STUDENT EDUCATION DURING THE REXUS/BEXUS Projects

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ABSTRACT

The new DLR Institute of Space Systems in Bremen has established a project office to support and manage German student activities related to the preparation of the BEXUS and REXUS (Balloon/Rocket Experiments for University Students) flights. This paper primarily describes the student mentoring and the educational activities undertaken by DLR and SSC with the aim of encouraging and promoting student knowledge throughout the first year of the REXUS/BEXUS student programme

1. INTRODUCTION

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 the Swedish Space Corporation (SSC) and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operation of the launch vehicles. Experts from DLR, SSC and ESA provide technical support to the student teams throughout the project. This includes technical support during testing phase and integration, as well as campaign management and operations at the launch site.

Each autumn starting in 2007 DLR and ESA issue an announcement of opportunity for experiments on stratospheric balloons and sounding rockets. Each flight carries a payload consisting of up to 5 student experiments with a launch from Esrange. During the 5 year programme, 2 BEXUS balloons are planned to be launched in early autumn and 2 REXUS missions to be launched in late spring of each year. Educational activities are coordinated between staff from Germany, Sweden and ESA. Individual support of student groups and experiment preparation is different for German and other European groups. In this paper the coordinated student support as well as the individual German experiment support is described.

The first missions within the new programme, BEXUS-6 and BEXUS-7, were launched on the 8th of October 2008 with 3 German and 5 other European experiments onboard. Furthermore, two rocket missions with 3 German and 3 other European experiments were launched in early March 2009.

Teams involved in the development and flight of the missions were directly supported by experts from DLR, SSC and ESA throughout the planning phase in documentation and accomplishment of the different reviews: PDR (Preliminary Design Review), CDR (Critical Design Review) and EAR (Experiment Acceptance Review). Technical support during the design, integration and testing phase of the experiments was also provided. A student training week with specialised lectures covering the fundamentals of spaceflight, as well as the basics of sounding rockets, balloon flights and atmospheric physics is organised once a year either at Esrange (2008) or in Oberpfaffenhofen (2009), Germany.

2. OBJECTIVES OF THE STUDENT PROGRAMME

The two main objectives of the REXUS/BEXUS programme are to promote students' knowledge in preparation and performance of a space flight and to encourage their interest in space science and technology. The goal is to get well educated young people who are able to contribute their knowledge to future space missions and who are inspired to participate in the space industry.

Within the programme, students are trained in teamwork, experiment documentation, review preparation and performance of PR activities. In this way the next generation of European space scientists and engineers are encouraged to participate in future space flight activities. Beside the training objectives

there are scientific and technological objectives for each individual experiment. These objectives are defined by each student group for their experiment. During the evaluation process these objectives are taken into account for the experiment selection. The scientific results are expected to be described and reported in a general form in the Student Experiment Documentation (SED) three months after the mission.

2008	**BEXUS**				**REXUS**			
	ESA/SNSB	**19**	**DLR**	**9**	**ESA/SNSB**	**11**	**DLR**	**10**
	Low Coins, I	3	TURAWIND	3	VipBip, I	3	Charpa	2
	Icarus, P	3	TURATEMP	-		4		
	Aurora, I	4	DOLS	6	Ittika, FIN	4	Agade	4
	StratoCens, S	5			Nisse, N, FIN			
	Timepix, CZ	4					(VibraDamp)	4
2009		**27**		**3**		**11**		**21**
	Navis, DK	4	MATI	3	BUGS, I	2	MONDARO	4
	Compass, I	3					VibraDamp	3
	CRIndIons, CZ	4			LapLander, S	5	TUPEX-3	4
	reel.SMRT, S	4			Suaineadh, UK, S	4	VECTOR	10
	Scope, P	4						
	SO-High, B	4						
	Spacefish, E	4						

Table 1: Selected experiments and number of students of each experiment. Behind the ESA experiments the nationality is given. The number of students given in the table for each experiment refers to the students who got a certificate in the 2008 group or took part on the training week in the 2009 group.

3. MISSIONS AND EXPERIMENTS

After the first Experiment Selection Workshops (ESW) carried out in March 2008 at DLR and at ESTEC (European Space Research and Technology Centre), 14 experiments were selected: 8 experiments including 3 from Germany for BEXUS-06 and BEXUS-07 missions, and 6 experiments including 3 German experiments for REXUS-05 an REXUS-06 missions (Tab. 1).

During the first BEXUS launch campaign two experiments from the Institute of Atmospheric Physics (IAP) at University of Rostock in Kühlungsborn (TURAWIND and TURATEMP) and an exobiological experiment (DOLS – Diversity of Life in the Stratosphere) by students from several German universities were launched. Student groups from Italy, Poland, the Czech Republic and Sweden launched 5 experiments. The Swedish team with the experiment Stratospheric Census was an international group. It consisted of five students from the Czech Republic, Germany, Austria, Netherlands and Australia, all studying in the Erasmus Mundus Space Science & Technology Master Programme ("SpaceMaster").

During the preparation for the first REXUS launch campaign one German experiment (VibraDamp, Aachen) failed the EAT (Experiment Acceptance Test). It was decided to fly this experiment in 2009 on REXUS-7. The student group will improve the design and continue with experiment preparation. The German experiment CharPa (Charge state of the mesospheric smoke Particles) from the IAP (Leibniz-Institute of Atmospheric Physics) and the Italian experiment VipBip flew on REXUS-05, the Experiments Ittika, Nisse and Agade on REXUS-06.

The number of students working on their experiments varied between 2 and 20. Not all students could participate in the programme's two main activities: the training week and the launch campaign. In general only four students of every team are funded to take part in the activities. For some experiments there are students involved who don't take the opportunity to participate in the training week or the launch campaign.

The BEXUS and REXUS missions end with the submission of the final reports in which the results and the degree of success are described by the students.

4. TASKS OF THE DLR BREMEN

The REXUS/BEXUS team of the DLR Institute of Space Systems in Bremen is part of the division Transport- and Propulsion Systems and is responsible for the organisation, support and integration of the German experiments. This organisation effort includes the interface to all partners of the programme, apart from the Swedish National Space Board SNSB: the DLR Space Agency, the DLR Mobile Rocket Base (MORABA), the Swedish Space Corporation (SSC), and the ESA Education Office. Main subjects of the organisational tasks are: preparation of the Experiment Selection Workshop (ESW), support for Student Training Week (STW) as well as preparation and carrying out of reviews.

Two general information documents are each prepared for REXUS and BEXUS with EuroLaunch: the short descriptions to get a technical overview and the more detailed User Manuals [1], [2]. The User Manuals are to help the students to understand technical requirements and mission operations.

Beside these general information documents, an SED Blank Book is provided with a defined structure of chapters and subchapters to facilitate the production of the experiment documentation (for a detailed description see chapter 5). Complementary to this SED Blankbook, the SED Guidelines give the students a lot of useful instructions. It has the same structure as the SED blank book and should help the students to prepare and document their experiment in an appropriate and structured manner.

In Cooperation with Eurolaunch a Flight Requirement Plan (FRP) is produced for every single mission prior to the launch campaign. This document contains information about the mission payload, mission preparation and post flight activities, as well as participating staff and students. After every mission a Campaign Report with detailed mission performance data is distributed to all participants.

5. EXPERIMENT DOCUMENTATION

Each experiment is to be described in only one document. This document is called the SED (Student Experiment Documentation). It has a defined structure and should contain all important information on the experiment. The SED should provide EuroLaunch, respectively the experts from SSC, DLR and ESA with details of the experiment requirements, the experiment setup, details of the planning of experiment development and mission performance. The table of contents of the SED Blank Book is given below**:**

Change Record
1. Introduction
2. Mission Requirements
3. Experiment Description
4. Reviews and Tests
5. Project Planning
6. Outreach Programme
7. Launch Campaign
8. Experiment Report
9. Abbreviations and References
10. Attachments

During the development of the experiment the SED is to be prepared and delivered by the student groups in 5 versions with increasing quantity and quality at specific times (Tab. 2):

1. prior to PDR
2. prior to CDR
3. as a Mid Term Report (progress report)
4. just before launch campaign
5. as a Final Report: 3 month after flight

The SEDs size and content depends on the complexity of the experiment. The first version should give a good overview with some technical details. A complete planning of experiment assembly and mission performance is expected in the second version. The Mid Term Report should concentrate mainly on test results, possible problems and delays in the time schedule which may be critical to meet a launch date.

Just before the launch Campaign a detailed planning of the preparation, integration and test phase at launch site is expected. The data acquisition and recording as well as the data evaluation after the mission should be described in this version.

The Final Report should comprise a subchapter called “Lessons Learnt” in which the students should try to list all things which could be improved. Special experiences and problems which occurred during the experiment development and the flight campaign should be reported here.

Phase	Time	description	Review	Doc. update
A	2. - 5.2.2009	ESW - Experiment Selection Workshop	EDR	SED Blank Book
B	23. - 27.3.2009	STW - Student Training Week	PDR	SED, vers 1
C	2. - 3. June 09	Meeting for Critical Design Review	CDR	SED, vers 2
D	July 2009 early Sept. 2009	MTR - Mid Term Report Delivery of Experiment Flight Hardware	 EAR	SED, vers 3
E	2.Oct. 2009	Launch Campaign, Launch of two balloons		SED, vers 4
F	end Oct. 2009 8. Jan 2010	Distribution of Campaign Report Submission of Final Reports		SED, vers 5

Table 2: Main activities, project phases and time schedule of the running BEXUS-08 and BEXUS-09 missions.
Reviews: EDR – Experiment Definition Review, PDR – Preliminary Design Review, CDR – Critical Design Review, EAR – Experiment Acceptance Review

6. STUDENT SUPPORT FOR REXUS AND BEXUS EXPERIMENTS

An overview of the main activities during the different experiment phases of BEXUS-08 and BEXUS-09 missions planned for October 2009 is given as an example in Tab. 2. The student support starts after the AO (Announcement of Opportunity) and experiment preselection by the DLR Space Agency for the German experiment proposals and by SNSB and ESA for the experiment proposals of other European countries. During the Experiment Selection Workshop (ESW) the Experiment Definition Review (EDR) is performed. In this review the student groups first present their proposed experiment. After discussion of open questions a panel meeting is arranged in which details of the experiment proposal are discussed. Results of this meeting with recommendations are given to the students for preparation of their experiment.

The next event after the ESW is the Student Training Week (STW) with the PDR. ESW and PDR are described in detail in chapter 7.

After the STW, students have to prepare the Critical Design Review (CDR). A meeting of the student groups together with selected board members is arranged. The whole planning of the experiment is to be presented by the student groups. Detailed mechanical and electrical design descriptions with drawings and schematics are expected as well as software and thermal design of the experiment. Special emphasis is put on the test plan for experiment flight hardware and the operational concept as well as a draft planning of the launch campaign and the mission itself. Also the planned and current outreach activities are important aspects of the CDR.

If necessary there may be support of test preparation and performance. For test planning a short description of test objectives, test requirements and performance are necessary. The DLR test facilities in Bremen, Oberpfaffenhofen or Berlin can be provided if necessary.

The ordering of experiment components for the German student teams is managed by the DLR team in Bremen in close cooperation with the students. The funding is provided by the German National Space Programme. The experiment hardware must be delivered for the BEXUS flights 2 weeks prior to launch and for the REXUS flights 3 month prior to launch. After delivery of the experiment hardware an Experiment Acceptance Review (EAR) and functional tests of all experiment specific measurements are performed. After the EAR there is the experiment integration into the experiment rocket modules or the balloon gondola. The REXUS experiments are tested after the integration together with the REXUS Service Module. About 3 weeks prior to launch a spin balancing test is performed to balance the the payload. Additionally the center of gravity and the inertial moment are measured to determine the mass of the yoyo-system. The yoyo-system is used to despin the rocket for experiments under reduced gravity.

Early during the launch campaign functional tests and interference tests are performed at the launch site. Details are to be documented in the SED. Student support during launch campaign comprises mainly experiment integration, test performance and problem solving.

7. STUDENT TRAINING WEEK (STW)

After the selection workshop up to four students from every group are invited to a Student Training Week (STW). The location of the STW alternates between Sweden (Esrange) and Germany (Oberpfaffenhofen). The first STW was in April 2008 at Esrange, hosted by SSC with an attendance of 43 students. The second STW was in March 2009 at the DLR centre in Oberpfaffenhofen hosted by MORABA personnel.

	Experiments	**Students**
2008 (Esrange)	BEXUS: 7, REXUS: 6	43
2009 (O'hofen)	BEXUS: 8, REXUS: 7	56

Table 3: Number of proposed experiments after the first AOs and number of participating students at the Training Weeks

The number of participating students fluctuated during the week, but more than 56 students could attend most parts of the programme (Tab. 3).

The STW always is comprised of 2 main parts:

1. PDR (Preliminary Design Review) of the proposed students' experiment
2. Students' training and information activities

7.1. Preliminary Design Review

During the last training week for each experiment a PDR was carried out in parallel to other students' activities. A special review panel between 6 and 10 experts was arranged in a different composition for each experiment, depending on the experiment's requirements. 19 space technology experts from DLR, SSC and ESA participated in the panels for the 15 selected experiments on REXUS and BEXUS.

Main subjects of the PDR are:

- Design concept (electrical, mechanical, and thermal)
- Technical, functional and operational requirements
- Current status of the experiment planning
- Schedule for development, production and testing
- Risk analysis (mission and safety)
- Planned outreach activities

During the presentation of the PDR the students present and discuss their experiment design concepts. They present their technical, functional and operational requirements as well as their experiment development schedule including necessary testing and risk analysis. Special ideas and proposals are expected for their outreach activities. After the students' presentations there is a panel discussion with questions and recommendations from the panel side and also questions and discussions of open issues from students' side. The panel's recommendations are formulated in the minutes of the review and distributed to the students to be included in their documentation.

7.2. Students' Training and Information Activities

The students' training and information activities during the STW comprise four different activities:

1. Lectures
2. "Ask Your Expert" sessions
3. Practical training
4. Site visits

In the classroom lessons, German, Swedish and ESA representatives provided general information of the participating organisations (DLR, SNSB, SSC, ESA, EuroLaunch) as well as information about the German, Swedish and the ESA space programmes. Concerning the flight opportunities of students' experiments detailed information is given about the following subjects:

- REXUS Service System
- Mechanical Integration
- Rocket Flight Dynamics
- BEXUS E-Link system
- Telemetry for REXUS and BEXUS
- Experiment Preparation Phases

- Reviews and Documentation
- Verification and Testing
- Coordinate Systems
- Fundamentals of GPS
- Atmospheric Physics
- REXUS and BEXUS Campaign Schedule
- Project Management
- Outreach

During a more general lesson outreach activities were explained to the students. These activities also include the production of a website and how to give an interview.

Four “Ask Your Expert” sessions for electrical and mechanical problems and questions were carried out for small student groups. These sessions gave the students the opportunity to discuss special problems directly with the experts.

During four practical training sessions, small student groups had the chance to learn details about space qualified soldering and to practise active soldering.

Site visits during the first training week in Esrange included the different rocket and balloon launch facilities, the laboratories for experiment preparation and the Swedish satellite control station on the Radar Hill. Outside of the Esrange launch area the Swedish Institute of Space Physics was visited. Students got an introduction into the institute’s test facilities and laboratories. Classroom lectures were given about ongoing scientific projects at the institute and scientific fundamentals of atmospheric and radiation research.

At the DLR Centre in Oberpfaffenhofen the site visits included the Columbus Control Centre, the test facilities (vacuum chamber) and the workshops for preparation and testing of different rocket systems and experiments.

At social events during the training week the students are given the opportunity to talk with most of the experts in a relaxed atmosphere about technical problems and other relevant technical or operational questions.

8. CONCLUSIONS

During the second year of the REXUS/BEXUS programme small improvements in documentation, review preparation and information distribution prior to the training week as well as for the launch campaigns are still necessary to make the programme more attractive for students. Beside this, special information activities are necessary to make the programme better known at the relevant institutes in Germany and other European countries.

9. REFERENCES

1. EuroLaunch: BEXUS User Manual (2008), http://www.rexusbexus.net/
2. EuroLaunch: REXUS User Manual (2008), http://www.rexusbexus.net/