SOUNDING ROCKET AND BALLOON RESEARCH ACTIVITIES SUPPORTED BY THE GERMAN SPACE PROGRAMME 2009 - 2011

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ABSTRACT

Mainly sounding rockets but also stratospheric balloons have played a crucial role in implementing the German Space Programme since many years. Main activities are conducted in Space Sciences, Microgravity Research, Earth Observation, and Technology Development. Additionally, rocket and balloon flights are used in the field of Education and Outreach by students of natural scientific and engineering subjects.

The 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 disciplines of life and physical sciences benefit from medium-duration rocket experiments. In the Earth Observation field balloon-borne measurements are conducted to validate atmospheric sounding instruments on satellites and to study the chemistry of the stratosphere. Student activities are successfully continued under the auspices of the Swedish-German programme REXUS / BEXUS.

1. INTRODUCTION

The German Space Programme is managed by the DLR Space Administration on behalf of the government. This assignment is in addition to the role of the German Aerospace Center DLR as major research establishment comprising the domains of aeronautics, space flight, transport and energy.

The disciplines Space Science, Microgravity Research, Earth Observation, and Technology Development are core elements of the German Space Programme. On the one hand sounding rockets and balloons represent a cost-effective tool for in-situ measurements in the Earth's atmosphere. On the other side experiments in nearly weightlessness can be performed on a free fall trajectory of rockets. Technological developments like thermal protection systems that can withstand a hypersonic atmospheric re-entry are tested by rockets on special trajectories. Smaller rockets and balloons are suitable tools for the education of students and the training of young scientists in space projects.

The Revised Agreement for the Esrange and Andøya Special Project (EASP) was signed by the governments of Sweden, Norway, Germany, France, and Switzerland as well as by the European Space Agency ESA in 2006. It secures the availability of both Scandinavian launch facilities ESRANGE, Sweden, and Andøya Rocket Range (ARR), Norway. In order to conduct space and atmospheric research with rockets and balloons German scientists of more than 20 research institutions benefit from these launch sites in European autonomy. Rocket and balloon flight campaigns are reliably conducted by EUROLAUNCH, a joint venture of the DLR entity MORABA (Mobile Rocket Base) and the Swedish Space Corporation (SSC).

In June 2007 the agreement on the German-Swedish REXUS / BEXUS Student Programme was signed by the German Space Agency, DLR, and the Swedish National Space Board, SNSB. In each of such missions half of the rocket (REXUS) or balloon (BEXUS) payload is made 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.

This paper reports on the rocket and balloon research activities supported by the German Space Programme in the time frame from mid 2009 to mid 2011.

2. SPACE SCIENCE

2.1 Aeronomy

2.1.1 ECOMA

The ECOMA project (Existence and Charge State Of Meteoritic Dust Particles in the Middle Atmosphere) represented an international cooperation of the Leibnitz Institute of Atmospheric Physics (IAP), Kuehlungsborn, and the Norwegian Defence Research Establishment (FFI). The main objective was the characterization of meteoritic smoke particles and the analysis of their interaction with charged constituents of the ionosphere. The project was successfully concluded in late 2010.

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 relative velocities between 11.2 and 73.6 km/s. Due to the friction with the molecules of the atmosphere they heat up quickly and are evaporated. The nanometer-sized dust or smoke particles produced

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in the altitude range between 100 and 70 km are assumed to play a major role in a variety of atmospheric processes. Examples are the nucleation of ice particles in the polar summer mesopause region and the nucleation of stratospheric particles that are involved in the formation of the ozone hole.

The main ECOMA rocket payload was a specially adapted particle detector for meteoritic grains provided by IAP (PIs: F.-J. Luebken, M. Rapp). Further payloads were a particle sampler, an electron and positive ion probe, and a Faraday rotation experiment. Numerous scientists from Germany, Norway, Sweden, and Austria developed this set of instruments. All flight campaigns used Nike/Improved Orion sounding rockets, which have been launched from ARR since 2006 (Tab. 1). The rocket measurements were regularly accompanied by observations from the ALOMAR ground station at ARR using radar and lidar.

Table 1: Conducted ECOMA campaigns

Launch	**Date**
ECOMA 1	8 September 2006
ECOMA 2	17 September 2006
ECOMA 3	3 August 2007
ECOMA 4	30 June 2008
ECOMA 5	7 July 2008
ECOMA 6	12 July 2008
ECOMA 7	5 December 2010
ECOMA 8	13 December 2010
ECOMA 9	19 December 2010

The last ECOMA campaign successfully took place in December 2010 comprising three rocket flights. The first rocket was launched prior to the Geminids meteor shower, the second one in the maximum of the shower, and the third one thereafter. Therefore, this campaign allowed for the characterization of undisturbed and disturbed atmospheric conditions due to the Geminids.

2.1.2. WADIS

The ECOMA activities are succeeded by the project WADIS (Wellenausbreitung und Dissipation in der Mittleren Atmosphäre; engl. wave propagation and dissipation in the middle atmosphere). The project was initiated in summer 2010 by the IAP team. It is funded by IAP and the DLR Space Administration. The main objectives are the analysis of gravity-wave dynamics effects in the middle atmosphere and measurements of atomic oxygen in-situ.

For the gravity-wave studies the already flown CONE sensors (Fig. 1) will be on board the rocket. Atomic oxygen measurements will be carried out by two new sensors - FIPEX and PHLUX. The Institute of Space Systems (IRS) of the University of Stuttgart will supply both sensor types. FIPEX (Fig. 1) was already flown on the ISS, and the PHLUX sensor will be tested on board the ESA space capsule EXPERT in 2011.

Two campaigns are planned from ARR, one in winter 2012 and one in spring 2013. In each campaign one Nike/Improved Orion sounding rocket will be launched together with 12 small Super Loki Datasonde rockets. The last ones will be provided by NASA free of charge due to a cooperation agreement with IAP.

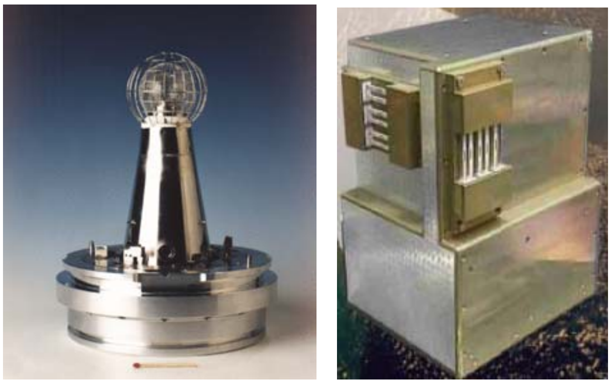

Figure 1: Left: CONE - Combined Sensor for Neutrals and Electrons. Right: FIPEX atomic oxygen sensor flown on the ISS.
Credits: IAP, Kuehlungsborn, TU Dresden

2.2 Solar Physics

SUNRISE is a balloon-borne solar telescope working in the ultraviolet spectral region down to 214 nm. Measured data in this region are not accessible from the ground. The instrument is able to produce spectral and polarimetric images of the solar photosphere and chromosphere with very high temporal and spatial resolution. Therefore, small-scale plasma structures below 100 km latitude can be observed. The scientific objective of the project is to understand the formation of magnetic structures in the solar atmosphere and to study their interaction with plasma processes of the sun. The solar magnetic activity exerts influence on the space environment of the Earth and causes the variability of solar irradiance. Among other sources, this one can be a significant driver of long-term climate changes.

SUNRISE is a joint project of German, US and Spanish scientific groups led by the Max Planck Institute for Solar System Research (MPS, PI: S. K. Solanki). The one meter aperture telescope was build by the company Kayser-Threde, Munich, under the responsibility of MPS. The instrumentation consists of a filter imager (SuFi) built by MPS and a magnetograph (IMaX) provided by the Instituto de Astrofisica de Canarias, Spain. The Kiepenheuer Institute for Solar Physics, Freiburg, was responsible for the image stabilisation system and the correlation wavefront sensor. The balloon gondola equipped with the power supply and the pointing and telemetry system was built by the High Altitude Observatory, Boulder. The NASA Columbia Scientific Balloon Facility, Palestine, arranged this mission.

On 8 June 2009 - just the morning when the 19th Sounding Rocket and Balloon Symposium commenced in Bad Reichenhall - the SUNRISE balloon was launched from ESRANGE (Fig. 2). On the way up to the stratosphere the balloon diameter increased to more than 100 meters carrying more than two tons of scientific equipment. Flying at heights up to 37 km the gondola left 99% of the Earth atmosphere below. During its travel beyond the Arctic Circle the telescope had an untarnished and continuous sun view for more than five days. The SUNRISE telescope worked well and collected more than six hundred thousand images and 1.2 TByte data on its hard discs. On 13 June 2009 the parachute landing of the telescope gondola was initiated. The gondola touched down on the Summerset Island in the north of Canada. The recovery of data, telescope and gondola was successful.

Figure 2: SUNRISE solar telescope during launch preparation at ESRANGE. Credit: MPS

A second mission is envisioned by MPS in 2012 after the refurbishing of the flown instruments. While the images taken in 2009 reveal the atmosphere of an extremely quiet sun in the solar minimum, a much higher solar activity can be expected in 2012.

3. MICROGRAVITY RESEARCH: LIFE AND PHYSICAL SCIENCES

3.1 TEXUS, MAXUS, MAPHEUS

In order to investigate of the effects of weightlessness ("microgravity") on physical, chemical, and biological processes numerous German scientists participated in five sounding rocket missions with 17 experiments (Tab. 2 and 3) during the period of this report. The microgravity duration ranges from 3 (MAPHEUS), 6 (TEXUS) to 12 minutes (MAXUS).

The flight of TEXUS 46 on 22 November 2009 was conducted by ESA. It was the third mission to exploit the EML (ElectroMagnetic Levitator) module cooperatively by ESA and DLR. This facility enables containerless processing of metallic melts with low levitation forces. Under such conditions thermophysical properties of alloy melts and their solidification dynamics can precisely be studied. Using the EML data the viscosity, surface tension, specific heat, electrical conductivity, and thermal expansion of chemically reactive metallic melts become measurable. These data are needed by the metallurgical industry for improved computer modelling to carry out more efficient casting processes. On ground such data are not achievable with the required precision.

During the TEXUS 46 mission the surface tension and viscosity of two metallic samples were measured. In the first case Pd-Si was investigated, which represents one of the best binary metallic glass formers. For this sample reliable data exist from earlier microgravity measurements. Therefore, a quantitative assessment of the quality of the data obtained during a quiet and force-free environment offered by TEXUS can be compared with the results of experiments performed on the Space Shuttle. The second sample in the EML facility was a steel alloy provided by the metallurgical industry. Its chilling behaviour on a ceramic plate was studied. The experiments were led by scientists of the DLR Institute of Materials Physics in Space.

On the same mission the Japanese Combustion Module was flown. The objective of the combustion of an array of five linearly aligned droplets of n-decane was to study the combustion properties in the case of partially premixing and pre-vaporization. While the Japanese scientists focused on the dynamics of the flame propagation the German team of the University of Munich investigated the emission of nitrogen oxide in the exhaust of the fuel.

TEXUS 47 was launched under the responsibility of DLR on 29 November 2009. The rocket carried four research modules. The TRACE module was used to investigate the solidification of a transparent model substance, which features a microstructure like metallic alloys (Fig. 3). This approach allows for an in-situ observation of a columnar-to-equiaxed transition of dendrites during solidification and the determination of the critical parameters. These data are important for numerical simulations of technically relevant castings. In practice, either columnar or equiaxed dendrites are desired. Equiaxed dendrites result in microstructures with isotropic properties. Columnar dendrites cause anisotropic structures, which are mainly preferred in components that are exposed to strong mechanical stress in a certain direction. The team of ACCESS e. V. was responsible for this experiment.

Table 2: German microgravity experiments on sounding rockets (May 2009 - March 2010)

Principal Investigator	Experiment	Mission
H. Fecht Univ. Ulm	Thermophysical Property Data of a Molten Steel	TEXUS 46
I. Egry DLR Cologne	Viscosity of a Pd-Si Melt – a Benchmark Experiment	TEXUS 46
K. Moesl TU Munich	Combustion Properties of Partially Premixed Sprays	TEXUS 46
G. Zimmermann ACCESS, Aachen	Columnar-to Equiaxed Transition in Solidification	TEXUS 47
A. Croell Univ. Freiburg	Vibrational Convection in Silicon Float Zones	TEXUS 47
P. Galland Univ. Marburg	Fast Gravitropic Primary Reactions of Fungi	TEXUS 47
R. Hampp Univ. Tuebingen	Molecular Responses of Plant Cells upon Gravity	TEXUS 47
M. Braun Univ. Bonn	Mechanisms of Gravisensing in Chara	MAXUS 8
B. Günther IFAM Bremen	Agglomeration of Ni Nanoparticles by Synthesis of Its Vapour	MAXUS 8
A. Griesche BAM Berlin	X-ray Diagnostics of Diffusion Processes in Metallic Melts	MAXUS 8

A new and up to now rarely investigated method to counteract the disturbing effect of the Marangoni convection in a Si floating zone melt is axial vibration. The formation of microscopic irregularities in the grown crystal caused by Marangoni convection can be avoided. Surface waves on the melt zone caused by vibrations are damped by the melt viscosity. This effect drives a flow that opposes Marangoni convection. The experiment on TEXUS 47 succeeded an experiment on MAXUS 4, where the validity of the concept was already proven by scientists of the University of Freiburg.

Two biological experiment modules were flown on TEXUS 47. In the first one the gravitropism of fungi was studied. This is the phenomenon how fungi sense the Earth gravitational field. The goal of the experiment, prepared by scientists of the University of Marburg, was the identification and characterization of the primary responses by applying fast in-vivo spectroscopy. A build-in centrifuge allowed for determining the kinetics and the absolute thresholds of the primary responses.

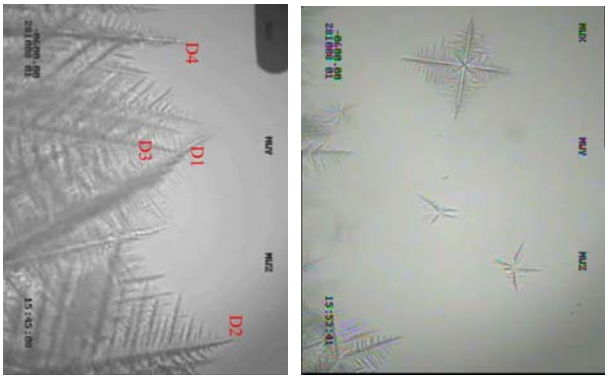

Figure 3: Columnar (left) and equiaxed (right) growth of dendrites in a transparent alloy as used in the TEXUS 47 mission. Credit: ACCESS e. V.

The second biological experiment was prepared the University of Tuebingen and investigated the molecular responses of plant cells upon changes in gravity. It is known that plants have developed sophisticated and fast response systems towards different forms of stress. Already weak interactions with the plant surface can result in immediate changes in the expression of specific genes. The same effect holds for exposure to changes in gravity. Therefore, such genes had to be identified in the experiment. One of the next steps will be to fully understand how this reaction is converted into physiological responses.

On 26 March 2010 ESA launched MAXUS 8 with four scientific modules was. Scientists of the University of Bonn investigated the mechanisms of cell structures to perceive gravity in both intensity and direction. Previous experiments with the Chara algae indicated that accelerations between 0.05 and 0.14-g are required to displace intracellular sediment particles towards the gravity sensitive plasma membrane site. The contact of these particles with gravity-receptors of the membrane induces specific responses of the cell. A centrifuge inside the module allowed a stepwise variation of the acceleration level acting on the cells.

Scientists of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials in Bremen studied the agglomeration behaviour of Ni-nanoparticles via an evaporation-condensation process. The question behind is how the particles cluster together into large fluffy agglomerates when sedimentation in microgravity is avoided. From this type of research new concepts for the design of more efficient catalysts are expected.

The objective of the XRMON project was to investigate diffusion processes in metallic and semiconductor melts. The knowledge of diffusion coefficients in melts is becoming more and more important in the casting industry. Accurate data on such coefficients is a crucial input to the models to improve the reliability of the simulations. The new feature of the MAXUS 8 module consisted in an X-ray setup. The visualisation of the diffusion process in the metallic melts in-situ was possible in microgravity for the first time. Scientists of the DLR Institute of Materials Physics investigated diffusion couples of Al/Al-Cu, Al/Al-Ni and Si/Ge.

For the second time a sounding rocket mission called MAPHEUS took place on 27 October 2010. In 2008 the Institute of Materials Physics in Space, Cologne, in collaboration with MORABA, Oberpfaffenhofen, and the Institute of Space Systems, Bremen, started this DLR internal R&D activity. Its purpose is to get a fast and low-cost access to microgravity conditions for materials sciences experiments. The maiden flight of the two stages Nike/Improved Orion rocket was conducted on 22 May 2009. An altitude of about 150 km with 100 kg scientific payload was achieved providing about 3 min of microgravity.

Table 3: German microgravity experiments on sounding rockets (April 2010 - May 2011)

Principal Investigator	Experiment	Mission
A. Meyer DLR Cologne	Diffusion Measurements in Metallic Melts	MAPHEUS 2
M. Kolbe DLR Cologne	Demixing in Cu-Co Alloy Melts	MAPHEUS 2
M. Sperl DLR Cologne	Magnetically Excited Granular Matter	MAPHEUS 2
G. Zimmermann ACCESS, Aachen	Columnar-to-Equiaxed Transition in Transparent Melt Solidification	TEXUS 49
D. Herlach DLR Cologne	Dendrite Growth Velocity as a Function of Undercooling in a Al-Ni Alloy	TEXUS 49
M. Kolbe DLR Cologne	Interaction of Ceramic Particles with a Solidification Front in Ni-Ta Alloys	TEXUS 49
O. Ullrich Univ. Magdeburg	Signal Transduction in Cells of the Immune System	TEXUS 49

The scientific payload of MAPHEUS 2 consisted of three modules. In ATLAS-M measurements of diffusion coefficients of altogether 32 samples of doped Ge and Al melts as well as Al-Cu-Ag alloys were performed. The demixing behaviour of 8 Cu-Co melts of different composition was studied in the DEMIX module. The MEGRAMA module (Fig. 4) permitted studies on the dynamics of granular matter. Specifically, magnets were used to excite paramagnetic particles in a gas. The subsequent “cooling” leading to compaction of the particles was analysed by video recording.

Figure 4: MEGRAMA setup of MAPHEUS 2. A camera records the movement of a granular gas. Credit: DLR-MP

Recently, on 29 March 2011 TEXUS 49 was launched by DLR carrying three research modules. The EML module was flown for the fourth time with two samples. Scientists of the DLR Institute of Materials Physics in Space studied the crystallisation kinetics as function of the undercooling on Al-Ni melts. Measurements on this alloy with a specific composition reveal a very unusual behaviour on ground. The dendritic growth velocity is decreasing with increasing undercooling. During a previous TEXUS mission two data points could be recorded in microgravity. They differ significantly from the values obtained on ground. Therefore, additional data are required to clarify the underlying physical mechanisms.

The interaction of ceramic particles with a dendritic solidification front was investigated in the second EML sample. Metallic materials can be reinforced by ceramic particles to improve their wear resistance. The objective of the experiment was to clarify when the particles are pushed ahead of the solidification front and when they are engulfed into the solidifying material. A high speed video camera recorded the solidification front of a Ni-Ta melt with ceramic particles. After the experiment the solidified microstructure will be investigated and correlated to the solidification velocity.

The TRACE module was flown on TEXUS 49 for the second time. Again, scientists of ACCESS investigated the columnar-to-equiaxed transition during solidifying a transparent alloy but with a different parameter set. The melt is neither affected by sedimentation nor by convection in microgravity. Therefore, the data can be used for calibration purposes and improvement of numerical models of casting processes.

In the third module the signal transduction in cells of the immune system was investigated by a team of the Universities of Magdeburg and Zurich. It is well known that the activity of cells of the immune system is severely affected in microgravity but the underlying molecular mechanisms are far from being understood. The aim of the experiment was to achieve a systematic overview of gravity-related gene expression in cells of the immune system. The hypothesis was to be tested that a specific kind of cell proteins are responsible for the interplay of gravity changes and cellular response.

4. EARTH OBSERVATION

4.1 MIPAS-B / TELIS / Mini-DOAS

The European spacecraft ENVISAT (ENVIronmental SATellite) was launched by ESA in 2002. It carries several 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). To provide always reliable information the instruments must remain properly calibrated and the evaluation routines must be accordingly adapted to instrument ageing.

In the framework of this ENVISAT long-term validation further two balloon campaigns were performed since 2009. The main payload of the flight on 24 January 2010 was the MIPAS/TELIS/Mini-DOAS spectrometric gondola (Fig. 5) with instruments from the Karlsruhe Institute of Technology (KIT, PI: H. Oelhaf), the DLR Remote Sensing Technology Institute, the University of Heidelberg, and international partners. EUROLAUNCH provided the launch services. A balloon of 402000 cubic meters volume carried the gondola with about 740 kg scientific payload in an extremely cold (-89 degrees C) stratosphere. At that time the arctic polar air mass vortex was centred over northern Scandinavia.

In addition to the validation of the measurements carried out in space the second goal of the balloon flight was to analyse the time dependent chemistry of chlorine and bromine in the stratosphere. Such measurements are needed for the validation and improvement of existing models of the Earth atmosphere. This approach shall allow a reliable prediction of future ozone changes and the anthropogenic impact on the climate. The remote sensing spectroscopic techniques covered the spectral range from the ultra violet to the microwave region. The balloon flight was linked to a parallel running aircraft campaign with the Russian high-flying GEOPHYSICA aircraft and measurements on the ISS with a Japanese instrument. The gondola performed a long-duration flight of 13 hours inside the polar vortex measuring the concentrations of more than 30 trace gases.

MIPAS-B is the balloon version of similar Fourier spectrometers used on the stratospheric research aircraft GEOPHYSICA and on ENVISAT. It operates in the thermal infrared region. Mini-DOAS is an ultraviolet to visible range spectrometer, while TELIS covers the microwave range. Meanwhile scientists and operators of balloons and aircrafts have acquired considerable skills of achieving suitably coincident measurements during tracing and back-tracing those air masses successively measured by one or two of the ENVISAT sounders and by the airborne reference instruments.

Figure 5: MIPAS/TELIS/Mini-DOAS gondola (left) during launch preparations at ESRANGE. Credit: KIT, Karlsruhe

A balloon with the same payload was launched at ESRANGE on 31 March 2011. The unique combination of remote sensing instruments covering spectral regions from the UV to the microwave was again capable of measuring more than 30 atmospheric chemically-active and long-lived species that are relevant for ozone loss and climate. This flight has been the first out of four planned within the project ENRICHED that is managed by CNRS, France, and KIT (PI: H. Oelhaf). It was funded by CNES, DLR Space Administration, and the involved scientific institutes. The CNES balloon team was responsible for the first flight campaign.

Thanks to the meteorological situation all measurements were conducted as planned inside the polar vortex. The flight enabled more than four hours of data recording.

5. EDUCATION

5.1 REXUS / BEXUS

REXUS / BEXUS (Rocket resp. Balloon EXperiments for University Students) is a German-Swedish student programme to acquire practical experience in real space projects on a regular basis. By annual calls for proposals the flight experiments are selected after evaluation by DLR and SNSB. The ESA education office cooperates with SNSB to additionally fly other European payloads on the Swedish share. All campaigns are conducted by the DLR-SSC launch provider EUROLAUNCH.

During the last two years the sounding rocket missions REXUS 7, 8, 9, and 10 were performed with altogether eight payloads from German students (Fig. 6). The one stage Improved Orion rocket was employed resulting in altitudes of about 90 km.

On 2 March 2010 REXUS 7 was launched with the German modules MONDARO and VIBRADAMP. In the first case a team of the University of Rostock measured the neutral gas density in the atmosphere with different pressure sensors and calibrated them. In the second experiment a lightweight case fitting into a standard REXUS module for damping residual accelerations during the microgravity phase was tested by students of the University of Applied Sciences, Aachen. The contactless damping mechanism is based on the eddy current principle.

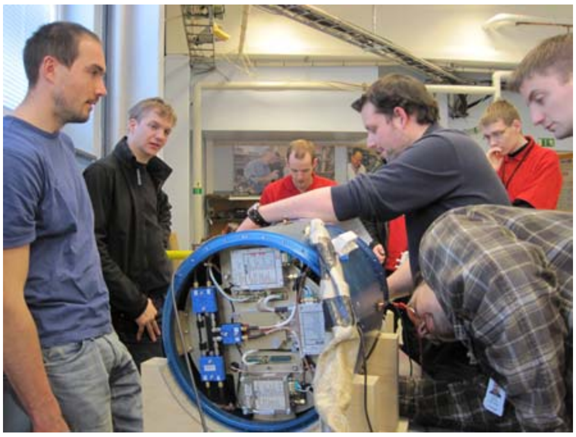

Figure 6: Students and engineers during the assembly of a REXUS rocket module. Credit: DLR-ZB

On 4 March 2010 REXUS 8 flew with another two payloads from Germany. TUPEX-3 prepared by students of the Technical University Berlin tested a newly developed communication system and a sun sensor for future applications in nano-satellites. In the VECTOR experiment a student team from the Technical University Munich verified concepts for tracking the rocket during flight. An S-band antenna communicated from the ground with a telemetry system on board the rocked. The computer used was developed by the students.

REXUS 9 was launched on 22 February 2011 with the payloads REMOS and EXPLORE. The modules were prepared by students of the University of Stuttgart and Offenburg. The first investigation concerned an in-situ measurement system of the thickness of an ablative heat shield material as can be used for re-entry vehicles. The second module tested refuelling technologies in a model setup. Such activities could become important in the Earth orbit when future orbital transportation stages for exploration missions are concerned.

REXUS 10 flew on 23 February 2011 with two German microgravity experiments. FOCUS tested a new concept for the manufacturing of space structures. Students of the Technical University Munich developed a composite structure und observed its deployment and the curing process of a synthetic resin by UV light. A granular gas consisting of macroscopic anisotropic particles was investigated by students of the Technical University of Magdeburg in the GAGA experiment. In contrast to investigations with spheres or irregular formed particles conducted so far the German students were interested in the effect of anisotropy of the particles on their collision behaviour and self organization. The movement of a few hundreds of mechanically excited small rods was recorded by a video camera.

From mid 2009 until mid 2011 the four balloon missions BEXUS 8, 9, 10, and 11 were conducted from ESRANGE. Typical float times of the balloons were 3 hours at an altitude between 20 and 30 km.

BEXUS 8 was launched on 10 October 2009 with two German experiments. Students of the University of Rostock prepared the MATI payload to measure small scale fluctuations of wind and temperature with high vertical resolution using three different methods. The second experiment REM tested the feasibility to receive L-Band signals from aircrafts. Students of the University of Applied Sciences in Bremen were responsible for this activity.

Another two German payloads flew on the BEXUS 11 mission. The balloon was launched on 23 November 2010 (Fig. 7). The PERDAIX experiment of the RWTH Aachen recorded the trajectories of charged particles of the cosmic radiation. A better understanding of the influence of the solar wind and the interplanetary magnetic field on the radiation budget is expected. In the RETA experiment students of the University of Kiel measured the radiation dose of charged and neutral particles in dependence on the altitude.

*Figure 7: BEXUS 11 balloon payload during launch preparations at ESRANGE.
Credit: DLR-ZB*

6. OUTLOOK

In addition to the planned continuation of the sounding rocket missions TEXUS (each 1.5 years), MAPHEUS (each year), REXUS (2 per year) some new highlights will materialize in the near future.

In September 2011 the SHEFEX 2 mission (SHarp Edge Flight EXperiment) is scheduled to demonstrate a hypersonic re-entry. A fully aerodynamic controlled vehicle will be flown. A suppressed trajectory of the second stage will allow an experiment time of about 45 seconds at a maximum velocity of Mach 10. As key technologies a facetted ceramic thermal protection system with an active cooling as well as ceramic based aerodynamic control elements - called canards - will be implemented. In 2012 a new series of sounding rocket missions called WADIS will commence. Scientists will study wave phenomena in the mesosphere and at the same time measure the atomic oxygen distribution.

In October 2010 the DLR Space Administration began to support a national student programme. It is called STERN (STudentische ExperimentalraketeN, Student Experiment Rockets) and offers a competition among student teams to design, build and launch small rockets equipped with a telemetry system. As rocket propulsion commercial solid boosters or own developments in the field of hot water vapour or hybrid systems can be applied. The associated activities are embedded in the lectures at German technical universities.

7. CONCLUSION

As part of the German space activities sounding rockets are recognised as important tools for research of the middle atmosphere of the Earth, for medium-duration microgravity experiments and for re-entry technology demonstrations. In the fields of Space Science and Earth Observation stratospheric balloons can reasonably complement ground-based and satellite investigations. Both sounding rockets and balloons are judged very beneficially for the education and training of students and young scientists.

In the 2009-2011 reporting period numerous German scientists participated in the sounding rocket missions ECOMA, TEXUS, MAXUS, MAPHEUS, and REXUS. The large balloon campaigns SUNRISE and MIPAS-B/TELIS/Mini-DOAS provided valuable scientific data of the solar and terrestrial atmosphere. BEXUS balloon missions were successfully used by students during their education process. Therefore, in the upcoming years the German Space Programme intends to continuously support the sounding rocket and balloon activities.

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