NATIONAL REPORT ON SOUNDING ROCKET AND BALLOON RESEARCH ACTIVITIES WITHIN THE GERMAN SPACE PROGRAMME

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ABSTRACT

Since many years sounding rockets and stratospheric balloons have played a crucial role in implementing the German Space Science, Microgravity Research, Earth Observation, and Technology Development programmes. Recently, their dedicated utilisation in the education process of students of space science and technology disciplines became an additional and exciting element. The German Space Agency DLR manages all these activities and funds the related experiments by grants.

Using rockets and balloons the current research focus in Space Science is the mesosphere and ionosphere of the Earth as well as the atmosphere of the sun. In Microgravity Research, the fields of life and physical sciences benefit from medium-duration rocket experiments. In Earth Observation balloon-borne measurements are conducted for the validation of atmospheric sounding instruments on the ENVISAT satellite. New technology is being developed for the next hypersonic re-entry flight of a SHEFEX rocket. The first REXUS / BEXUS student activities under the auspices of the Swedish-German student programme were conducted in 2008.

1. INTRODUCTION

The German Space Programme is managed by the Space Agency DLR on behalf of the government. This assignment to DLR is in addition to its important role as major research establishment comprising 29 institutes and facilities in the areas of aeronautics, space flight, transport and energy at 13 sites.

The disciplines Space Science, Microgravity Research, Earth Observation, and Technology Development are core elements of the German Space Programme. Sounding rockets and balloons represent a cost-effective tool for in-situ measurements in the Earth's upper atmosphere as well as for performing experiments in weightlessness on a free fall trajectory of a rocket. In addition, smaller rockets and balloons are suitable tools for the education of students and the training of young scientists in space projects.

In December 2003 a bilateral cooperation agreement called EuroLaunch was signed by the Swedish Space Corporation (SSC) and the German Aerospace Center (DLR). This joint venture provides technical services to experimenters from Europe and worldwide based on the long-term competence of the technical centers SSC Esrange and DLR MORABA (Mobile Raketen Basis).

In January 2006 "The Revised Esrange and Andoya Special Project Agreement - EASP", signed by the governments of Sweden, Norway, Germany, France, and Switzerland as well as by the European Space Agency ESA, entered into force. It updates the original EASP agreement concluded in 1971 and secures the availability of both Scandinavian launch facilities Esrange, Sweden and Andoya Rocket Range (ARR), Norway to conduct space and atmospheric research with rockets and balloons. For German scientists of more than 20 research institutions it guarantees a regular access to space in European autonomy and therefore ensures research continuity.

During the previous ESA Symposium on rockets and balloons, which took place in Visby in June 2007, an agreement on the "German-Swedish REXUS / BEXUS student programme" was signed by the Space Agency DLR and the Swedish National Space Board (SNSB). In each such mission half of the rocket (REXUS) or balloon (BEXUS) payload is available to students from German universities and high schools. SNSB has opened up the Swedish share also to students from the remaining ESA member and associated states. The flight campaigns are coordinated by EuroLaunch.

This report gives an overview of the German rocket and balloon research activities in the time frame from mid 2007 to mid 2009 and outlines the German plans for future activities within the Revised EASP Agreement.

2. SPACE SCIENCE

2.1 Aeronomy

The rocket project ECOMA (Existence and Charge State Of Meteor Dust Particles in the Middle Atmosphere) is an international cooperation of the Leibniz

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Institute of Atmospheric Physics (IAP) and the Norwegian Defence Research Establishment (FFI). Its main objective is the characterization of meteor smoke particles and the analysis of their interaction with charged constituents of the ionosphere.

Asteroids and comets are remnants of the formation of our solar system some 4.6 billion years ago. Smallest fragments of these objects are continuously colliding with the Earth at high velocities. Due to the friction with the molecules of the atmosphere they heat up quickly and are evaporated. Fragments larger than some 10 cm have a chance to reach the ground after loosing some centimeters in diameter due to ablation. Along the trail through the atmosphere its molecules are ionized and excited to illuminate as well. This effect can be observed from the ground as a meteor event. The overall mass of meteor dust collected by the Earth is estimated to be around 50,000 tons per year. The nanometer-sized smoke particles produced in the altitude range between 70 and 100 km are assumed to play a major role in a variety of atmospheric processes. Examples are the nucleation of ice particles as well as stratospheric particles, which are involved in the ozone hole generation.

The ECOMA main payload consists of a specially adapted particle detector for meteor grains provided by the IAP (Fig. 1). Further instruments are an electron probe, a particle sampler, a positive ion probe, and a Faraday rotation experiment provided by scientists from Germany, Norway, Sweden, and Austria.

Figure 1: ECOMA Particle Detector for Meteor Grains (left) and a Combined Sensor for Neutrals and Electrons (CONE). Credits: IAP

ECOMA campaigns employ Nike/Improved Orion rockets, which are launched from Andoya. The in-situ measurements in the middle atmosphere are accompanied by ground-based methods using both optical and radar techniques.

In summer 2007 ECOMA 3 was launched shortly after the MASS (Mesospheric Aerosol Sampling Spectrometer) sounding rocket. The MASS instrument was provided by the University of Colorado, Boulder in order to achieve complementary scientific data.

The ECOMA campaign carried out in summer 2008 consisted of three launches into the polar mesosphere, together with co-ordinated ground-based measurements using radar and lidar. These rockets were launched under different atmospheric conditions, both with and without the presence of polar mesospheric summer echoes, and at a highly variable plasma density.

Initially, two double campaigns were planned for November 2009 in Andoya, and for summer 2010 in Spitsbergen. Due to operational and scientific constrains the two campaigns were merged into one larger campaign of four launches. This campaign is currently scheduled for December 2010 in Andoya. The first two rockets will be launched prior to the Geminids meteor shower at different atmospheric ionization conditions, while the third launch will take place during the shower, and the last one thereafter. This long lasting campaign shall be able to characterize undisturbed and disturbed conditions of the middle atmosphere due to the meteor shower. Tab. 1 lists the so far conducted as well as planned campaigns.

Table 1: Conducted and planned ECOMA campaigns

Mission	Launch Date	Range
ECOMA 1	8 Sept. 2006	ARR
ECOMA 2	17 Sept. 2006	ARR
ECOMA 3	3 August 2007	ARR
ECOMA 4	30 June 2008	ARR
ECOMA 5	7 July 2008	ARR
ECOMA 6	12 July 2008	ARR
ECOMA 7	December 2010	ARR
ECOMA 8	December 2010	ARR
ECOMA 9	December 2010	ARR
ECOMA 10	December 2010	ARR

2.2 Solar Physics

SUNRISE is a balloon-borne solar telescope working in the ultraviolet spectral region down to 220 nm, which is not accessible from the ground. The scientific objective of the project is to understand the formation of magnetic structures in the solar atmosphere and to study their interaction with the plasma flows of the sun. The solar magnetic activity exerts influence on the space environment of the Earth and causes the variability of the solar irradiance. Among other sources, this one may be a significant driver of long-term changes of the terrestrial climate.

The telescope shall provide images of the solar photosphere and chromosphere with high spatial and temporal resolution. The projected diffraction limited spatial resolution of 35 km could never be obtained from ground during time intervals of hours to days. It will allow resolving magnetic structures with spatial scales of the order of 100 km on the solar surface. Such scales cannot be studied systematically from the ground because of image distortion by turbulence in the lower atmosphere of the Earth.

SUNRISE is a joint project of German, US, and Spanish scientific groups led by the Max-Planck Institute for Solar System Research (MPS), Katlenburg-Lindau. The 1 meter telescope (Fig. 2) was built by Kayser-Threde, Munich under the responsibility of MPS. The instrumentation consists of a filter imager built by MPS and a magnetograph provided by the Instituto de Astrofisica de Canarias, Spain. The Kiepenheuer Institute for Solar Physics, Freiburg was responsible for the image stabilisation system. The balloon gondola, equipped with the pointing, power and telemetry systems, was built by the High Altitude Observatory, Boulder. The balloon has to carry a total mass of 2.7 tons.

Figure 2: SUNRISE solar telescope during integration. Credits: MPS

A first successful ten hours test flight of the gondola system was carried out by the Columbia Scientific Balloon Facility from Fort Sumner, USA in October 2007. A second test flight took place from Esrange on 28 June 2008 managed by EuroLaunch. The first mission of the full scientific payload is scheduled for June 2009 again from Esrange. During its journey of about four to five days in heights up to 40 km the telescope will have continuous view to the sun. The mission will end with a parachute landing and payload recovery in northern Canada.

3. MICROGRAVITY LIFE AND PHYSICAL SCIENCES

3.1 TEXUS, MASER, MAXUS, MAPHEUS

The life and physical sciences in the German Space Programme deal mainly with investigations of the effects of weightlessness ("microgravity") on physical, chemical, and biological processes. In these domains 277 German experiments on the sounding rockets TEXUS, MAXUS, MASER, Mini-TEXUS, SPAR, and VOLNA were performed in the timeframe 1975 until now. TEXUS enables a scientific payload of up to 250 kg and 6 minutes microgravity at a level better than 10^{-4} g. The ballistic flight phases of the other rockets provided microgravity conditions ranging from 3 min (Mini-TEXUS), 6 min for MASER and SPAR, and up to 13 min for MAXUS, respectively. In 1995 the Russian rocket VOLNA was used by DLR for a fluid physics experiment that required 20 min microgravity conditions.

In fall 2007 the 30th anniversary of the first flight of a German TEXUS rocket was celebrated. TEXUS proved to be the "workhorse" for German microgravity experiments with a share of 85% of all sounding rocket flights. It can be regarded as the backbone of regular medium-duration flight opportunities provided by the German and ESA microgravity programmes.

Fig. 3 shows the distribution of all performed German microgravity experiments on rockets in relation to the different research disciplines. Most of the experiments were carried out in the field of materials research followed by fluid physics, and gravitational biology. Biotechnology experiments (protein crystallisation, electrophoresis, cell fusion) attracted the interest of scientists mainly in the first years of sounding rocket activities.

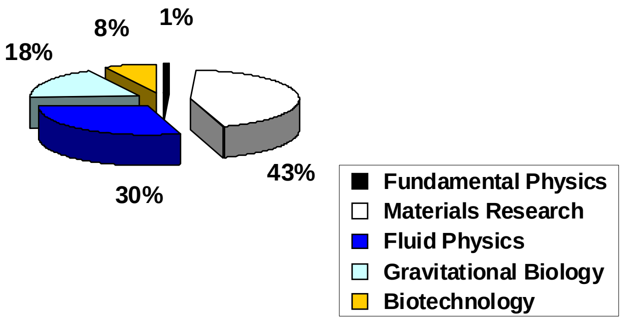

Figure 3: Share of German experiments in different research disciplines flown on sounding rockets in the timeframe 1975-2009.

During the period of this report, i. e. mid 2007 to mid 2009, German scientists participated in four sounding rocket missions and conducted twelve life and physical sciences experiments (Tab. 2).

The flight of TEXUS 44 on 7 February 2008 was the second mission to exploit the EML (ElectroMagnetic Levitator) module cooperatively by ESA/DLR. This facility enables containerless processing of metallic melts to investigate their thermophysical properties and solidification dynamics. Using the EML precise data of

Table 2: Performed German microgravity sounding rocket experiments (May 2007 - May 2009)

Principal Investigator	Experiment	Mission
I. Egry DLR Cologne	Undercooling and Demixing of Cu-Co Alloys	TEXUS 44
H. Fecht, R. Wunderlich Univ. Ulm	High Precision Thermophysical Data of Al-Ni Melts	TEXUS 44
D. Herlach DLR Cologne	Non-equilibrium Solidification of Al-Ni Melts	TEXUS 44
D. Volkmann Univ. Bonn	Kinetics of Gravi-sensitive Membrane Recycling	TEXUS 44
C. Tropea TU Darmstadt	Spray Impact onto a Heated Surface	TEXUS 45
M. Dreyer ZARM Bremen	Two-phase Flows in Open Capillary Channels	TEXUS 45
R. Hilbig Univ. Hohenheim	Adaptability of Fish to Reduced Gravity and Calcium Uptake of Inner Ear Otoliths	TEXUS 45
F. Garcia-Moreno TU Berlin	In-situ X-ray Moni-toring of Metallic Foaming	MASER 11
K. Eckert TU Dresden	Chemically Driven Capillary Convection	MASER 11
A. Griesche DLR Cologne	Diffusion Coefficients in Metallic Alloy Melts	MAPHEUS 1
S. Steinbach DLR Cologne	Solidification Dyna-mics of Al-Si Alloys	MAPHEUS 1
L. Ratke DLR Cologne	Gelation of Aerogels	MAPHEUS 1

the viscosity, surface tension, specific heat, electrical conductivity, and thermal expansion of chemically reactive melts become achievable. Such data of high-melting alloys are not achievable under normal gravity with the required precision due to contamination and other disturbing effects. But they are needed by the metallurgical industry for improved computer simu-lations to carry out more efficient casting processes.

On the TEXUS 44 mission conducted by ESA the surface tension, viscosity and specific heat of an Al-Ni alloy melt were investigated. In the chosen composition this alloy represents a catalytic precursor material applied in industry. This sample was also exploited to measure the growth velocity of dendrites during rapid solidification. The second sample of the EML facility was a "sphere in a sphere" consisting of a Cu- and Co-rich melt, respectively. The interfacial tension of this material combination was successfully determined.

On the same flight a dedicated module for investigations in the field of gravitational biology was employed. It is well known that the ability of plants to sense gravity is limited to specialized cell types (statocytes) in shoots and roots. Membranes, the dislocation of membrane bound molecules (membrane recycling), and the plant hormone auxin are assumed to be finally responsible for gravity controlled growth. The scientific objective of the experiment was the identification and characterization of the gravity dependant membrane recycling process. Seedlings of the model plant Arabidopsis and roots of maize were investigated.

TEXUS 45 was launched under the responsibility of DLR on 21 February 2008. The rocket carried a payload of three research modules. The CCF (Capillary Channel Flow) module was re-used for the forth time to investigate the stability of capillary driven fluid flow in partly open channels. CCF provides the verification for the flow rate limit and corresponding critical flow velocities. If a certain critical flow is exceeded, the flow does not remain steady. The surfaces collapse at the open sides of the capillary and gas ingestion occurs at the outlet (Fig. 4). Such data are important for the future

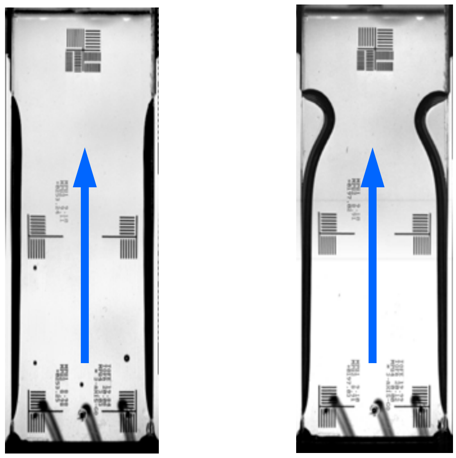

Figure 4: Fluid flow with free surfaces at both sides of a parallel plate. Subcritical (left) and criti-cal (right) flow under microgravity. In the latter case the free surfaces collapse and gas ingestion occurs at the outlet. Credits: ZARM

design of so-called surface tension tanks being used for the storage of liquid fuels in satellites and rocket upper stages. This TEXUS mission represented the fine tuning of an extended research programme planned on the ISS.

The DOLFIN project investigated the Dynamics Of Liquid FIlm/wall INteraction associated with liquid spray impact onto a heated target. The aim was to clarify the hydrodynamics and heat transfer of such a process, the efficiency of cooling, and to improve the process modelling. Fig. 5 shows the water spray impact on a copper surface in microgravity and at hypergravity.

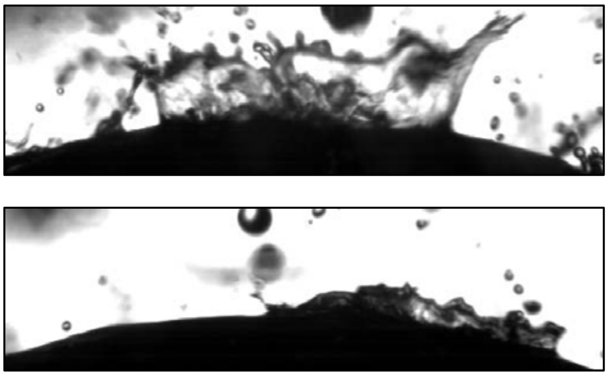

Figure 5: Water spray impact monitored at a bent copper surface under µg (above, TEXUS 45) and at 2g (below, centrifuge at ZARM Bremen). Credits: TU Darmstadt

In practical cases liquids come into contact with hot surfaces in the form of finely dosed sprays during a number of processes, such as mixture formation in combustion chambers, spray-coating of materials, and cooling of high-performance electronic components.

In the field of gravitational biology the adaptability of fish to reduced gravity was investigated on the TEXUS 45 flight. Specifically, the calcium uptake of inner ear stones of fish was measured under microgravity conditions provided by the ballistic rocket flight (10^{-4} g) and a centrifuge on board the research module (0.04 g), respectively. Altogether 72 cichlid fish (Fig. 6) travelled into space and returned safely.

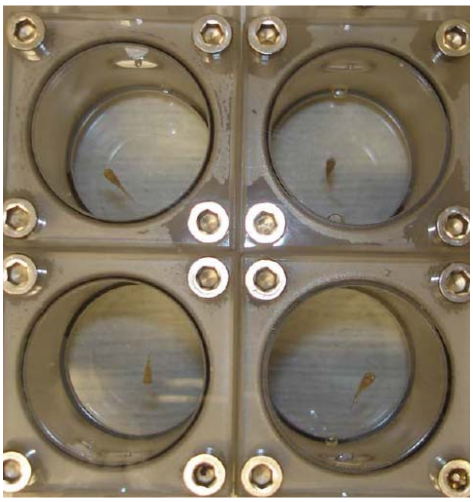

Figure 6: Experiment cells with fish to study their adaptability to reduced gravity. Credits: SSC

In general, sounding rocket missions do not only carry stand-alone scientific payloads, but sometimes they also represent important precursor missions. For instance, this is true in the case of the TEXUS-EML and TEXUS-CCF modules flown on TEXUS 44 and TEXUS 45, respectively. These modules are precursors of major research instrumentation planned to be accommodated on the ISS. In this context DLR currently develops

- the CCF Facility for the Microgravity Science Glovebox on COLUMBUS in collaboration with NASA and planned for flight in 2010, as well as
- the Electromagnetic Levitator core component, called EML Experiment Unit, for the European Drawer Rack on COLUMBUS in collaboration with ESA and planned for flight in 2011.

MASER 11 was launched on 28 May 2008 with two experiments headed by German scientists. The XRMON (X-Ray MONitoring) experiment investigated the foaming of molten aluminium by X-ray analysis in-situ. This method allows a quantitative investigation of local changes in density, pore size distribution and cell wall rupture. On the same mission the CDIC (Chemically Driven Interfacial Convection) experiment was flown for the second time and investigated the convective transport of chemical species across a liquid interface. More insight into the interplay between chemistry and interfacial tension driven hydrodynamic instabilities is expected.

The next microgravity rocket missions planned by DLR and ESA are listed in Tab. 3.

Table 3: Future microgravity missions with German experiments

Mission	Launch	German Experiments	
		No	Area
TEXUS 46 *)	Nov 2009	4	Materials Research (3), Combustion (1)
TEXUS 47 #)	Nov 2009	4	Materials Research (2), Biology (2)
MAXUS 8 *)	Mar 2010	4	Biology (1), Materials Research (3)
MAPHEUS 2 #)	tbd		Under review
MASER 12 *)	tbd		Under review

*) ESA #) DLR

Among them, for the second time a new mission type called MAPHEUS 2 is going to materialise. In 2008 the Institute of Materials Physics in Space, Cologne in collaboration with MORABA, Oberpfaffenhofen, and the Institute of Space Systems, Bremen started a DLR internal R&D activity to get an easy, fast and cheep access to microgravity conditions. The mission name is derived from MAterialPHysikalische Experimente Unter Schwerelosigkeit. The maiden flight of the two stage rocket, achieving an altitude of about 150 km with 150 kg payload and providing about 3 min microgravity, was conducted on 22 May 2009. The payload consisted of 3 scientific modules: ATLAS-M for measurements of diffusion coefficients in metallic melts, ARTEX-M for solidification of an Al-Si alloy, and AEROGET-M for the gelation of aerogel benchmark samples.

4. EARTH OBSERVATION

4.1 MIPAS-B / TELIS and TWIN

The European spacecraft ENVISAT (ENVIronmental SATellite) was launched by ESA in 2002. It carries three atmospheric trace gas sensors, two of them are SCIAMACHY (SCanning Imaging Absorption Spectro-Meter for Atmospheric CHartographY) and MIPAS (Michelson Interferometer for Passive Atmospheric Sounding). These instruments help to monitor how and how much the Earth's atmosphere is changing. In order to provide reliable information the instruments must remain properly calibrated and the evaluation routines must be adapted to instrument ageing. This is why ENVISAT was intensively validated at the beginning of its lifetime. This is also true why the satellite's data products are still regularly checked by independent measurements. About once per year dedicated validation campaigns are performed with contributions from ESA and national space agencies. DLR has been continuously supporting scientists for their work in algorithm improvement and validation.

The latest satellite validation campaign, which also aimed at the in-situ atmospheric chemistry and physics, took place in March 2009 by launching two large balloons from Esrange. For the first time within the ENVISAT's validation programme EuroLaunch as the balloon service provider was contracted. The campaign demonstrated that this joint venture SSC Esrange - DLR MORABA represents an attractive alternative for balloon-borne research on the European market.

Three calibration instruments (Fig. 7) were launched on 11 March 2009 using a balloon with 400,000 cubic meters volume and reaching an altitude of about 40 km. The main instrument on board of the gondola was MIPAS-B provided by the Research Centre Karlsruhe, a sister instrument of MIPAS on ENVISAT. The TELIS (TEtrahertz and submillimeter LImb Sounder) instrument was provided by DLR, and Mini-DOAS, an UV/VIS spectrometer, by the Heidelberg University. These sensitive instruments measured more than forty trace gases relevant for ozone chemistry and climate.

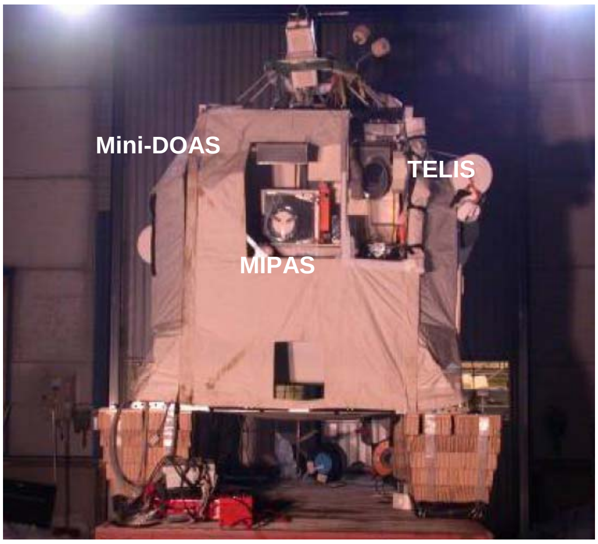

Figure 7: MIPAS / TELIS / Mini-DOAS instruments after assembly. Credits: KIT

The balloon payload TWIN (Fig. 8) was launched on 10 March 2009 with a balloon of 150,000 cubic meters volume and flew more than five hours at an altitude of more than 30 km. The payload carried two scientific instruments. One of them was the in-situ CRYOSAMPLER from the Frankfurt University. This instrument collected and returned air samples to be analysed in the terrestrial laboratory for halocarbons and other stable constituents.

The second instrument was an in-situ analyser called HALOX from the Research Centre Juelich. It measured halogen radicals in the stratosphere and upper troposphere. These substances are unstable and cannot be collected because they may not come into contact with instrument surfaces. Halogen radicals like chlorine oxide and bromine oxide play a central role within the destruction of the Earth's ozone layer.

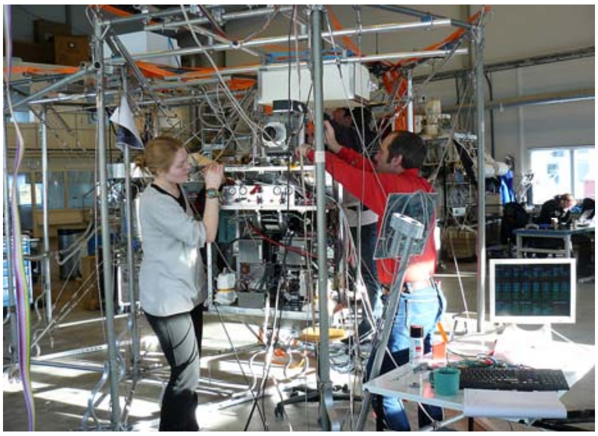

Figure 8: TWIN balloon payload during assembly. Credits: DLR

5. TECHNOLOGY DEVELOPMENT

5.1 SHEFEX

The SHEFEX 1 vehicle (SHarp Edge Flight EXperiment) was successfully launched from Andoya on 27 October 2005 and reached a re-entry velocity of Mach 6.5 during about 20 sec. The main objective of the experiment was to correlate numerical analysis data with real flight data in terms of aerodynamic effects and to test a new structural design concept of the thermal protection system. This mission represented the first step towards the demonstration that sharp leading edge configurations are qualified for hypersonic re-entry vehicles and facetted thermal protection systems can significantly reduce the manufacturing and maintenance cost compared to conventional systems.

In contrast to the ballistic trajectory of the first flight the new project SHEFEX 2 (Fig. 9) is planned to demonstrate a hypersonic re-entry with a fully aerodynamic controlled vehicle. A more powerful motor combination of the rocket together with a suppressed trajectory of the exo-atmospheric burning second stage will allow an available experiment time of about 45 sec at a velocity of Mach 10.

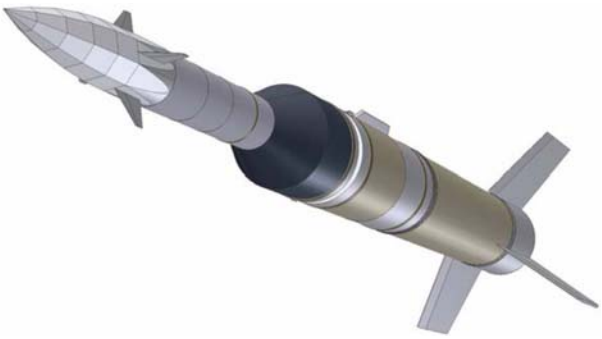

Figure 9: Planned SHEFEX 2 re-entry vehicle using a more powerful rocket configuration consisting of the Brazilian motors S40 and S44. Credits: DLR

Besides the facetted ceramic thermal protection system, ceramic based aerodynamic control elements (canards), mechanical actuators, a new automatic flight control unit will be implemented as key technology feature. Different inertial platforms and a star tracker sensor will provide accurate data related to position and orientation of the vehicle during flight.

Altogether eight DLR research entities at different sites in Germany cooperate in this project. In addition, seven external partners from Germany, Brazil, Australia, USA, and ESA are also involved in the mission. The flight preparations are well advanced. The launch of SHEFEX 2 is planned in 2010.

6. EDUCATION

6.1 REXUS / BEXUS

REXUS / BEXUS (Rocket resp. Balloon EXperiments for University Students) missions provide students with practical experience in real space projects on a regular basis. It is an activity that allows for accommodating modestly complicated experiments to keep the turnaround times and costs low. By annual calls for proposals the flight experiments are selected after evaluation by DLR and SNSB/ESA. The flight campaigns are coordinated by EuroLaunch. The first call within the German-Swedish student programme was issued in 2007 and resulted in the balloon missions BEXUS 6/7 in October 2008 (Fig. 10).

Figure 10: BEXUS 6 balloon during launch preparations. Credits: DLR

Three experiments of German student teams were on board. The TURATEMP and TURAWIND experiments coming from the University of Rostock and the Leibniz Institute of Atmospheric Physics, Kuehlungsborn investigated turbulences in the stratospheric temperature and wind field, respectively.

The third experiment called DOLS (Diversity and Origin of Life in the Stratosphere) was implemented by an interdisciplinary team made up of students from the universities of Braunschweig, Tuebingen, Heidelberg, Munich, Mainz, Cambridge, and Barcelona. The collected bacteria and spores, whose principal existence and ability to survive in the hostile environment of the stratosphere has already been proved by previous experiments, are currently analysed in the laboratories on ground. The scientific question behind these investigations is, whether microorganisms in the stratosphere are coming from Earth or outer space.

The student rocket REXUS 4 under responsibility of SSC was launched on 22 October 2008 and reached an altitude of 175 km in a spin-stabilized mode. During the mission a new rocket service system of EuroLaunch, supplying up to five scientific experiments with power and data interfaces for up- and downlink, was successfully tested.

The payload carried four German technology experiments. MIRIAM investigated the inflation of a balloon in space and its following re-entry in the atmosphere. HISPICO tested a High-Integrated S-Band Transmitter planned for pico-satellites and VERTICAL verified a deployment mechanism for solar panels of a future pico-satellite. The IGAS antenna system analysed the reception of GPS signals on board of a spinning rocket. Students from the University of the Federal Armed Forces in Munich, the Mars Society Germany and the Technical Universities of Berlin and Munich participated in these experiments.

Under the auspices of the German-Swedish student programme the first two sounding rockets REXUS 5 and 6 (Fig. 11) were launched on 9 March 2009 (REXUS 6) and 12 March 2009 (REXUS 5). The rockets reached an altitude of about 90 km and the flights succeeded nominal.

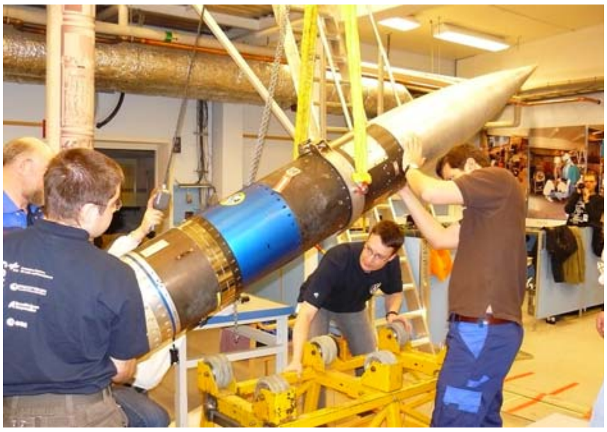

Figure 11: Preparation of the REXUS 6 student rocket. Credits: DLR

The missions consisted in the following German experiments: CHARPA of students from the universities of Rostock, Munich and Stockholm, as well as AGADE of students from the universities of Freiberg, Dresden and Brandenburg. CHARPA investigated charged, nanometer-sized meteor smoke particles in the upper mesosphere and has the objective to check whether the current measured by a Faraday cup is produced by charged dust directly or via a triboelectric charging effect.

AGADE (Applied Geomagnetism for Attitude Determination Experiment) aimed for analysing and comparing a set of different compact, commercially available 3-axes magnetometer assemblies together with a high precision magnetometer. During the rocket flight the variations of the Earth's magnetic field were measured and will be compared with data from ground measurements. Finally, the test will clarify whether such sensors together with an on board attitude determination software could be exploited in small scale satellites.

The second call covering experiment proposals for BEXUS 8/9 (autumn 2009) and REXUS 7/8 (spring 2010) was issued in November 2008. The experiment selection workshop took place in Bonn in February 2009. Four German experiments were finally selected and the associated student groups started their projects.

CONCLUSION

Sounding Rockets are recognised as valuable tools for research in space and in the Earth's middle atmosphere, for microgravity experiments as well as for new technology demonstrations. In the fields of Space Science and Earth Observation they can complement ground-based and satellite investigations. Both sounding rockets and stratospheric balloons are also considered as valuable educational and training tools for students and young scientists.

In the 2007-2009 period of this report the German Space programme successfully capitalized on the sounding rocket flights ECOMA, TEXUS, MASER, MAPHEUS and REXUS. Balloon flights with the payloads SUNRISE, MIPAS-B/TELIS and TWIN were successfully conducted and BEXUS balloon campaigns provided students first practical experiences, which are typical for space projects.

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