REXUS 2 – THE FIRST EUROLAUNCH PROJECT

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ABSTRACT

Sounding rocket and balloon launches have been conducted since more than 30 years at Swedish Space Corporation (SSC), ESRANGE. MORABA, the Mobile Rocket Base of the German Aerospace Center (DLR), has planned and performed sounding rocket and balloon launches throughout the world since the late sixties.

With the creation of EuroLaunch, the long-lasting co-operation of the two complementary technical centres ESRANGE and MORABA is being enhanced and intensified.

The REXUS 2 student rocket was the first project to be designed, built and launched under the EuroLaunch cooperation.

1. INTRODUCTION

A driving force in research by means of sounding rockets, has been the German Aerospace Center, which through its Mobile Rocket Base team, has conducted launches and operations all over the world. The Swedish Space Corporation and the German Aerospace Center have now entered into a deeper relationship by establishing a joint co-operation called EuroLaunch. On December 8th, 2003, a co-operation agreement was signed at ESRANGE.

The agreement will strengthen the long-lasting and ongoing relationship between SSC and DLR within the area of sub-orbital services for upper atmosphere and microgravity research as well as future fields of research interest. EuroLaunch is currently involved in several projects which aim at strengthening the co-operation and also providing new possibilities to the scientific communities.

The first EuroLaunch project was the REXUS 2 student rocket, which was successfully launched on October 28th, 2004 at ESRANGE. Within the REXUS 2 project the flexible work sharing of EuroLaunch has been put to its first test, as personnel from the two organisations have supported each other during heavy workload periods.

2. ORGANISATION

ESRANGE is a technical facility for scientists from all over the world where they can conduct research by means of sounding rockets, balloons, unmanned aerial vehicles (UAV) and ground based instruments. It is situated in Lapland, the northernmost part of Sweden.

The main tasks of MORABA are the support of national and international space projects including design, preparation and operation of sounding rockets and balloon payloads for scientific applications. A unique feature is the complete complement of mobile equipment which enables them to setup remote launching sites anywhere in the world.

3. FIRST PROJECT

The basic idea for the creation of the REXUS program (Rocket borne EXperiments for University Students) is to provide an exo-atmospheric experimental platform to university students in the field of aerospace technology. Besides the standard education curriculum additional motivation for students should be provided by an opportunity to design and fly their own scientific experiments. This also develops a team spirit, responsibility and teaches a scientific approach to solving problems.

The scientific payload capacity was shared between Swedish and German student experimenters organised in small groups but due to the short development time of this project the German contribution to the payload was a professional middle atmospheric research package. It was developed by the Institute of Atmospheric Physics IAP in Kühlungsborn, Germany and the University of Graz in Austria.

The REXUS program is coordinated with the MAXUS microgravity research program and scheduled prior to the MAXUS launch also to serve as a test condition for the range infrastructure and personnel. This assures an additional security for planning.

3.1 LAUNCH VEHICLE

The launch vehicle for REXUS 2 comprised the unguided, solid propellant, single stage Improved Orion rocket (M112 Hawk) from military surplus and is shown in Fig.1. The motor is a dual thrust burner with a boost phase of 5 seconds and a sustainer phase of approximately 21 seconds. The rocket accelerates the payload for 26 seconds with peak acceleration during the boost phase of 20g.

Fig.1 Improved Orion Sounding Rocket

The total motor hardware consists of the rocket motor itself with an exhaust nozzle extension, a boat tail shape tail can with three stabilizing fins and a motor adapter with an integrated gas driven high velocity separation system to permit safe payload recovery by the aft parachute system. The payload section was built up from standard type cylinder sections containing experiments, service and recovery system and covered by an gas driven ejectable ogive nose cone also including parachute recovery. A Yo-Yo despin system is not installed as a vehicle spin is required for scientific reasons.

The total mass of the rocket was 514 kg including a propellant mass of 290 kg and a payload mass of 98 kg. With a payload length of 2673 mm the complete vehicle measured 5620 mm; the motor and payload diameter was 356 mm (14”). Tab.1 describes the modular built up of the launch vehicle including corresponding masses.

Tab.1 Vehicle Configuration and Payload

Module	Struc. Mass [kg]	Equip. Mass [kg]	Total Mass [kg]	Remarks
Imp. Orion Motor w/ Tail Can, 3 Fins	416.0	-/-	416.0	l=2.678m; x_{CGaft}=1.490m
Motor Attachment Ring Separation Unit, Manacle Ring	5.2	3.8	9.0	l=0.265m; Mg
Recovery Module Parachute (2 stage), Heat shield, Manacle Ring	9.6	8.3	17.9	l=0.300m; Manacle I/F on both sides; Mg
Service Module Power Supply, MIDAS Platform, TM, XPDR	4.9	13.0	17.9	l=0.290m; Manacle I/F to Recovery; Mg
REXUS Module Vibration Meas. Unit (VMU) Solar Compass (SC) Pressure & Height (P&H) Passive Exp. Box (Pass) Cargo Box (CB)	3.5	5.5	9.0	l=0.288m; Radax I/F; Mg
Ion-Probe Module Plasma-Probe Exp. (PP) Ion-Probe Exp. (IP) E-Boxes	3.5	4.5	8.0	l=0.288m;Radax I/F; Mg; deployable hatch
ECOMA Adapter Module ECOMA Exp. (ECOMA) Faraday Antennae (FA) Angle Measurement (AM) RadFet (RF)	4.4	13.5	17.9	l=0.090m; Radax to Manacle I/F; Mg
4:1 Ogive Nosecone Nosecone Recovery System, Separation Unit, Manacle Ring, ECOMA Cover	9.5	3.7	13.2	l=1.422m; Manacle I/F; Al
Screws & Balance Mass	-/-	2.0	2.0	
Total Payload	40.6	54.3	94.9	

The flight trajectory is displayed in Fig.2 with the corresponding flight events listed in Tab.2.

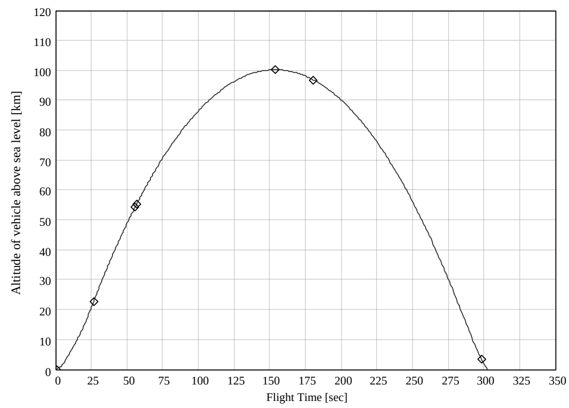

Fig.2 Predicted Flight Trajectory

Contrary to usual flight sequences, the Improved Orion motor was not separated directly after burn out but shortly after apogee, to minimize disturbances through separation action which can lead to coning payload behaviour and severely affects scientific measurement conditions.

Tab.2 Flight Events

#	Time [sec]	Altitude [km]	Event
1	T+ 0.0	0.00	Lift-off
2	T+ 26.0	22.72	Imp. Orion burn-out (nominal)
3	T+ 55.0	54.23	Nosecone ejection
4	T+ 56.0	55.17	Ion-Probe hatch deployment
5	T+153.0	100.24	Apogee
6	T+180.0	96.82	Motor separation
7	T>300.0	3.30	Recovery sequence activation

The flight events such as nose cone jettison, hatch deployment and motor separation were activated by mechanical timers while the start of the recovery sequence was controlled by barometric switches at an altitude of 10,000ft on the down-leg.

3.2 PAYLOAD

The scientific part of the payload consisted of two cylindrical experiment modules and one exposed top deck covered by the nose cone during the ascent.

The following universities and institutes contributed the corresponding experiments to the project:

Leibniz Institute of Atmospheric Physics at the University of Rostock Schlossstr. 6 D-18225 Kühlungsborn Germany	ECOMA particle detector Plasma Probes
Institute of Communication Networks and Satellite Communications Technical University of Graz Inffeldgasse 12 A-8010 Graz Austria	Ion Probe Faraday Antennae
Department of Space Science Luleå University of Technology SE-971 87 Luleå Sweden	RadFet Angle Measurement Solar Compass Vibration Measurement Unit
Kiruna Space and Environment Campus P.O Box 812 SE-981 28 Kiruna Sweden	Pressure Measurement
Kiruna Space High school P.O Box 5052 981 05 Kiruna Sweden	Passive Experiments

The experiments are described separately by the students involved. There are also critical design reviews and final reports on the student experiments available in the internet.

In addition, the payload included a service module containing a MIDAS inertial platform for attitude measurement, 3-axes accelerometer, data processors, telemetry (TM) transmitters, radar transponder and power supply. An S-band wrap around antenna was used for telemetry downlink and two radar antennae and a transponder supported radar tracking. The parachute recovery system was installed in an extra module; the motor adapter contains the separation system. Fig.3 presents an overview of the payload and Fig.4 shows some of the Swedish experiments installed in boxes and placed onto a supporting structure to be integrated into the standard modules.

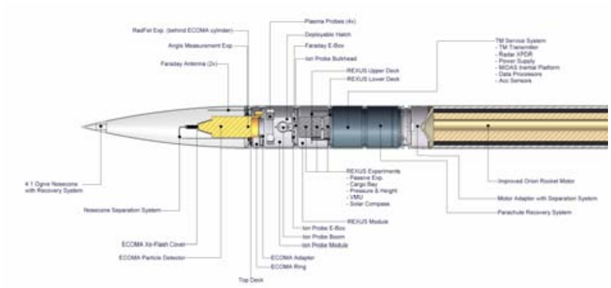

Fig.3 Payload Layout

Special requirements of some experiments i.e. deployable windows or access through the outer structure, were realized. Also a variety of voltages and data sampling rates was provided by the service system.

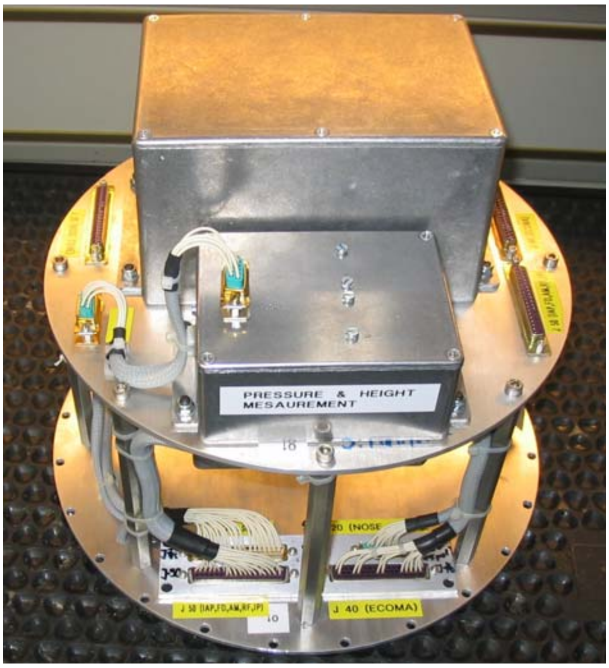

Fig.4 Swedish Experiments

To complete the payload arrangement, the necessary Electrical Ground Support Equipment (EGSE) including power supplies, decommutators, TM receivers and PCs, had to be customized.

3.3 PROJECT MANAGEMENT AND SCHEDULE

In the following the volume of work is illustrated by the milestones of this project. The different project tasks were shared between ESRANGE and MORABA personnel taking their specific skills into account. Only due to the interdisciplinary cooperation of a professional team can short time projects like this be carried through.

Project Management	ESRANGE
Student Contacts	ESRANGE
Payload Layout	MORABA
Payload Engineer	MORABA
Trajectory Calculations	MORABA
Service System	MORABA
Cabling of P/L	ESRANGE/MORABA
Recovery System	MORABA
Motor Preparation	ESRANGE
Launch Service	ESRANGE/MORABA

The REXUS kick-off meeting took place on the 1st of March 2004, the successful lift-off was on the 28th of October 2004, comprising only eight months of overall preparation time for both, the participating students and scientists as well as the engineers. As the complete payload consisted of newly assembled or built components and experiments, a complete mechanical layout and electronic concept had to be set up. The reason for such a compact project time was to comply with the fixed launch schedule for the MAXUS vehicle, where the REXUS sounding rocket launch provided test conditions for range systems and personnel. IN addition short project times were required for the students involved, since most universities have difficulties in engaging into long term projects. Finally, there was the intention to push on and establish the REXUS as an ongoing program. Tab.3 shows the project milestones within that eight month period.

Tab.3 Project Milestones

#	Date	Task
1	01.March 2004	REXUS 2 Kick-off Meeting, Selection of experiments by PDRs, Decision on motor hardware, P/L components, TM setup, radar tracking
2	31. March 2004	ESRANGE student experiments decided, experiment CDRs
3	31. July 2004	P/L layout ready and main structures ready, Student experiments ready for integration
4	06. Sept. 2004	Progress Meeting, decision on personnel exchange for P/L cabling
5	24. Sept. 2004	Recovery system packed and ready
6	30. Sept. 2004	Service system ready
7	08. Oct. 2004	Integration of experiments finished
8	15. Oct. 2004	Bench testing and final assembly of modules
9	19. Oct. 2004	Environmental testing of complete P/L
10	20. Oct. 2004	Motor preparation
11	22. Oct. 2004	Start of campaign at ESRANGE
12	28. Oct.2004	Test countdown
13	28. Oct. 2004	Hot countdown
14	29. Oct. 2004	P/L recovery operation
15	02. Nov. 2004	End of campaign at ESRANGE
16	22. Feb. 2005	Post flight analysis finished, Student experiment final reports finished

For a better understanding of all minor tasks prior the hotter phase of the project, a detailed view of the different tasks and schedule is presented in Tab.4.

Tab.4 Detailed Schedule of Hot Phase

Week	Task
37. 6.9.-10.9.	Finish fabrication of processor boards
	First testing of processor boards
	Finish cabling of E-box
	Cabling of Service Module
	Finish fabrication of hatch, antenna support, integration
38. 13.9.-17.9.	Cabling of Service Module
	EGSE modification
	Cabling of experiment modules
	Test of electronic boards and E-box
	Equipment of nosecone recovery system and separation
	Packing and transport of motor hardware to Esrange
39. 20.9.-24.9.	Cabling of Service Module
	Testing of microcontroller
	Packing of parachute system
	Test of recovery electronic
40. 27.9.-30.9.	Complete testing of service systems, Integration of ECOMA, TM checkout
41. 4.10.-8.10.	Complete testing of service systems and experiments
42. 11.10.-15.10.	Final assembly of complete P/L
	Packing and transport of P/L to Stockholm for spin balance testing
43. 18.10.-22.10.	Packing and transport of additional equipment to Esrange
	Travel to Esrange
44. 25.10-31.10.	REXUS/ECOMA campaign at Esrange

Although additional problems occurred after the environmental testing of the payload, the time schedule could be maintained, but only due to enormous engagement of all people involved.

During the campaign operations at ESRANGE, the payload was completely disassembled after the spin balancing. All major components of the service system were checked, some experiments modified or updated (software) and the TM and radar compatibility was verified. Finally, everthing was reintegrated and flight event timing checked.

Fig.5 displays the REXUS paylaod during the final flight simulation testing on bench at ESRANGE.

Fig.5 REXUS Payload during Flight Simulation Test

3.4 SUMMARY

After the flight and recovery of the REXUS sounding rocket, a comprehensive analysis of the student experiments pointed out that, even though some of the experiments were less than 100% successful, the overall experimental value for the student groups was significant. Experience gained in project work, technical proof of theories, post flight data analyses and documentation on a real experiment was highly appreciated by the students and provided motivation for further activities in space research. As also for the universities, the preparation time was very short, this type of project was new and not all necessary information was available at start-up, the educational support of the students during their preparation time can be improved. For the next missions the payload engineers will implement definite interfaces to mechanics, electronics and telemetry for the experimenters.

The mesospheric experiments from the research institutes performed perfectly and collected a large amount of scientific data. Especially the newly developed ECOMA particle detector worked as it was designed to.

The cooperation of ESRANGE and MORABA worked very well. With increasing time pressure and work load collaboration and team play was developing setting the basics for the future; there was a true team spirit.

4. OUTLOOK

The main part of work in the future for EuroLaunch will consist of projects under the ESRANGE Andoya Special Project (EASP) and the national programs in Europe. An idea that will be further supported by EuroLaunch in the upcoming years is the possibility to use sounding rockets for student experimental missions. A student rocket will be launched by EuroLaunch from ESRANGE every year and participation will not be restricted to students from Sweden and Germany. Universities from other European countries will be able to participate in cooperation with Swedish and German universities. The next launch of a REXUS student sounding rocket is planned for February 2006.