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 Board (SNSB). The Swedish share of the payload has been made available to students from other European countries through a collaboration with the European Space Agency (ESA).

EuroLaunch, a cooperation between the Esrange Space Center of SSC and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operations of the launch vehicles. Experts from DLR, 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	Preface, 2.3, 3.5.1, 4.2.2, 4.5, 5.1, 6.1.5, 6.1.6, 8.1, Appendix A	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

Abstract: These guidelines are to help the students participating in the REXUS/BEXUS student programme to produce the necessary Student Experiment Documentation (SED). They give information about the expected content of each chapter. To ease the generation of the SED, a blank book to be used by the student teams is available on the Teamsite.

Keywords: REXUS, BEXUS, SED - Student Experiment Documentation

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 directly address the student teams and include references to the standards provided by ECSS (European Cooperation for Space Standardization).

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 doc-file to be used as a starting point for each student group to describe all aspects of their experiment. There is no limit to the number of pages used for this SED, but succinctness 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 and the experts from SNSB, 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.

This preface should be replaced with an experiment relevant preface by the team.

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 additional revisions are necessary – this will be judged by the organisers. Changes should be listed in the change record list on the second page of the document.

File Naming

The naming convention for the SED is as follows:

1. BX for BEXUS or RX for REXUS, plus number of flight
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)
4. Date of issue in format ddmmmyy

e.g. BX09_COMPASS_SED_v3-0_24Apr09.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 also be updated 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.

Before submitting the SED, always check the document for consistency and ask an outside colleague for a review. Use a spelling and grammar checker to correct language mistakes. *Ask for feedback on how comprehensible the document is.*

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.

1. Write a good Introduction in Chapter 1
2. Define the Experiment Requirements in Chapter 2
3. Provide details of the project planning in Chapter 3
4. Describe the complete preliminary design in Chapter 4
5. Give a brief overview of the planned tests in Chapter 5
6. Provide tables and preliminary information in Chapter 6.1
7. Provide preliminary information in chapter 7.1

Important: All the chapters/sections should have content when the SED is submitted for the first time, even if the information is preliminary. Please do not leave any part of the document blank.

For more information on the PDR see Appendix A

Version 2

Before the CDR, the experiment requirements are already fixed. Briefly review the corresponding chapters (Chapter 1 and 2) to improve clarity and accuracy. Requirements 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.

1. Describe the complete detailed design in Chapter 4
2. Give a detailed verification plan in Chapter 5
3. Update the project plan, in particular the risk register and schedule, in Chapter 3
4. Give a detailed description of the campaign preparation activities in Chapter 6
5. Provide some lessons learned during designing the experiment in Chapter 7

Note again the importance of maturing the experiment design at this stage. After the CDR, the design is frozen so that the experiment can be built and verified. It is required to cover every detail of the experiment in Chapter 4 for the CDR, which will require meticulous preparation. This should include all detailed drawings/schematics for mechanics, software and electronics

For more information on the CDR see Appendix A

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. If necessary, make adjustments to the finished design in Chapter 4
2. Update in particular the component list in Section 4.3, including the status of component orders
3. Update and finish the verification plan in Chapter 5
4. Update the campaign preparation information in Chapter 6
5. Give a draft data analysis plan in Chapter 7.1 as well as updated lessons learned

6. Update the Gantt chart and risk register in Chapter 3 to reflect the current status

For more information on the IPR see Appendix A

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. Update and finalise all information in Chapter 6, in particular the input for the Campaign / Flight Requirement Plans and details of the experiment time events
2. Other chapters should not need updating at this stage but if difficulties were encountered during testing, an update may be necessary. Chapter 4 should describe the whole experiment as-built, in detail
3. Give a detailed data analysis plan in Chapter 7.1 as well as updated lessons learned from the testing
4. Update the Gantt chart and risk register in Chapter 3 to reflect the current status

For more information on the EAR see Appendix A

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. Provide details of the experiment results and data analysis in Chapter 7
2. Special emphasis should be placed on a summary of all Lessons Learned during the whole experiment project
3. Update other Chapters of the SED where necessary (e.g. abstract must be updated) – it should be clear throughout the document that the experiment has flown, i.e. experimenters should be careful with the use of future tense in version 5

Access to SED by various parties

The SED in all its versions will be circulated to EuroLaunch engineers and experts from DLR, ZARM, SNSB and ESA. 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 which should be kept confidential outside of the REXUS/BEXUS programme, please 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

Briefly describe the scientific or technical field relevant to the experiment, the questions addressed and assumptions made.

Reference key papers in the field, where applicable.

Mention names of any projects that have synergies with the experiment.

1.2 Mission Statement

Here the overall purpose of the experiment shall be outlined, this should be one or maximum two short paragraphs outlining the current *problem* and the required *solution.* This statement should draw on the scientific/technical background and will form 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

List all objectives of the experiment. What shall be measured/tested/investigated?

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

If applicable, distinguish between scientific and technical objectives. If appropriate, number the objectives or use tables.

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

Define 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 be quantitative (with the exception of broad financial constraints). The verifiability of the objectives should be considered but need not be included specifically.

If necessary, clarify what is not in the scope of the experiment.

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

1.4 Experiment Concept

Give an overview of the concept of the experiment which will be carried out. Name the key elements of the experiment (e.g. sensors, cameras, particle detectors).

Name the functional and/or physical blocks of the experiment (e.g. data taking unit, sensor unit).

Describe in general terms how these elements interact, without providing any technical detail. Provide a 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.

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

Briefly present the team members and their respective roles in the team.

Include their:

- 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, give the title of the course and the number of ECTS points awarded. 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, indicate 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.

Before starting the detailed experiment design, these functional, performance, design, and operational requirements need to be determined.

Analyse the experiment objectives, and the requirements of the vehicle, and then list all the experiment requirements.

Use an appropriate numbering scheme and/or a table.

Throughout the design and fabrication of the experiment, check whether all requirements 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 document ECSS-E-ST-10-06C [4] which is available on the REXUS/BEXUS TeamSite.

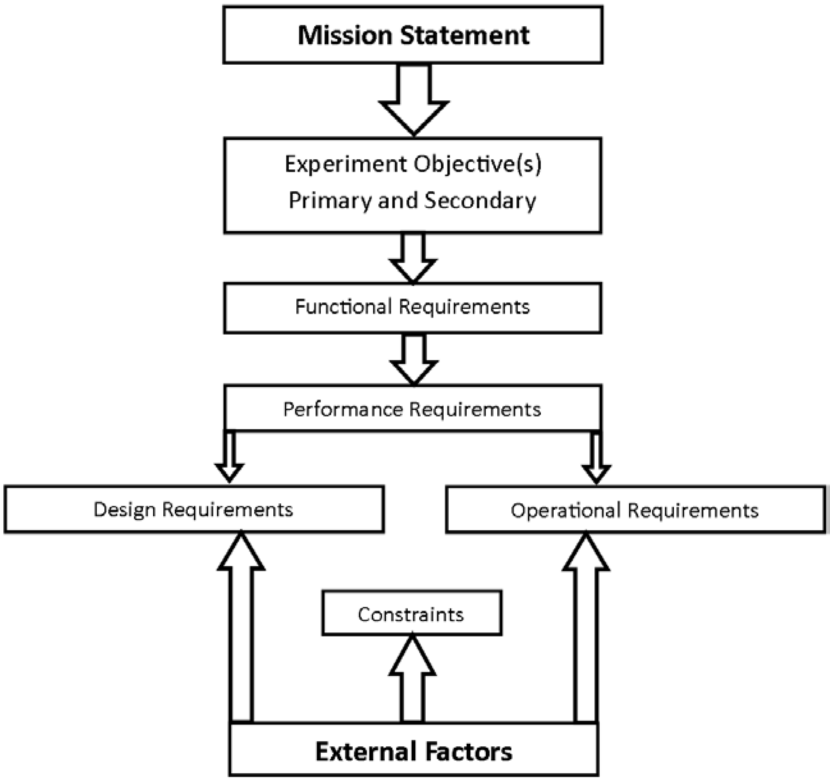

Figure 2-1: Idealised requirements flow chart

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.

Assume a hypothetical simple balloon experiment with the goal of measuring temperature in the stratosphere. The 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

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.

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 and 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.

Note that the functional requirement F.1 has led to 3 performance requirements. While it would be shorter to mention all performances in one requirement, this is not done, because it is often easier to verify the requirements individually.

2.3 Design Requirements

Design requirements define all design (system engineering) aspects that the experiment needs to fulfil in order to achieve the experiment objectives. While functional requirements and performance requirements originate from the experiment team, design requirements can 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)
- 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. Some of these requirements are directly imposed by EuroLaunch; many are listed in the REXUS/BEXUS User Manuals.

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 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 prior and after flight. 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 things which limit cost, schedule and implementation techniques available to the team. E.g. the project budget is limited to 10,000 Euros.

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 recommend 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.

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. [7]

The WP breakdown 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). Please 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.

Don't forget project management, documentation and outreach! The WBS should include 100% of the work for the project (not more, not less).

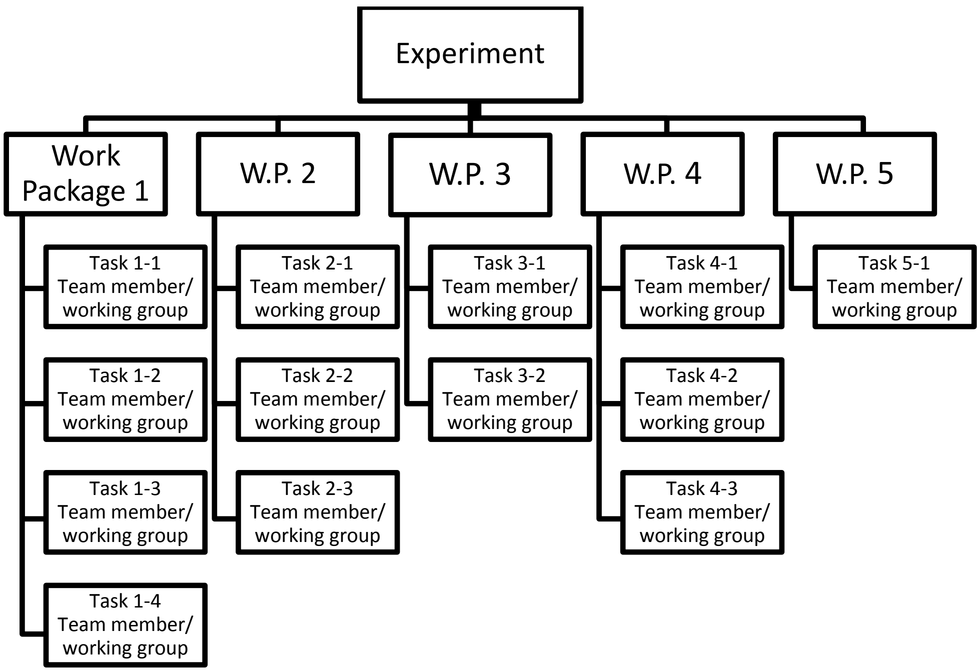

Figure 3-1: Example Work Breakdown Structure (WBS)

3.2 Schedule

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

Ensure that the chart includes post-flight activities, such as analysis and reporting. Remember 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.

Check the delivery time of critical components, especially long lead items (LLIs), and ensure that these are ordered as soon as possible. The Gantt chart 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 the 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 clear(e.g. delayed part delivery, test repetition required…).

It is recommended to include a top level Gantt chart 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 – the list of tasks which takes the longest and thus drives the project completion, and help them in allocating resources in the next section.

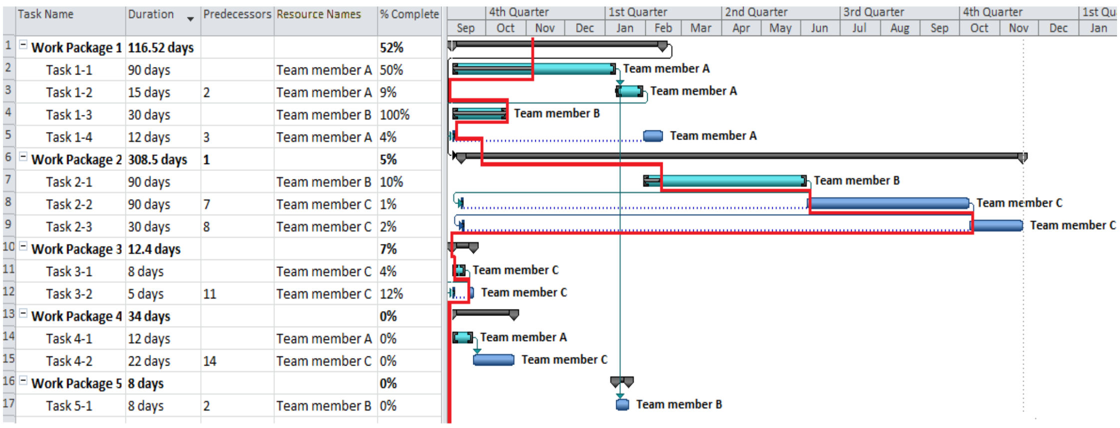

Figure 3-2: Example Gantt Chart with progress line, critical path and resource allocation

Feel free to use a landscape page and colour code to create a more clear and effective chart. Include the status of structural components (designed, ordered, delivered, assembled, tested), as well as electrical boards, sensors etc. Also show the status of the software. If there are several units using different software, indicate their status separately.

At CDR level, all components must have been designed or ordered.

At IPR level, all subsystems must have been assembled and tests have started.

At EAR level, all subsystems must have been tested and verified.

3.3 Resources

3.3.1 Manpower

Explain the work distribution within the team. This should not be a repetition of section 1.5.2.

When assigning team members, consider their skills, experience and availability.

Consider what measures are necessary if a team member suddenly becomes unavailable. Seriously consider recruiting members that can back-up another member for critical tasks.

Describe in detail here the manpower 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.

Estimate the manpower available 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. Take into consideration holidays and exam periods here. 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. Don't forget 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. Take those hours into account as well.

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

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

3.3.2 Budget

Show detailed costs and funding estimations in table form.

3.3.3 External Support

List the organizations, departments or companies that provide sponsorship or in-kind support. For example, professors of a university or institute, local companies or nearby research laboratories, facilities to which access is possible, etc. Mention any support or expertise which is lacking.

3.4 Outreach Approach

Outline the approach to publicising and communicating about the experiment. Describe the team's website or blog and how it is planned to evolve, include the link. Also mention any contact with local or national media representatives.

See Appendix B for further suggestions.

3.5 Risk Register

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

Use the following method to manage the risks within the project:

- Identify the risks in certain relevant categories
- Estimate the probability (P) and severity (S) of each risk
- Calculate the risk index (P x S)
- Propose actions to mitigate or remove the risks, or reduce them to an acceptable level
- Record all of the above in a risk register (see template below)

Update the risk register 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

…etc.

Adapt these to the experiment and add other categories.

Consider risks to the experiment, to the vehicle and to personnel.

Probability (P)

A. Minimum – Almost impossible to occur

B. Low – Small chance to occur

C. Medium – Reasonable chance to occur

D. High – Quite likely to occur

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

Severity (S)

1. Negligible – Minimal or no impact
2. Significant – Leads to reduced experiment performance
3. Major – Leads to failure of subsystem or loss of flight data
4. Critical – Leads to experiment failure or creates minor health hazards
5. Catastrophic – Leads to termination of the REXUS 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 classification, ranging from very low to very high and being coloured green, yellow, orange or red as described below.

Table 3-1: Risk index and magnitude scheme

Probability (P)					
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)	1	2	3	4	5

Table 3-2 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

Note that the SED template contains an embedded excel file which automatically calculates the Risk Index and correctly formats the cell. 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, the magnitude of some risks will be reduced by either:

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

In this case, 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 reduced risks can subsequently be entered between the original entries (see example of MS20 and MS21 below).

Table 3-3: Risk Register Template with examples

ID	Risk (& consequence if not obvious)	P	S	P x S	Action
TC10	Critical component is destroyed in testing	B	3	Low	Order spare components and keep them available
SF10	Part of experiment falls from balloon gondola over populated area during flight	C	5	High	Seek advice from EuroLaunch how to reduce probability
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
MS21	(residual of MS20)	C	1	Very low	Acceptable risk: no action

4 EXPERIMENT DESCRIPTION

In the following sections, describe the design of the experiment in detail. 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. **Try to give most information in diagrams, graphics or tables. Keep the text to a minimum and provide details that are not essential to understand the experiment in the appendix.**

Design the experiment 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

Describe the different subsystems of the experiment and how they interact with each other.

Use schematics and a block diagram. 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. These shall be detailed in the following subsections.

Before defining and describing these interfaces, make sure to consult the REXUS/BEXUS User Manuals [1].

4.2.1 Mechanical

Describe the fixation and mounting of the experiment and its different components to the vehicle. Indicate the mounting pattern of the experiment. Give the amount and size of bolts/nuts/washers (in a table).

Also indicate and justify any special requirements.

Do not go on to describe the mechanical design of the experiment.

<u>For REXUS:</u>

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

<u>For BEXUS:</u>

The attachment to the experiment rails of the gondola must be clearly shown and described. Include a diagram of this interface.

4.2.2 Electrical

Describe the electrical interface to the vehicle.

For REXUS:

If applicable, describe the usage of the REXUS service module. Briefly describe the use of:

- Signals
- Power
- Up- and downlink
- Grounding

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, describe the usage of the E-Link

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

If applicable, describe the usage of BEXUX batteries (Gondola Power)

- 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 a transmitter or receiver is used, 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.

4.3 Experiment Components

List all components of the experiment and give, in table(s):

- Availability, cost and supplier
- Number
- 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. Also in the appendix, provide relevant data sheets.

Please also provide the following table as a summary (**this table is compulsory, please do not change the units or coordinate system**):

Table 4-2: Experiment summary table

Experiment mass (in kg)*:	
Experiment dimensions (in m):	
Experiment footprint area (in m^2):	
Experiment volume (in m^3):	
Experiment expected COG (centre of gravity) position:	

For BEXUS

If the experiment consists of several separate boxes or units, please indicate the volume, mass and CoG for each of them.

For REXUS:

Please state whether the mass includes the experiment module.

At PDR level, the numerical values must be good estimates. At this point, all major components should be decided upon.

At CDR level, all numerical values have to be well calculated or measured.

4.4 Mechanical Design

Describe the mechanical design, the material used for the structure/boxes and how every component is mounted to the structure/boxes.

Refer to the applicable sections in the REXUS/BEXUS User Manual [1] about vibration, (shock) loads and how to mount the experiment to the gondola, in case of BEXUS.

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

At PDR level, layout diagrams should be clear. Materials should be selected.

At CDR level, include necessary detail, assembly, manufacturing and other relevant drawings in the Appendix. The experiment CAD model shall also be included and uploaded to the teamsite in .STEP format.

At CDR level, carry out stress analysis and load calculations where applicable (Finite Element Analyses (FEA) is recommended and may be required for some experiments).

4.5 Electronics Design

At PDR level, describe the electronics (and selected components) of the experiment using electronics schematics. Usually, the schematics follow the sub-functions of the block diagram. Pay attention to how power is distributed in the system, and do not neglect the inclusion of a grounding scheme. Test the circuits on a breadboard.

At CDR level, refine the electronics schematics and give the design for the PCB(s). The power distribution and interfacing should be finalised.

At IPR level, provide a list of all interconnecting cabling used in the experiment. The PCB design needs to be frozen.

Indicate how many PCB(s) are used and where they are located.

4.6 Thermal Design

Determine 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.

Include a table of components and their operating/survivable ranges. Where any components lie outside of the design range, explain how this is handled.

Example:

Minimum/Maximum Expected Operating Temperature: -10°C/+65°C

Minimum/Maximum Expected Survivable Temperature: -30°C/+65°C

Table 4-3: Example component thermal ranges table

Component	Operating T (°C)		Survivable T (°C)		Comments
	Min	Max	Min	Max	
Camera	0	70	Unknown	Unknown	Operating temperature as stated in the camera data sheet. Thorough testing shows continued good operation at -20°C – see test report.
Processor	-40	85	-55	85	-
Power Unit	-40	85	-55	85	-

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.

At PDR level, provide basic thermal calculations.

At CDR level, a detailed thermal analysis might be necessary (use of a software package is recommended).

4.7 Power System

Calculate the power budget of the experiment. If applicable, consider the power consumption during different phases (prior to flight, during flight, after flight) with a good safety factor. This calculation is preferably done in Ah and 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 (the integral of which is the Ah) is strongly encouraged.

Give a table with all power-consuming experiment systems.

If batteries are used, give their type and number and attach their datasheet in the appendix. Otherwise, indicate that the power supply provided by the launch vehicle is required.

4.8 Software Design

Describe the software of your on-board experiment and your ground station. This chapter should be used as an aid to designing the experiment's software not only documenting it.

The following topics should be covered:

1. Purpose
   Give a short introduction of the software purpose. 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
      Give a brief description of the process overview, a block diagram which includes the technical process field is good here (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
      Make considerations about error behaviour. Describe safety related concepts like redundancy or watchdog if applicable.

   c) Interfaces
      Describe the interfaces in your setup. Describe the communication interface (e.g. UART, Ethernet, Rocket Signals). Indicate the minimum bandwidth requirement, the normal bandwidth requirement and the maximum bandwidth requirement. Design the transmission packets and consider fail-safe data transmission possibilities. Also consider the process field interfaces (e.g. USB sensors, CAN bus,..) and the user interface.

   d) Data acquisition and storage
      Estimate the amount of data gathered and discuss its storage on-board the experiment. Describe storage package architecture and calculate buffer sizes and data transmission rates to permanent storage devices if applicable.

   e) Process Flow
      Describe the process flow of your experiment. Use process-flow-charts, sequential-function-charts or state-machine-diagrams if applicable.

   f) Modularisation and pseudo code
      Break down the functionality of your system into independent modules, such that each can be solved separately. Describe the different modules and their interfaces. You can use pseudo code or UML-diagrams for the description if applicable.

3. Implementation
   Decide about the programming language and development tools you want to use. Address the need of an operating system or the usage of programming libraries if applicable. Describe elementary parts of you source codes (e.g. interrupt service routines).

4.9 Ground Support Equipment

Describe all 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).

Describe the software design of the ground segment and detail the handling of received data.

Indicate what programming language(s) and development environments are used.

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

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

If the experiment will fly on the REXUS or BEXUS for a second time (regardless of whether you reapplied or were a back-up team), list all changes from the initial flight configuration in this chapter and link them to the appropriate section in the SED.

5 EXPERIMENT VERIFICATION AND TESTING

After design and implementation of the experiment according to the experiment requirements (Chapter 2), it has to 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 [6].

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, list all the requirements in a table and define how to verify them.

There are four established verification methods. For details see: ECSS-E-ST-10-02C [6]:

- 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).
  Verification by analysis is performed by e.g. running a computer simulation on some parts of the experiment. Verification by similarity is performed by stating that a part of the experiment is similar to a part that has already been flown successfully.
- 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.

List all the requirements 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	Verification	Test number	Status
D.1	The experiment shall operate in the temperature profile of the BEXUS balloon.	T	Test 1	To be done, see test plan
O.X	The experiment shall be equipped with an arm plug that can be removed easily prior to launch.	I, T	Test 2	To be done at EAR
D.X1	If the experiment uses its own batteries: The experiment batteries shall be qualified for use on a BEXUS balloon / REXUS rocket.	A	-	✓ See test results
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	-	✓ See test results

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

- Requirement D.1 is clearly to be verified in several tests.
- Requirement O.X can be verified by inspection (simply looking whether the arm plug is there in the design phase) 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 proved 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, it shall be linked it 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. If the verification has been performed, place a tickmark (or similar). Otherwise, indicate when the verification is planned.
  *Note: The flight is **not** part of the verification process. All requirements have to be verified prior to the campaign.*

5.2 Test Plan

Review the previous section and identify the tests that will be required for the experiment or its parts.

Describe all the planned tests in tables like the following (one for each test):

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

Test number	
Test type	Examples are: Thermal / vacuum / thermal vacuum / vibration (transient or sinusoidal) / shock / electromagnetic interference
Test facility	
Tested item	the whole experiment (system level test), a subsystem or a single component
Test level/procedure 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

Provide a list of all the planned tests.

5.3 Test Results

Record the results of the tests and whether further testing is necessary. Indicate (e.g. in a table) whether each test was successful or not. Provide graphs, figures and photos where applicable. Include only an overview of the test results – full test reports can be included in the appendix.

6 LAUNCH CAMPAIGN PREPARATION

A launch campaign needs meticulous preparation. EuroLaunch 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, be sure to change information in both sections – 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 [3].

6.1 Input for the Campaign / Flight Requirement Plans

EuroLaunch 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 each mission there will be a **Payload Manager** who is responsible for the C/FRP. The C/FRP defines the mission payload, the mission requirements and also the services to be provided by EuroLaunch. Special requirements for mission preparation, mission performance and for post flight activities have to 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. 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

Please provide the following table as a summary (note that the table is cross-referenced to that in Section 4.3, updating the document or the field will automatically update the values):

Table 6-1: Experiment mass and volume

Experiment mass (in kg)*:	
Experiment dimensions (in m):	
Experiment footprint area (in m^2):	
Experiment volume (in m^3):	
Experiment expected COG (centre of gravity) position:	

For BEXUS

If the experiment consists of several separate boxes or units, please indicate the volume, mass and CoG for each of them.

*For REXUS:

Please state whether the mass includes the experiment module.

6.1.2 Safety Risks

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 pyrocutters/pyroactors
- 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)
- 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. umbilicals)
- 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.

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 not 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.

6.1.3 Electrical Interfaces

Please complete one of the following tables (either BEXUS or REXUS), giving a summary of the experiment's electrical interfaces. 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.

At PDR level, the numerical values can be good estimates.

At CDR level, all numerical values must be well calculated or measured.

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)
	Data rate - downlink:	Kbit/s
	Data rate – uplink	Kbit/s
	Interface type (RS-232, Ethernet):	(Ethernet recommended)
Power system: Gondola power required? Yes/No		
	Peak power (or current) consumption:	W or A
	Average power (or current) consumption:	W or A
Power system: Experiment includes batteries? Yes/No		
	Type of batteries:	
	Number of batteries:	
	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:	(usually no) from/to s after lift-off
Up-/Downlink (RS-422) required? Yes/No		
	Data rate - downlink:	Kbit/s
	Data rate – uplink	Kbit/s
Power system: Service module power required? Yes/No (usually yes)		
	Peak power consumption:	W
	Average power consumption:	W
	Total power consumption after lift-off (until T+600s)	Wh
	Power ON	s before lift-off (usually 1200)
	Power OFF	s after lift-off (nominally 600)
	Battery recharging through service module:	Yes/No
Experiment signals: Signals from service module required? Yes/No		
	LO:	Yes/No
	SOE:	s after/before lift-off
	SODS:	s after/before lift-off

6.1.4 Launch Site Requirements

Please list any special equipment, facilities, consumables or tools needed prior, during or after launch that should be provided by EuroLaunch. Consider space needed, tables, chairs power outlets.

6.1.5 Flight Requirements

For BEXUS

Clearly state the desired float duration and altitude.

Clearly state any requirements on time of launch and/or day light.

For REXUS

Clearly state the desired apogee of the vehicle if applicable.

Clearly state whether a de-spun or spinning vehicle is required.

6.1.6 Accommodation Requirements

For BEXUS

Include any requirements or preferences for gondola placement.

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).

Include any requirements for viewing from the side of the gondola and/or through the top/bottom of the gondola.

Include any requirements to have the gondola covered, partially covered or uncovered.

For REXUS

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

6.2 Preparation and Test Activities at Esrange

Plan and describe the activities at Esrange, prior to launch.

Give the timeline and the procedures which must be carried out.

Organise the team: Who is doing what, and when?

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

The planned activities must be clearly shown here, consider using a table or chart and include tasks, people responsible, time/day, and duration.

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!

6.3 Timeline for Countdown and Flight

Describe 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?

List the sequence of events in a table.

Mention the time relative to the launch (T=0), the duration of the action, the expected altitude and any other relevant information.

NOTE: Include all late access events and Remove before Flights items (RBFs) here! How this is carried out must be clarified with EuroLaunch.

6.4 Post-Flight Activities

Plan and describe the activities after landing.

Include a recovery sheet here. 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. Please think about conditions of recovery where a payload can be in a very difficult to reach place and often with snow around. For REXUS, it is not normally necessary to provide such information, where this is the case, please state clearly that no recovery actions are needed.

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

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

6.4.1 Presentation during Post-Flight Meeting

At the end of a launch campaign there will be a Post-Flight Meeting for the organisers and the experiment teams to review the flights together. As part of this meeting there will be reports from every experiment team with a short presentation of their experiment operations and preliminary results.

During the meeting there may be also a discussion about the positive and negative aspects of the whole programme and the launch campaign with feedback and lessons learned from all participating students. Points for this discussion may be listed under Lessons Learned.

6.4.2 Input to Campaign Report

Some weeks after the campaign, a Campaign Report will be issued by EuroLaunch. Each team should submit a one-page written summary of their 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.

6.4.3 Final Experiment Report

The final experiment report is the 5th version of the SED and has to be provided at the latest 3 months after the launch campaign. It should be structured in an appropriate manner.

The final report should reflect that the project is completed, therefore consideration should be made for the tense used throughout. Ideally the report should use a uniform verb tense throughout (past) without the use of the imperative mood or first person.

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, describe how you will produce scientific results. Plan how to use and analyse the data or evaluate the results.

Indicate when and what kind of activities are planned, and what kind of facilities, instruments, etc. you intend to use.

7.2 Launch Campaign

1. Flight preparation activities during 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)

7.3 Results

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 Lessons Learned

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)

You should already start documenting the lessons learned during the design, implementation and testing process.

8 ABBREVIATIONS AND REFERENCES

8.1 Abbreviations

This section contains a list of all abbreviations used in the document.
Add abbreviations to the list below, as appropriate.
In version 5 of the SED (final version), delete unused abbreviations.
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
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
SNSB	Swedish National Space Board
SODS	Start Of Data Storage
SOE	Start Of Experiment
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

Please stick to a single referencing format.

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

(Books, Paper, Proceedings)

[1] EuroLaunch: **BEXUS User Manual** (2014), **REXUS User Manual** (2014)

[2] European Cooperation for Space Standardization ECSS: Space Project Management, **Project Planning and Implementation**, ECSS-M-ST-10C Rev.1, 6 March 2009

[3] SSC Esrange: **Esrange Safety Manual**, REA00-E60 , 23 June 2010

[4] European Cooperation for Space Standardization ECSS: Space Engineering, **Technical Requirements Specification**, ECSS-E-ST-10-06C, 6 March 2009

[5] European Cooperation for Space Standardization ECSS, Space Project Management, **Risk Management**, ECSS-M-ST-80C, 31 July 2008

[6] European Cooperation for Space Standardization ECSS: Space Engineering, **Verification**, ECSS-E-ST-10-02C, 6 March 2009

[7] Project Management Institute, **Practice Standard for Work Breakdown Structures – second Edition**, Project Management Institute, Pennsylvania, USA, 2006

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 following items should be prepared for presentation and described in detail in the respective chapters of the SED:

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

Critical Design Review - CDR

Experiment documentation must be submitted **around 2 weeks** (the exact dates will be announced) before the review (SED version 2). A presentation covering the status of the experiment should be prepared.

The experiment should have a certain status before performing the CDR:

- The detailed design of the experiment should be finished
- The design status should allow to start the built up of experiment flight hardware
- The design phase and part of the testing should be completed

Content of CDR:

- 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
- Planning of the launch campaign with inputs for the Flight Requirements Plan (FRP)

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.

The experiment should have reached a certain status before performing the IPR:

- The experiment design should be completely frozen
- The majority of the hardware should have been fabricated
- Flight models of any PCB should have been produced or should be in production
- The majority of the software should be functional
- The majority of the verification and testing phase should have been well planned
- The experiment should be ready for service system simulator testing (requiring experiment hardware, electronics, software and ground segment to be at development level as minimum)

Content of IPR:

- General assessment of experiment status
- Photographic documentation of experiment integration status, with comments were necessary
- Discussion of any open design decisions if applicable
- Discussion of review items still to be closed
- Discussion of potential or newly identified review item discrepancies
- Discussion of components or material still to be ordered or received by the team

- Clarification of any technical queries directed towards the visiting expert
- Communication and functional testing (Service System Simulator testing for REXUS and E-link testing and BEXUS)

Experiment Acceptance Review - EAR

Experiment documentation must be submitted **at least five working days** (the exact date will be announced) before the review (SED version 4). This will take place six weeks after IPR.. 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 program 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
- Experiment acceptance decision: Passed/conditional pass/failed. If a conditional pass is elected, the immediate action items should be discussed, along with an appropriate deadline(s).

APPENDIX B – OUTREACH AND MEDIA COVERAGE

Include 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

Attach copies or photographs of the above if possible and include reference numbers in the list.

APPENDIX C – ADDITIONAL TECHNICAL INFORMATION

Include in this Appendix:

- Engineering drawings
- Electronics schematics
- PCB layouts
- Datasheets of components
- Test reports
- Experiment checklists

If required to avoid lengthy appendices only an index may be included and the data sheets provided in a separate data package. This should be specifically mentioned within the main document.

APPENDIX D – CHECKLISTS

Include in this appendix all checklists for experiment preparation and test activities at Esrange and integration events.