TEXUS AND MAXUS
AN OVERVIEW OF THE LATEST DEVELOPMENTS FOR THE FUTURE

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ABSTRACT

The sounding rocket program TEXUS & MAXUS at Astrium provides European scientists the possibility to execute their experiments in a microgravity environment with microgravity times of approximately 6 minutes (TEXUS) or 12 minutes (MAXUS). A large number and variety of experiment modules for various disciplines has been built and successfully flown over a period of more than 32 years with the German Space Agency (DLR) and the European Space Agency (ESA) as customers. Recently the French space agency CNES has also expressed their interest in performing technology experiments onboard a dedicated TEXUS flight.

This paper gives an overview of the latest developments for the TEXUS and MAXUS sounding rockets which will ensure that the increasing scientific requirements can be satisfied with more and more complex experiment modules.

1. INTRODUCTION

The TEXUS/MAXUS Sounding Rocket Program at Astrium (at that time ERNO Raumfahrttechnik) was initiated in 1976 with the aim to provide to scientists and experimenters the opportunity to perform technological experiments and investigations under microgravity conditions. Until today 47 TEXUS launches and 8 MAXUS launches have been successfully performed from the Esrange Space Center near Kiruna, Sweden.

2. TYPICAL SOUNDING ROCKET CONFIGURATIONS

Our TEXUS and MAXUS rockets consist of two major sections: the motor and the payload which is mounted on top of it, see Figure 1 and Figure 2. The modular payload comprises the Recovery System with the parachute, the Service Module and the Experiment Modules. On MAXUS rockets additionally a guide control system (GCS) and a telemetry and tracking unit (TTU) complement the payload.

2.1 TEXUS Rocket

The unguided TEXUS rocket is 13 m long and carries an experimental payload of up to 280 kg. Typically a microgravity of 10^{-5} g is achieved for a period of 360 to 390 sec.

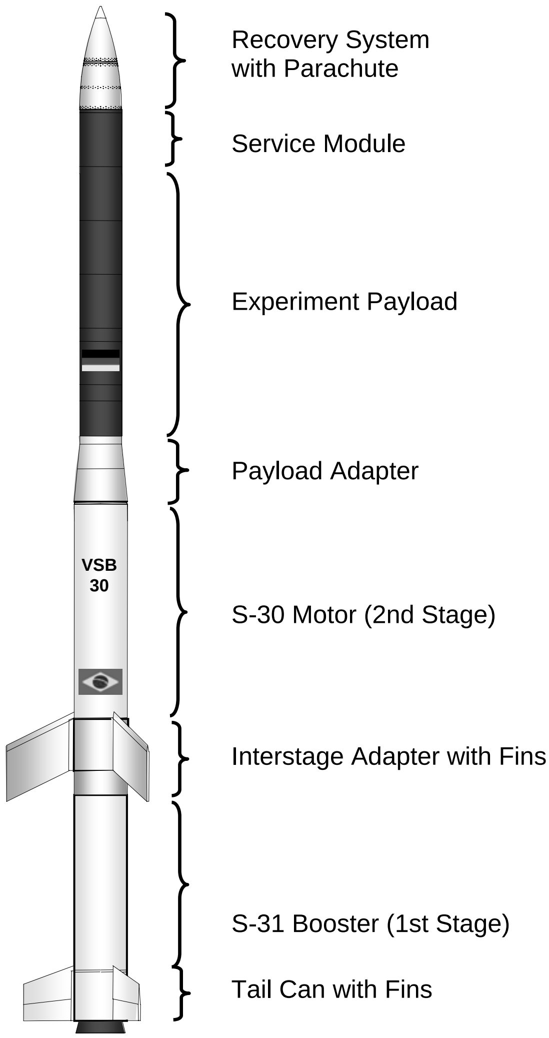

Figure 1: TEXUS Rocket Configuration (DLR, Astrium)

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2.2 MAXUS Rocket

The guided MAXUS rocket is 17 m long and carries an experimental payload of up to 480 kg. Typically a microgravity of 10^{-5} g is achieved for a period of 720 to 780 sec.

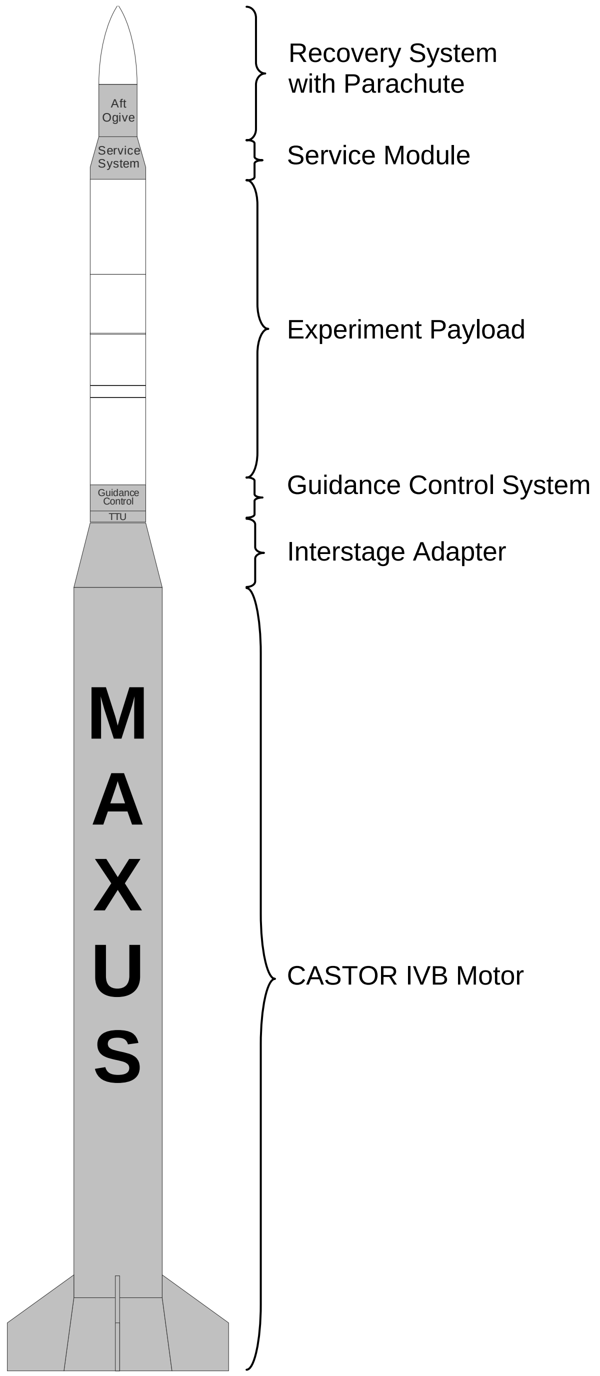

Figure 2: MAXUS Rocket Configuration (Astrium)

3. LAUNCH CAMPAIGN 2008

3.1 TEXUS 44

The TEXUS 44 payload was successfully launched and recovered on 7 February 2008. Three experiment modules were onboard this flight. The majority of the payload was occupied by the ESA EML Module (Electro-Magnetic Levitator) which carried two samples (NiAl and CuCo) for the conduction of the following experiments:

- *High-Precision Thermophysical Property Data of Liquid Metals for Modeling of Industrial Solidification Processes,* Fecht (D)
- *Non-Equilibrium Solidification, Modeling for Microstructure Engineering of Industrial Alloys (NEQUISOL),* Herlach (D)
- *Undercooling and Demixing of Cu-based Alloys (COOLCOP),* Egry (D)

In addition two modules for biological experiments - one for ESA, one for DLR - were part of the TEXUS 44 payload:

- ***ESA:*** *Responses on Microgravity Exposure of In-vitro Cultures of Epithelian Follicular Cells from Thyroid,* Ambesi (I)
- ***DLR:*** *Kinetics of gravity-sensitive membrane recycling under reduced gravitational conditions,* Volkmann (D)

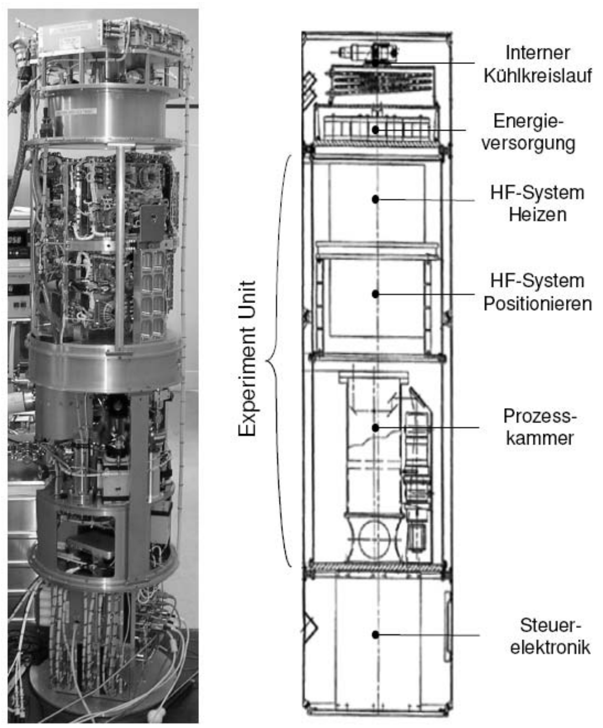

Figure 3: EML Experiment Module (Astrium)

3.2 TEXUS 45

TEXUS 45 was launched two weeks after TEXUS 44 on 21 February 2008 and its payload was also successfully recovered. On this combined DLR/ESA mission three experiment modules were onboard:

- ***DLR**: Individual behavioural adaptability to diminished g-forces and calcium uptake of inner ear otoliths in fish,* Hilbig (D)
- ***DLR**: Sprayaufprall auf beheizte Oberflächen unter Mikrogravitation,* Tropea (D)
- ***ESA**: Two-phase Flow in Capillary Channels,* Colin (F), Dreyer (D)

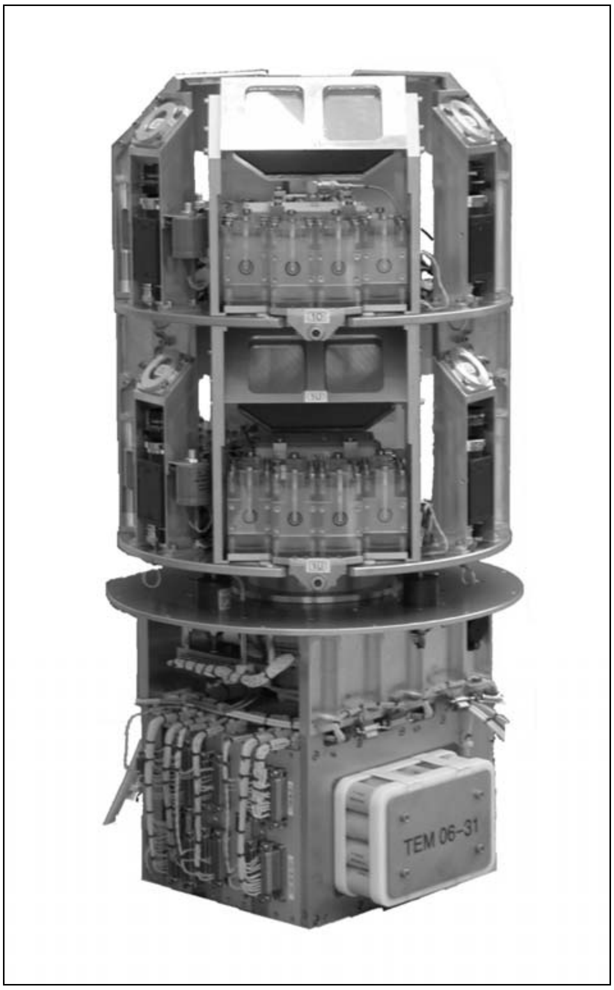

Figure 4: Experiment Module "Hilbig" (Astrium)

3.3 New Features on TEXUS 44 & 45

Several of the TEXUS 44 & 45 experiments asked for specific new developments to fulfill the scientific objectives. For most of them the main focus lies on the visual observation of the phenomena under investigation. Since the nature of the experiments and the respective requirements are quite diverse, also the solutions to be found and implemented are different.

The TEXUS 44 EML module was refurbished after its maiden flight on TEXUS 42 in December 2005. For the re-flight one of the analog cameras was replaced by a digital high-speed camera with an image rate of 200 frames per second. It was required that these images should be recorded onboard and the same time down-linked to the ground for the direct control of the experiment during the flight. Also, the observation of the metal alloy samples from their state at low temperatures - in which they are dark - up to their hot, molten state - in which they are extremely bright - made it necessary to implement an aperture control via telecommand and a gain and shutter speed control via dedicated onboard software.

The new development of a video control and recording system based on a commercial compact PC made it possible to combine in a cost efficient and reliable way an optimum use of commercial hardware with a re-use of available equipment. The video control and recording system is able to record the digital images onboard a solid-state-disk and convert and transmit in parallel the digital images in analog format so that the existing TV module and ground infrastructure can be used. A dedicated software application processes the video images, determines the correct gain and shutter speed for the digital camera and commands the camera directly. With this new feature the dynamic range which is already built into the camera could be considerably increased and the images quality optimized significantly.

The TEXUS 45 experiment "Tropea" required two challenging capabilities. For the overview of the experiment chamber high resolution (2,048 x 2,048 pixels) camera images were recorded at 5 frames per second. The detailed view was observed by a high-speed digital camera at 15,000 frames per second with a resolution of 256 x 128 pixels and recorded as well. For this special application a dedicated commercial camera was procured which already included many of the required features. For the real-time control of the experiment during the flight the analog images were down-linked in parallel.

In the TEXUS 45 "Hilbig" experiment the images of nine fish tank assemblies were observed during the pre-launch activities and recorded onboard without the need for a real-time downlink of the image data. As a result a cost efficient solution for the recording of digital camera images on commercial solid-state-disks was implemented.

4. UPCOMING LAUNCH CAMPAIGNS

In the next launch campaign which is scheduled for November 2009 two rockets, TEXUS 46 & 47, will be launched in a double campaign.

4.1 TEXUS 46

The TEXUS 46 is an international mission subsidized by three Space Agencies. One of the modules is again the EML module on its third flight. It will serve for the execution of experiments for DLR and ESA. It has been refurbished from its flight on TEXUS 44 and enhanced by new features and functions. The experiments on EML-3 aim the research of the following scientific objectives:

***ESA** (steel sample):*

- *Chill cooling for the electromagnetic levitator in relation with continuous casting of steel,* Gandin (F)
- *High precision thermo-physical property data of liquid metals for modeling of industrial processes,* Fecht (D)

***DLR** (PdSi sample):*

- *Measurement of Surface Tension and Viscosity on a PdSi Sample,* Egry (D)

The second experiment module onboard TEXUS 46 is the Japanese Combustion Module. The Droplet Combustion Unit (DCU) is the core of the experiment and has been developed by the Japanese Space Agency JAXA. The supporting systems and infrastructure around the DCU have been developed and integrated by Astrium. All required tests to verify the compliance with the established TEXUS standards have been performed by the TEXUS team at the Astrium facility in Trauen with the support of the JAXA and the ESA team as well as the Japanese and the European investigators. The ESA contribution of the combustion experiment aims at the investigation of:

- *Combustion properties of partially pre-mixed spray systems (CPS) in the field of droplet and spray combustion,* Sattelmayer (D)

4.2 TEXUS 47

The TEXUS 47 mission is a national DLR flight which carries onboard four experiment modules for the investigation of the following scientific objectives:

- *Vibration-induced convection in floating zone growth,* Cröll (D)
- *Gravity induced absorbance changes in Phycomyces,* Galland (D)
- *Transparent Alloys for Columnar Equiaxed Solidification (TRACE),* Zimmermann (D)
- *Identifizierung schwerkraftabhängiger Signalketten im Modellsystem Arabidopsis,* Hampp (D)

4.3 New Features on TEXUS 46 & 47

After the return from its second flight on TEXUS 44 the EML experiment module was fully refurbished and modified for the implementation of new scientific objectives. For the second re-flight two digital cameras with an image rate of 200 frames per second were requested. This could be implemented by development of the next generation of the video control and recording system. Besides the established features (camera exposure control, recording of digital images and downlink of analog images in parallel) it has now the capability of storing uncompressed digital images from several sources at 100 MByte/sec.

The video system that was flown on TEXUS 44 EML-2 was re-built and improved by software upgrades so that it could be implemented in the TEXUS 45 "Cröll" experiment for the observation of the Si column during the melting and solidification process. The brightness of the sample when it is molten by the heat generated by a halogen lamp in a mirror furnace can be visualized in the same quality as the "dark" and cold sample by using the automatic gain and shutter speed control, adjusted to the specific lighting conditions of this experiment.

The TEXUS 45 "Zimmermann" experiment features a new three axis control of sample cell movement and enables the scientists on the ground to select in real-time during the flight the areas of interest.

In the TEXUS 45 "Galland" experiment highly sensitive amplifiers for the detection of photon emissions from the phycomyces sample cultures have been implemented. The challenge in this case was the electrical stability of the power supply and the measurement circuitry since current in the order of µ-Amperes have to be detected and amplified for a reliable measurement of the responses of the organisms to the microgravity environment.

4.4 MAXUS 8

The MAXUS 8 flight is scheduled for March 2010 in a single launch campaign. Four experiment modules will be executed during the microgravity phase of the flight.

The experiment modules are currently under development by Astrium and Swedish Space Corporation (SSC) and cover several scientific disciplines:

- Astrium: *Cytoskeletal mechanisms of gravisensing in Chara,* Buchen (D)
- Astrium: *IMPRESS, Microstructure formation in Ti-46Al-8Nb and Ti-46Al-8Ta during solidification,* Gandin (F)
- Astrium: *Morphology of metal alloy agglomerates using Ni vapour synthesis,* Günther (D)
- SSC: *In-situ x-ray monitoring of advanced metallurgical processes under microgravity and terrestrial conditions,* Mathiesen (N)

The technological challenges in the development of the experiment modules lay in the high temperatures (1,800 °C) for the processing of the TiAl samples in the IMPRESS furnaces and the evaporation of Ni for the "Günther" experiment. In this experiment module several different techniques were investigated and tested. Either the implementation could not be achieved in time, or the minimum evaporation rates could not be reached, or the required sample material purity could not be established. Finally, the "wetted wire" technology was identified and positively verified in a bread-board test set-up as the solution to achieve the scientific objectives.

5. FUTURE MISSIONS

Currently two flights for DLR, ESA and the French Space Agency CNES are under discussion. The envisaged launch dates are in 2011. In the frame of the Cryogenic Upper Stage Technology (CUST) program the Agencies intend to perform several experiments for the demonstration and validation of the propellant management technologies of a new European cryogenic upper stage launcher, e.g. Ariane 5.

The first flight of these new technological experiments is scheduled for spring 2011 on TEXUS "CRYSTAL" (CRYogenic Stage Technology Advanced Laboratory) in a double campaign with the next national DLR TEXUS flight. Potential candidates for the first CRYSTAL flight are two DLR experiments and one CNES experiment, all three potentially with cryogenic Nitrogen as test fluid.

The second flight, TEXUS "CRYSTAL 2", which could be performed in fall 2011 would carry one large CNES experiment and one DLR experiment onboard. During this flight it is planned to subject the payload not only to the TEXUS typical microgravity environment but also to provide an acceleration profile which is representative of the Ariane 5 environment. For this purpose a new Thrust Module (TSM-X) is required and will be developed by Kayser-Threde. A first drawing of this new development is shown in Figure 5.

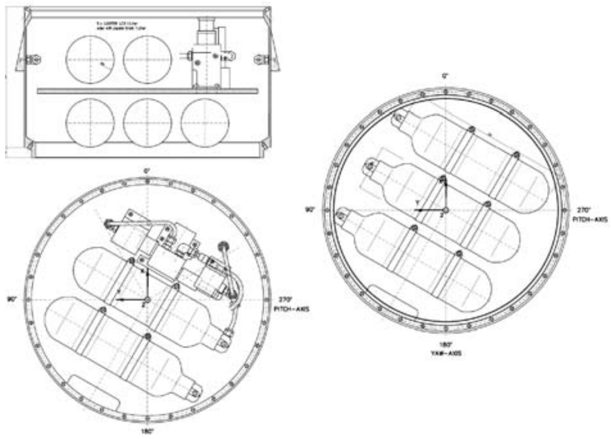

Figure 5: New Thrust Module TSM-X (Kayser-Threde)

6. SUMMARY

In more than 32 years the technologies we used in the TEXUS and later the MAXUS rockets has advanced significantly. By implementing up-to-date technologies in our service systems and experiment modules we keep pace with the increasing demands from the scientific community. The specific environment of the sounding rockets allows us to use commercial hardware wherever possible in order to implement the latest technologies and remain cost efficient at the same time.

The real-time data and video transmission together with the improved tele-commanding capabilities provide the scientists with an environment during the flight as if they were located next to their experiment in the lab.

Our main focus is and will be the implementation of the scientific requirements of the scientists in an optimal way. TEXUS 46 and TEXUS 47 are scheduled for launch in November 2009 and MAXUS 8 for March 2010, and the preparations for the next launches in 2011 are already under way.

7. ACKNOWLEDGEMENTS

The author would like to thank the funding Agencies DLR and ESA, the scientists and our industrial partners who have strongly supported the TEXUS/MAXUS Program for more than 32 years and who have already taken steps to keep it going in the future.