufficient capacity to run the experiment during pre-flight tests, flight preparation and flight.	R, A	Datasheet 1, Analysis 2	R –Done May 2018 A – June 2018	**Pending**

Comments on examples (Table 5-1**):**

- Requirement O.X can be verified by inspection (simply looking whether the arm plug is there) and by testing (demonstrating) that it can actually be removed easily.
- Requirement D.X1 could theoretically be verified by testing the batteries in the applicable conditions, i.e. performing a thermal vacuum test. However, if it can be proven that the batteries (same batteries from the same manufacturer) have been flown successfully in these conditions before and are recommended for this purpose, the batteries can simply be verified by similarity.
- Requirement D.X2 can be verified by review-of design. It can be shown that rechargeable batteries have been chosen in the design. Requirement D.X2 can also be verified by analysis. Through a power budget calculation (analysis), the battery capacity can be shown to be sufficient.
- Where a requirement is verified by testing or analysis, it shall be linked to the relevant test (which should be listed in Section 5.2).
- In the “Status” column, the status of the verification item should be indicated. For every verification method one of the following notes should be inserted, including the corresponding period or date:
    - **To be done** – if the requirement has not been verified yet with that specific verification method
    - **Done and failed** – if the method was enacted but the requirement was not verified
    - **Done** – if the requirement has been verified with that specific verification method and was successful
- In the “Verification result” column, the closure status of the verification item should be indicated. For every requirement, the closure status can be identified as:
    - **Verified** – if all the requirement has been successfully verified for all the verification methods indicated in the “Verification” column
    - **“Blank space”** – if the requirement has not been totally verified yet, but verifications already performed were successful
    - **Not verified** – if at least one of the verifications was not successful

Note: *Your experiment’s flight on REXUS or BEXUS is* ***not*** *part of the verification process. All requirements must be verified prior to the flight.*

5.2 Verification Plan

After reviewing the previous section, the tests and/or analysis required for the experiment, or its parts shall be identified.

In particular, all the planned tests should be described in tables like the following (one for each test). Tests should also be included in the Work Breakdown Structure and Schedule in Chapter 3.

Table 5-2: Example of a test description for a particular test

Test number	*E.g. Test 3*
Test type	*E.g. Thermal (Hot, Cold, Cycles) / vacuum / thermal vacuum / vibration (transient or sinusoidal) / shock / electromagnetic interference / static load /*
Test facility	*It is important to indicate where you will perform the testing. In your University? External facilities?*
Tested item	*the whole experiment (system level test), a subsystem or a single component*
Model	*Qualification/Flight/Prototype/Proto flight Model*
Procedure, Test level and duration	*Example: Acceptance test, 3 min. Justification for this value may be referenced.*
Test campaign duration	*Example: 2 days (1 day build-up, 1 day testing and packing)*
Test campaign date	*If no exact date is set yet,* ***include at least the month***
Test completed	*YES/NO*
Requirements verified	*REQ ID #1: YES/NO/PARTIALLY* *REQ ID #2: YES/NO/PARTIALLY* *…*

Comments on model philosophy:

- **Qualification model:** This model is close to the end item in all design aspects and functions. It is used for qualification testing.
- **Flight model:** This is the flight-end item. Functional and environment acceptance testing shall be performed on this model.
- **Protoflight model:** This model corresponds to the flight end item on which has been undergone partial or complete qualification and acceptance testing.
- **Prototype model:** This model has a reduced scope compared to the protoflight model and is used to qualify a limited number of parts.

Within the frame of the REXUS/BEXUS programme, the most common model philosophy is the protoflight. The use of different models is more costly but reduces the risks induced by the novelty of some design aspects. Further information on model philosophy can be found on ECSS-E-ST-10-02C [8].

5.3 Verification Results

In this section, the results of the verification process should be recorded and it should be stated whether further testing is necessary. Fill in the table below and provide graphs, figures and photos where applicable. Only an overview of the test results should be included – full test reports can be included in the appendix.

Table 5-3 - Example of a test result overview

Verification number	*E.g. Test 3*
Type of test	*E.g. Environmental Test*
Facility	*E.g. Thermal Vacuum Chamber*
Verified item	*E.g. Full experiment*
Verification description	*E.g. The experiment has been placed in the TVC and kept running for 1 h after stabilisation at a temperature of -30 °C*
Expected results	*E.g. The experiment should remain working down to -30 °C and the PCB must stay within the temperature range specified in the datasheet.*
Obtained Results	*E.g. After reaching a constant value of the temperature of -30°C, the temperature of PC 104 has maintained a constant value (below the maximum limit provide by the datasheet), without further increasing.*
Conclusions	*E.g. Successfully verified / Partially verified / Not verified*

6 LAUNCH CAMPAIGN PREPARATION

A launch campaign needs meticulous preparation. EuroLaunch (SSC/MORABA) should be aware of all information needed to be able to successfully fly the experiment. Therefore, all the necessary information must be summarised in this chapter, even if it can also be found in another section of the SED (when updating the document, it's important to change information in both sections – it is recommended to consider the use of automatic cross referencing to avoid errors).

Furthermore, it is necessary to detail any special activity during launch preparation, countdown, flight, or recovery (it may be necessary to request specific approval for some activities).

Finally, any special provisions that need to be arranged in advance should be described (e.g. a clean room, special tools, dry ice, etc.). These are called **launch site requirements**. It is recommended that details of the launch site requirements are communicated in advance for organizational purposes and in order not to violate rules and regulations mentioned in the Esrange Safety Manual [9].

6.1 Input for the Campaign / Flight Requirement Plans

EuroLaunch (SSC/MORABA) will issue a Campaign Requirement Plan (CRP) for BEXUS or Flight Requirement Plans (FRPs) for REXUS. The C/FRP is the document that gives an overview of all experiments on an individual BEXUS balloon or REXUS rocket mission. In particular, it details the interfaces (mechanical, electrical, etc.) that every experiment has toward the launcher. The first versions of these documents are distributed after the CDR. For all BEXUS missions, SSC is responsible for the CRP whereas MORABA is responsible for all REXUS FRPs. The C/FRP defines the mission payload, the mission requirements, and the services to be provided by EuroLaunch. Special requirements for mission preparation, mission performance and for post flight activities must be listed here for every experiment.

From the experiment teams, first inputs for the CRP/FRP are required at the PDR and comprise the following information:

1. Dimensions and mass of experiment components
2. Ground and Flight Safety risks
3. Electrical interfaces (power consumption, use of uplink and downlink)
4. Launch site requirements
5. Flight Requirements
6. Accommodation Requirements
7. Special requirements (experiment preparation, calibration, tests, flight conditions, e.g. time of day, visibility)
8. Timeline for mission preparation and post mission activities

6.1.1 Dimensions and mass

It is mandatory to complete the following table as a summary (the table is cross-referenced to that in Section 4.3, updating the document or the field will automatically update the values. If this doesn't work, the table in section 4.3 can be copied and pasted.):

Table 6-1: Experiment mass and volume

Experiment mass (in kg):	
Experiment dimensions (for BEXUS) or module size (for REXUS) (in m):	
Experiment expected COG (centre of gravity) position:	

For BEXUS

If the experiment consists of several separate boxes or units, the dimensions, mass, and COG of each component should be indicated.

For REXUS:

It should be stated whether the mass includes the experiment module, bulkhead, hatch, etc.

The mass of the system should be specified at the following stages:

- Mass at lift-off (with module).
- Mass at de-spin (with module).
- Mass at re-entry (with module).

6.1.2 Ground and Flight Safety Risks

The team shall complete the table in the SED template. The risks shall consider all stages of the campaign, flight, recovery and experiment transport. The risks shall include, but are not limited to:

- Stored energy devices
    - Mechanical (e.g. springs)
    - Chemical (e.g. batteries or explosives – including pyro cutters/pyro actors)
- Chemical substances in liquid or powder form
- Radioactive material
- Flammable substances
- Pressure vessels (including those sealed at ground pressure)
- Hazardous mechanical systems (e.g. fast moving parts)
- Transmitters (both high power transmission and those with frequencies which may affect flight systems)
- Lasers
- High voltage systems (>60V DC)
- High temperature systems (>60^{o}C)
- Sharp or cutting edges

- Any ground support equipment interfacing with the armed rocket (e,g. umbilical connections)
- Any late access events on BEXUS after pick-up.

The description of risks, key characteristics and mitigation shall be succinct and clear. Where available, Material Safety Data Sheets (MSDS) shall be included in the appendix.

It is important to note that inclusion/use of many of the above items in an experiment or during the campaign requires specific permission from EuroLaunch – inclusion in the SED is required but does not guarantee acceptance for flight.

Perceived risks i.e. those which the team know not to be risks, but may be deemed so by those encountering the experiment for the first time shall also be included.

Example:

Table 6-2: Example Safety Risks

Risk	Key Characteristics	Mitigation
Flight of Lithium-Ion Batteries	Type: LSH 20 (Li-$SOCl_2$) Number of: 12 Total Capacity: 156Ah	Batteries tested in thermal vacuum to 0.5mbar under expected mechanical, electrical and thermal load. Batteries previously flown on BEXUS 12.
Use of Radioactive sample during ground testing	Type: Cobolt-60 Radiation: Gamma & Beta Mass: <1g Energies: 1173.2, 1332.5 KeV (γ), 317.9 (β)	Low energy, small, sealed sample does not pose hazard to health, even if ingested. Team received training in handling radioactive substances. Material Safety Data sheet and appropriate warning signs shall be displayed in the working area.
Use of Laser during flight	Type: Class 3B Power: wavelength	Closed path, not possible to expose path without cutting power. Team received training in handling lasers.

6.1.3 Electrical Interfaces

One of the following tables (either BEXUS or REXUS) must be completed, giving a summary of the experiment's electrical interfaces (power consumption, use of uplink and downlink, number of E-Link connections (BEXUS), Number of required IP addresses (BEXUS)). The necessary calculations should be performed in the applicable sections in Chapter 4.

The units should not be changed and should be stated clearly in the table.

Table 6-3: Electrical interfaces applicable to BEXUS

BEXUS Electrical Interfaces		
E-Link Interface: E-Link required? Yes/No		
	Number of E-Link interfaces:	Usually 1
	Number of required IP addresses:	Usually 2, one for the experiment and one for your ground station.
	Data rate – downlink (max. and average):	Kbit/s
	Data rate – uplink (max. and average):	Kbit/s
	Interface type (RS-232, Ethernet):	(Ethernet recommended)
Power system: Gondola power required? Yes/No		
	Peak power and current consumption:	W and A
	Average power and current consumption:	W and A
	Total power and current consumption after lift-off	Wh and Ah
Power system: Experiment includes batteries? Yes/No		
	Type of batteries:	
	Number of batteries (and S x P):	
	Capacity (1 battery):	Ah
	Voltage (1 battery):	V

Table 6-4: Electrical interfaces applicable to REXUS

REXUS Electrical Interfaces		
Service module interface required? Yes/No		
	Number of service module interfaces:	Usually 1
	TV channel required? If yes, when is it required:	(Optional) from/to s after lift-off
Up-/Downlink (RS-422) required? Yes/No		
	Data rate – downlink (max and average):	Kbit/s
	Data rate – uplink (max and average):	Kbit/s
Power system: Service module power required? Yes/No (usually yes)		
	Peak power and current consumption:	W and A
	Average power and current consumption:	W and A
	Total power and current consumption after lift-off (until T+600s)	Wh and Ah
	Power ON	s before lift-off (usually 600)
	Power OFF	s after lift-off (nominally 600)
	Battery recharging through service module:	Yes/No
Experiment signals: Signals from service module required? Yes/No (specify if they are related to flight events e.g. nosecone separation, etc.)		
	LO:	Yes/No
	SOE:	s after/before lift-off
	SODS:	s after/before lift-off
	Pyro(s):	s after lift-off

It is suggested to use and implement rocket signals in the experiment timeline, especially for experiments requiring time synchronization.

6.1.4 Launch Site Requirements

This section should contain a list of any special equipment, facilities, consumables, or tools needed prior, during or after launch that should be provided by EuroLaunch, taking in consideration also space needed, tables, chairs, power outlets, gases, dry ice, chemicals, laminar flow benches, use of a bio/chemical laboratory, laboratory equipment, etc.

Example:

Table 6-5: Example for Launch Site Requirements

Category	**Item**	**Amount**
Workstation	Table	1
	Chair	5
	Whiteboard	1
	Power Supply, 0 – 30V	1
	Power extension cord	2
	…	
Measuring instruments	Multimeter	1
	Oscilloscope	1
	Spectrum analyser	1
	…	
Consumables	Zip ties	multiple
	PVC Electrical Tape	multiple
	…	
Chemicals	Isopropyl alcohol	100 ml
	…	
Labs / Rooms	*If needed, explain what kind of lab or room you would need and when you would need to have access to it* *List also material needed inside the lab / room.*	1
…	…	

6.1.5 Flight Requirements

For BEXUS

The desired float duration and altitude must be specified.

The team should also state any requirements on time of launch, considering local sunrise and sunset time.

Table 6-6: Flight Requirements applicable to BEXUS

Optimal altitude	
Preferred path	
Minimum float time	
Ground track length	
Light/dark condition	**Note**: Here it also shall be described if the light/dark condition is needed on ground or at the flight altitude. If needed at the flight altitude, it would be beneficial to define a launch window.

For REXUS

The team should state flight requirements and timeline events requirements applicable to REXUS.

Table 6-7: Flight Requirements applicable to REXUS

De-spun/spinning	**Note:** If your experiment requires reduced gravity, the rocket needs to be de-spun.
Weather conditions during countdown	
Module temperature during countdown	**Note**: If your experiment module should be kept in a defined temperature range, this should be described here.
Launch window	

Table 6-8: Flight Requirements on timeline events applicable to REXUS

Yo-yo de-spin	
Motor separation	
Nosecone ejection	

6.1.6 Accommodation Requirements

For BEXUS

Any requirements or preferences for gondola placement should be included in this section.

In particular, the team shall include any requirements on placement specifically away from or close to other experiments or BEXUS flight systems (both on the gondola and the flight train). Also, requirements for viewing from the side of the gondola and/or through the top/bottom of the gondola should be specified. To clarify the written requirements a schematic should be included and referred to.

Any request to have the gondola covered, partially covered or uncovered must be also specified.

For REXUS

The team shall include any requirements/preferences for position in the payload stack with reference to nosecone, the service module, interference with other experiments, or the Centre of Gravity at lift off, de-spin or recovery.

6.2 Preparation and Test Activities at Esrange

In this section, the activities at Esrange prior to launch should be described.

The team shall give the timeline and the procedures which must be carried out.

It is recommended to organise the team: Who is doing what, and when? The team should create a checklist and indicate the responsible person for each task giving the following information:

- Experiment preparation
- Functional tests of the experiment
- Flight simulation
- Duration

The planned activities must be clearly shown here, consider using a table like the one below and include tasks, people responsible, time/day, and duration.

Table 6-9: List of planned activities

Time/Day	Main Task	Description	Responsible	Duration [h:m]	Comments

To save time and increase efficiency, activities should be prepared and practiced in the form of check-listed processes. These shall be referenced and included in the appendix. Reference can be made to previous year's Campaign Requirement Plan (CRP) to have an idea of the time available at Esrange for the experiment preparation and test activities – in addition to the campaign morning meeting teams can make use of team morning meetings to clarify and allocate tasks. Having a whiteboard or display is very useful on campaign to keep track of who should be doing what.

Teams should also be sure to make maximum use of the personnel attending campaign, try not to have overworked and underworked colleagues!

Furthermore, operational activities for the experiment shall be described. The launch crew team should know:

- Is there any remove before flight part?
- Is there any special recovery operation to be performed by the recovery team?
- Is there any special handling procedure during motor mating, roll out, loading and/or countdown?
- Does the team need a late access?
- Is there a temperature range to be respected during operations?

6.3 Timeline for Countdown and Flight

This section should contain information about all operational aspects necessary to perform the experiment.

- When will the experiment start recording data? When will it stop?
- When and how is the experiment switched on?
- What events take place during the flight?

The sequence of events should be listed filling in the table below, mentioning the time relative to the launch (T=0), the duration of the action, the expected altitude and any other relevant information (experiment signals synchronised with main flight events before LO, such as Power ON signal, are highly discouraged):

Table 6-10: Example of timeline of the REXUS experiment events

Time [s]	Signal	Function
T-600s	POWER ON	Experiment switched on
T- 350s	SOE	Camera start to acquire data
T- 125s	SODS	First sync of the signals
T+0s	LO	Second sync of the signals
T+56s	SOE OFF	Camera is switched off
T+600s	POWER OFF	Experiment switched off

Table 6-11: Example of timeline of the BEXUS experiment events

Time [s]	Task	Comment
T-5:00 h	Team briefing	Reminder of scheduled tasks
T-2:00 h	Functionality test	Verify experiment is in working condition
T-1:30 h	Remove all RBFs	Late access to experiments[2]
T 0:00 h	Launch	Monitor experiment
T+1:30 h	Float phase	
T+4:30 h	End float phase	

[2] NOTE: All late access events (REXUS & BEXUS) and Remove before Flights items (RBFs) shall be included here! Late access options can be found in the manual [6] [7], but how this is carried out must be clarified with EuroLaunch (SSC/MORABA).

6.4 Post-Flight Activities

This section should contain the description of all the activities to be performed after landing.

A recovery sheet like the one in the example below, should be included:

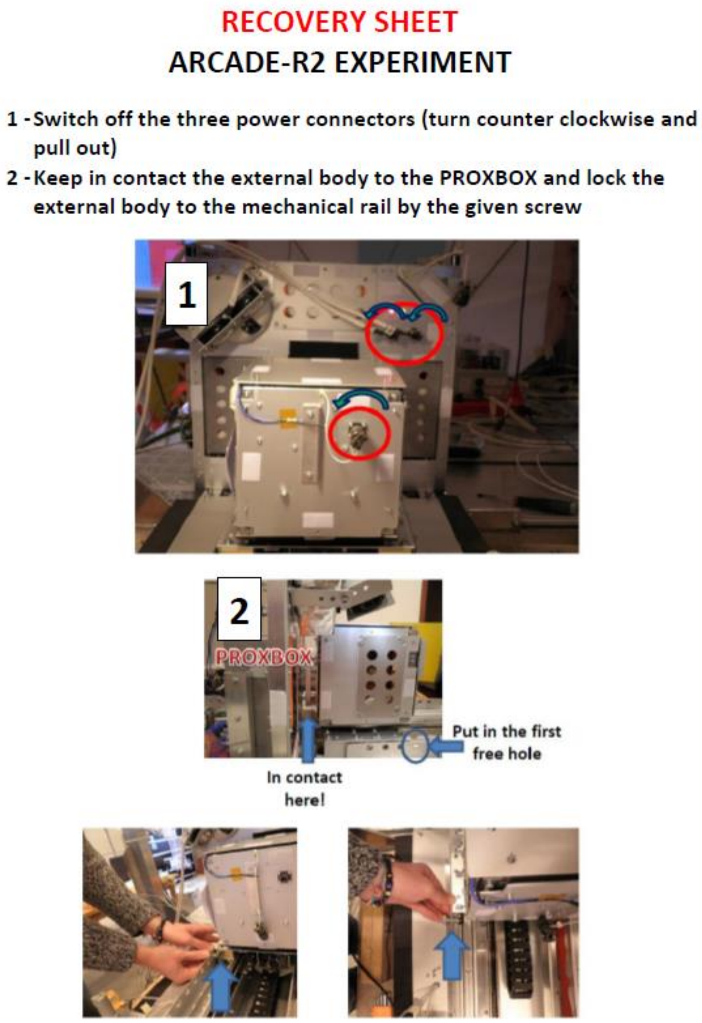

Figure 6-1 - Example of Recovery Sheet of Team ARCADE-R2 Experiment of BEXUS 17

This should show what must be done by the recovery team (from EuroLaunch). Ideally this is one sheet showing a very simple procedure such as disconnecting a single cable. One should think about conditions of recovery where a payload can be in a very difficult place to reach and often with snow around. For REXUS, it is not normally necessary to provide such information but, in this case, it should be clearly stated that no recovery actions are needed.

Upon return of the experiment to Esrange plan the timeline and the procedures which must be carried out.

It is recommended to organise the team: Who is doing what and when?

- Experiment and sample recovery
- Transport of equipment and samples back home
- Analysis and evaluation of experiment data

7 DATA ANALYSIS AND RESULTS

7.1 Data Analysis Plan

In space projects, a successful flight is not the end of the story. It is also of utmost importance to analyse and use the data gathered during the flight as well as to draw conclusions about the success of the experiment and think about "Lessons Learned". The scientific/technical results should link directly to the mission statement and experiment objectives.

In this section, the team shall describe how they will produce scientific results and how they plan how to use and analyse the data or evaluate the results.

It should be indicated when and what kind of activities are planned, and what kind of facilities, instruments, etc. they intend to use.

7.2 Launch Campaign

This section should include:

1. Flight preparation activities as they happened during the launch campaign
2. Flight performance
   - Form and amount of data
   - Possible failures and malfunctions, failure analysis
   - Power consumption
   - Thermal behaviour of the experiment
3. Recovery (condition of experiment, reusability, damages)
4. Post flight activities (disassembly, first data evaluation, packing)

This section shall be filled after the campaign. All advance planning for the campaign shall be described in chapter 6.

7.3 Results

This section should contain:

1. Technical results and scientific data evaluation
   Estimated scientific success with respect to objectives
2. Outlook
   - Further data evaluation
   - Improvement of experiment and recommendations
   - Planned presentations and publications.

7.4 Input to Campaign Report

Some weeks after the campaign, a Campaign Report will be issued by EuroLaunch. In this section, there should be a copy of the one-page written summary of the experiment operations, preliminary results and plans for further data analysis or experiment follow-up. A picture of the team and/or the experiment should also be included.

7.5 Lessons Learned

This section is dedicated to all the lessons learned during the participation in the REXUS/BEXUS programme. In particular, it should contain a list and description of:

1. Special experiences and problems
   - during the project
   - during the experiment preparation and development
   - during tests and reviews
   - during the flight campaign
2. Identified failures and mistakes
3. Possible improvements
   - of the experiment (planning, testing, documentation)
   - of the internal team management
     (time management, communication inside and outside)

It is important to **start documenting the lessons learned already from the first SED version**, describing the lessons learned not only during the design, implementation and testing process but also during the organisation and management phases.

8 ABBREVIATIONS AND REFERENCES

8.1 Abbreviations

This section contains a list of all abbreviations used in the document.
Any additional abbreviations can be added to the list below, but, in general, all acronyms and abbreviations should be defined the first time they are used.
In version 5 of the SED (final version), unused abbreviations should be deleted.
It is recommended to use a dedicated software or 'add-in' to capture and record all abbreviations and acronyms used in the document.

ASAP	As Soon As Possible
CDR	Critical Design Review
COG	Centre of Gravity
CRP	Campaign Requirement Plan
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EAR	Experiment Acceptance Review
ECTS	European Credit Transfer System
ESA	European Space Agency
Esrange	Esrange Space Center
ESTEC	European Space Research and Technology Centre, ESA (NL)
FST	Flight Simulation Test
FRP	Flight Requirement Plan
GUI	Graphic User Interface
IPR	Integration Progress Review
LO	Lift Off
MORABA	Mobile Raketen Basis (DLR, EuroLaunch)
PCB	Printed Circuit Board (electronic card)
PDR	Preliminary Design Review
RBF	Remove Before Flight
SED	Student Experiment Documentation
SNSA	Swedish National Space Agency
SODS	Start Of Data Storage
SOE	Start Of Experiment
SSC	Swedish Space Corporation
T	Time before and after launch noted with + or -
TBC	To be confirmed
TBD	To be determined
WBS	Work Breakdown Structure
ZARM	Zentrums für angewandte Raumfahrttechnologie und Mikrogravitation

8.2 References

The document should stick to a single referencing format, with IEEE being preferred.

It is recommended to use a dedicated referencing software or inbuilt tool/add-in to correctly reference material throughout the document.

[1] ECSS, “ECSS Standards,” [Online]. Available: https://ecss.nl/standards/.

[2] ECSS, “ECSS-E-ST-10-06C – Technical requirements specification,” 6 March 2009. [Online]. Available: https://ecss.nl/standard/ecss-e-st-10-06c-technical-requirements-specification/.

[3] ECSS, “ECSS-M-ST-10C Rev.1 – Project planning and implementation,” 6 March 2009. [Online]. Available: https://ecss.nl/standard/ecss-m-st-10c-rev-1-project-planning-and-implementation/.

[4] Project Managment Institute, Practice Standard for Work Breakdown Structures - Second Edition, Pennsylvania, USA, 2006.

[5] ECSS, “ECSS-M-ST-80C – Risk management,” 31 July 2008. [Online]. Available: https://ecss.nl/standard/ecss-m-st-80c-risk-management/.

[6] EuroLaunch, “BEXUS USER MANUAL V8,” 03 June 2021. [Online]. Available: https://rexusbexus.net/bexus/bexus-user-manual/.

[7] EuroLaunch, “REXUS USER MANUAL V7-17,” 26 November 2021. [Online]. Available: https://rexusbexus.net/rexus/rexus-user-manual/.

[8] ECSS, “ECSS-E-ST-10-02C Rev.1 – Verification,” 1 February 2018. [Online]. Available: https://ecss.nl/standard/ecss-e-st-10-02c-rev-1-verification-1-february-2018/.

[9] SSC, “Esrange Safety Manual - SCIENCE-60-4208,” 12 June 2020. [Online]. Available: https://sscspace.com/wp-content/uploads/Esrange-Safety-Manual.pdf.

APPENDIX A – EXPERIMENT REVIEWS

The review reports from each review shall be included here.

Preliminary Design Review - PDR

Experiment documentation must be submitted **around 2 weeks** (the exact date will be announced) before the review (SED version 1). The documentation shall meet the level of details required in the relevant section of these SED guidelines. In addition, the team shall prepare a presentation to be given in front of review panel and upload the presentation on the TeamSite after the review.

1. REVIEW PANEL

The review panel is composed of experts from DLR, SNSA, ESA, SSC, ZARM and DLR MORABA. For each review, a chair is designated in the review panel to lead the progress of the discussion and ensure that all points are covered during the timeframe of the PDR. In addition, a member of the panel is responsible for taking minutes in order to provide all relevant information to be included in the PDR report which will be sent to the team.

2. TIMELINE

A typical PDR timeline (can be adapted) may be:

- 10 minutes pre-discussion with panel only
- 20 minutes presentation
- 50 minutes review (comments and questions from the panel)
- 10 minutes post-discussion with panel only

3. CONTENT OF THE PRESENTATION

All students participating to the review shall take an active part of the presentation. Examples points to be addressed during the presentation are (non-exhaustive):

- Short introduction to the experiment
- Team organization and task distribution
- Top level/driving experiment requirements
- Experiment setup, expected mass, volume, power consumption
- Preliminary design concept (electrical, mechanical, thermal,…)
- Current status of the experiment planning and schedule for development, production and testing
- Risk analysis (experiment and safety)
- Outreach activities
- Identified problems

4. CONTENT OF THE REVIEW

Typically the review panel will address the following points (can be subject to change if needed):

- **General comments**
  - Presentation
  - SED
- **Technical**
  - Requirements and constraints
  - Mechanics
  - Electronics and data management
  - Thermal
  - Software
  - Verification and testing
  - Safety and risk analysis
  - Launch and operations
  - Organisation, project planning & outreach
  - Others

5. RESULT

A detailed report of the PDR containing actions and comments raised by the panel will be sent to the team around 1-2 weeks after the review. The result of the review can either be:

- PASS: All sections of the SED are duly completed with PDR-level information or even more advanced level information and all critical points of the experiment have been identified and addressed.
- CONDITIONAL PASS: Some PDR-level information and/or critical points of the experiment are not addressed.
- FAIL: The level of information provided does not reach the PDR-level.

All actions and comments shall be addressed for the next review. The panel can ask the team for a SED update in case some key information is missing at PDR level.

Critical Design Review - CDR

Experiment documentation must be submitted **around 2 weeks** (the exact dates will be announced) before the review (SED version 2). The documentation shall meet the level of details required in the relevant section of these SED guidelines.

In addition, the team shall prepare a presentation to be given in front of review panel and upload the presentation on the TeamSite after the review.

1. REVIEW PANEL

The review panel is composed of experts from DLR, SNSA, ESA, SSC, ZARM and DLR MORABA. As per the PDR, both a chair and minutes responsible are designated for each review.

2. TIMELINE

A typical CDR timeline (can be adapted) may be:

- 10 minutes pre-discussion with panel only
- 20 minutes presentation
- 1h10 review (comments and questions from the panel)
- 10 minutes post-discussion with panel only

3. CONTENT OF THE PRESENTATION

All students participating to the review shall take an active part of the presentation. Example points to be addressed during the presentation (non-exhaustive) are:

- Team organization and time schedule, manpower
- Report of experiment status incl. cost calculation
- Experiment set-up
- Detailed mechanical and electrical design description (drawings and schematics)
- Data management design (TM, TC, data storage)
- Software design
- Thermal design
- Interfaces to the vehicle (mechanical, electrical, data transmitting)
- Possible interference with other experiments
- Test plan for experiment flight hardware
- Operational concept, launch campaign and mission planning
- Description of pre-flight, in-flight and post-flight activities
- Risk analysis

- Safety concept
- Planned and running outreach activities

4. CONTENT OF THE REVIEW

Similarly, to the PDR, the review panel may address the following points (subject to change if needed):

- **General comments**
    - Presentation
    - SED
- **Technical**
    - Requirements and constraints
    - Mechanics
    - Electronics and data management
    - Thermal
    - Software
    - Verification and testing
    - Safety and risk analysis
    - Launch and operations
    - Organisation, project planning & outreach
    - Others

5. RESULT

A detailed report of the CDR containing actions and comments raised by the panel will be sent to the team around 1-2 weeks after the review. The result of the review can either be:

- PASS: All sections of the SED are duly completed with CDR-level information or even more advanced level information. All actions and comments from PDR have been tackled.
- CONDITIONAL PASS: Some CDR-level information and/or critical points of the experiment and/or some major actions and comments from PDR are still not addressed.
- FAIL: The level of information provided does not reach the CDR-level.

All actions and comments shall be addressed for the next review. The panel can ask the team for a SED update in case some key information is missing at CDR level.

Integration Progress Review - IPR

Experiment documentation must be submitted **around one week** (the exact date will be announced) before the review (SED version 3). The input for the Campaign/Flight Requirement Plans should be updated if applicable. The IPR will generally take place at the location of the students' university, normally with the visit of one expert.

Content of IPR:

- Team presentation of project status
- Review of schedule status with respect to REXUS/BEXUS programme timeline and upcoming activities
- Follow-up of CDR action items
- Discussion of any open design decisions if applicable
- Discussion of review items still to be closed
- Discussion of potential or newly identified action items
- Discussion of components or material still to be ordered or received by the team
- Clarification of any technical queries directed towards the visiting expert(s)
- General assessment of experiment status
- Photographic documentation of experiment integration status, with comments where necessary
- Communication and functional testing (Service System Simulator testing for REXUS and E-link testing and BEXUS)
- Description in the teams' own words, of the integration plan leading up to the EAR.
- Discussion of the test plan and inspection of available facilities where applicable.
- Decision of review outcome: PASS/CONDITIONAL PASS/FAIL. If a CONDITIONAL PASS is elected, the immediate action items should be discussed, along with an appropriate deadline.

A detailed report of the IPR containing a description of the experiment status, actions and comments raised by the visiting expert(s) will be sent to the team around 1-2 weeks after the review.

Experiment Acceptance Review - EAR

Experiment documentation must be submitted **around one week** (the exact date will be announced) before the review (SED version 4). The review may take place at either the location of the students' university, or a DLR, SSC, ZARM or ESA institute.

Content of EAR:

- Team presentation of project status
- Follow-up of IPR action items
- Review of schedule status with respect to REXUS/BEXUS programme timeline and upcoming activities
- Demonstration of the fully integrated experiment
- Experiment mass properties determination/discussion
- Mechanical and electrical interface checkout
- Electrical Interface Test (REXUS Service System Simulator test or BEXUS E-link functionality test)
- Flight Simulation Test (FST) – including a full end to end system demonstration
- Photographic documentation of experiment integration status, with comments where necessary
- Experiment acceptance decision: PASS/CONDITIONAL PASS/FAIL. If a CONDITIONAL PASS is elected, the immediate action items should be discussed, along with an appropriate deadline(s).

A detailed report of the EAR containing a description of the experiment status, actions and comments raised by the visiting experts will be sent to the team around 1-2 weeks after the review.

APPENDIX B – OUTREACH AND MEDIA COVERAGE

Here the team should insert a summary list or table of all outreach actions performed and media coverage received. This should include:

- The URL of the website, social media pages etc.
- Any performed outreach actions, e.g. publishing press releases, contacting journalists, designing a logo or information brochure
- Details of media coverage, e.g. newspaper articles, radio/TV interviews, internet news articles, etc.
- Presentations given by the team members, e.g. at the university or a conference
- Exhibitions of the experiment, e.g. at a fair or university open day

It is recommended to attach copies or photographs of the information and material listed above, if possible, and include reference numbers in the list. Any pictures should be credited.

APPENDIX C – ADDITIONAL TECHNICAL INFORMATION

This Appendix shall include:

- Engineering drawings
- Electronics schematics
- PCB layouts
- Datasheets of components
- Verification reports

APPENDIX D – CHECKLISTS

In this appendix all checklists for experiment preparation and test activities at Esrange and integration events should be included.