TEXUS AND MAXUS
PREPARATIONS 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 by the Astrium team and successfully flown over a period of 34 years with the German Space Administration (DLR) and the European Space Agency (ESA) as customers.

This paper gives an overview of the recent TEXUS and MAXUS launch campaigns and describes some of the developments which are currently performed to provide also in future the optimum service for the scientific community in the field of sounding rockets.

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 50 TEXUS launches and 9 MAXUS launches have been performed from the Esrange Space Center near Kiruna, Sweden.

2. TYPICAL SOUNDING ROCKET CONFIGURATIONS

The TEXUS and MAXUS rockets consist of two major sections: the motor and the payload which is mounted on top of it, see Figure 1. 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.

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

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

Figure 1: TEXUS Rocket Configuration (DLR, Astrium)
3. LAUNCH CAMPAIGNS 2009-2011

In the last two years three launch campaigns with four launches were conducted:

- the TEXUS 46 & 47 double campaign,
- the MAXUS 8 single campaign and
- the TEXUS 49 campaign.

The TEXUS 48 flight which was scheduled to be performed together with TEXUS 49 had to be moved to fall 2011 due to modifications of the experiment design which were requested by the customer and the experimenter.

3.1 TEXUS 46 and TEXUS 47

TEXUS 46 was launched and its payload successfully recovered on 22 November 2009.

Two experiment modules were onboard this flight. The DLR/ESA EML Module (Electro-Magnetic Levitator) which carried one steel and one PdSi sample for the determination of surface tension, viscosity and thermophysical properties, as well as a chill cooling experiment. The TEXUS 46 flight was the third for the EML experiment module developed and built by Astrium. It is the largest and heaviest one ever built for a European Sounding Rocket flight. The ESA/JAXA JCM Module (Japanese Combustion Module) was developed by JAXA with the support of Astrium for experiments in the Field of Droplet and Spray Combustion.

TEXUS 47 was launched one week after TEXUS 46 on 29 November 2009 and its payload was also successfully recovered. On this DLR mission four experiment modules were flown. Two of them were biological experiments:

- Gravity Induced Absorbance Changes in Phycomyces, Galland (D)
- Identification of Gravity-dependent Signal Chains in Arabidopsis, Hampp (D)

The other two covered material science investigations.

- Vibration-induced convection in floating zone growth, Cröll (D)
- Transparent Alloys for Columnar Equiaxed Solidification (TRACE), Zimmermann (D)

All experiments modules worked nominal and flawlessly.

3.2 MAXUS 8

The MAXUS 8 flight was performed on 26 March 2010 in a single launch campaign. Four experiments were executed during the microgravity phase of the flight. The experiment modules were developed by Astrium and Swedish Space Corporation (SSC) and covered several scientific disciplines:

- Astrium: Morphology of Metal Alloy Agglomerates using Ni Vapour Synthesis, Günther (D)
- Astrium: Mapping Cytoskeletal Mechanisms of Gravisensing in Chara, Buchen (D)
- Astrium: IMPRESS, Microstructure Formation in Ti-46Al-8Nb and Ti-46Al-8Ta during Solidification, Gandin (F)
- 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 (up to 1,850 °C) for two of the experiments: the processing of the TiAl samples in the IMPRESS furnaces and for the Ni evaporation. For the Ni evaporation several different techniques were investigated and tested without satisfactory results before the implemented solution was indentified. The "wetted wire" technology worked perfectly during the flight and the preliminary evaluation of the scientific samples and the interpretation of the data showed interesting results.

3.3 TEXUS 49

On 29 March 2011 TEXUS 49 was launched and the payload successfully recovered. This DLR mission marked the fourth flight of the EML module. This time an Al68.5-Ni31.5 sample and a Ni98Ta2 + Ta2O5 sample were processed during the flight.

From the first flight of EML on TEXUS 42 in November 2005 to the fourth flight on TEXUS 49 the observation system has been continuously upgraded. From initially three analog cameras with frame rates of 25 / 100 / 150 Hz and on-board storage on DV recorders the system was stepwise upgraded by replacing two of the analog cameras by digital cameras with provided frame rates of 400 Hz each for this year's flight. The data are stored on modern MiniPCs based on commercial components and qualified for the implementation on TEXUS and MAXUS flights. In addition these MiniPCs provide e.g. control of aperture or shutter speed of the cameras based on selectable regions of interest of the received image data.
Figure 2: EML-4 Camera Scheme (Astrium)

A valuable feature for the scientific interpretation of the EML visual observation was the implementation of trigger signals for the digital cameras which ensured that the images were taken and recorded such that they alternated between both cameras, ref Figure 2. By means of digital post-processing and tracing of the shapes from two different angles at 800 Hz the scientific output was increased significantly.

The second experiment was performed in an upgraded re-flight module of TEXUS 47 and was aimed at the investigation of columnar-to-equiaxed transition during solidification of a transparent model alloy. The improvements were made in the visual observation system to provide a higher resolution and better quality of the recorded image data. This was realized by implementing a digital camera system with a MiniPC for camera control and on-board storage of the images, similar to the EML video system.

The biggest challenge on the TEXUS 49 flight was the biological experiment “Signal transduction in cells of the immune system in microgravity” of Prof. Ullrich (University of Magdeburg, University of Zurich). The flight hardware was mainly based on existing design from previous TEXUS and MAXUS flights and consequently well known and rather straightforward during the flight preparation.

The logistics, the preparation and the post-processing of the biological samples required precise planning and coordination between the science team and the engineering and operations teams. The biological samples to be subjected to the micro-gravity conditions during the flight were human immune cells. It is the nature of these living organisms that they need to be prepared with extreme care and in a well conditioned environment to achieve the optimum quality for the launch day.

The laboratories at Esrange are already well equipped for that purpose and in addition the science team brought along all other equipment and consumables they needed. Due to the dependency of the rocket launch and payload recovery on the weather conditions it was necessary not to plan only for the nominal scenario with a launch in the first hot countdown but also to take several days of delay into account. Accordingly the cell cultures were prepared and cultivated such that for up to eleven countdown days a fresh set of samples would be available.

The countdown procedure itself was also adapted to the needs of the science team. Their sample preparation started 4 hours before the planned lift-off time. The sequence for the preparation and arming of the VSB-30 rocket motor shortly prior to lift-off was modified with respect to previous launches so that the time-critical installation of the samples was started only an hour before the lift-off time. The professionalism of the Esrange/DLR-Moraba team and their experience with the reliable Brazilian VSB-30 motor made this extremely important change possible.

The countdown sequence went smooth and without any holds so that the TEXUS 49 was launched exactly as planned. After a nominal micro-gravity flight and re-entry the payload landed softly on the ground. The first recovery helicopter returned the biological samples within 1 hour and 15 minutes. Immediately the science team started the stabilization and post-processing. This tedious procedure was also vital for the scientific success and required highest concentration from the lab team and perfectly working equipment. Less than eight hours after the handover of the flown sample container the samples were loaded into a helicopter which transported them in a cryogenic container to the airport of Kiruna where the Swiss Air Force plane to Zurich was already waiting. Only 14 hours after the launch of TEXUS 49 the samples arrived in their home lab at the University of Zurich, thanks to the excellent coordination between all involved teams.

A few days later, after the first preliminary evaluation, the science team informed us that the quality of the samples is excellent!
4. UPCOMING LAUNCH CAMPAIGNS

4.1 TEXUS 48

In the frame of ESA's Cryogenic Upper Stage Technology (CUST) program two experiments for the demonstration and validation of the propellant management technologies of a new European cryogenic upper stage launcher have been developed and are now in the integration and test phase at Astrium. The first flight of these new technological experiments is financed by DLR on TEXUS 48 "CRYSTAL" (CRYogenic Stage Technology Advanced Laboratory) to be launched in a single campaign in November 2011.

Both experiment modules are similar in their general architecture. The central part between the electronics section (bottom) and the observation and supply deck (top) contains a tank with a scaled-down representation of an Ariane 5 Propellant Management Device (PMD) for liquid hydrogen (LH2) or liquid oxygen (LOX) respectively. In Figure 3 the LH2 PMD module is shown without the dewar which holds the tank and the separator. This dewar reduces the thermal losses in this cryogenic system which operates at temperatures as low as -200 °C. For the TEXUS flight the cryogenic fluids LN2 and LOX are replaced by liquid nitrogen (LN2) which is safer to handle and provides equally good results for the technology validation.

Since the liquid nitrogen evaporates during the countdown sequence a filling mechanism had to be developed that allows the refilling of LN2 until a few minutes prior to lift-off. At that time no person is allowed to be inside the launch tower for safety reasons. Consequently a retraction mechanism will be installed in the launch tower which pulls back the connector from the filling port at the experiment outer structure via a remote command given from the blockhouse where the engineering team is located during the countdown.

4.2 TEXUS 50

The TEXUS 50 launch campaign is envisaged for spring 2013. Currently several potential experiment candidates are identified and possible accommodation scenarios are under investigation.
4.3 MAXUS 9

For the MAXUS 9 flight ESA has already selected the experiments. The payload complement will consist of four experiment modules and the required system modules. With this flight we will continue the excellent cooperation between SSC and Astrium which was established more than 20 years ago. Together with our long-term subcontractors we have already started the preparation of the flight which is envisaged for 2013.

Three of the experiments will be provided by Astrium and one by our MAXUS joint venture partner SSC. Two of the experiment modules have already flown on MAXUS 8 and will be refurbished and adapted for the flight on MAXUS 9:

- **GRADECET** - high-temperature furnaces for the investigation of the gravity dependence of microstructure formation and segregation in peritectic TiAl-based alloys based on the IMPRESS module (Astrium)
- **XRMon-diff** - in-situ observation of chemical diffusion phenomena in rod-like metallic samples embedded in isothermal long-capillary furnaces using X-ray diagnostic systems (SSC)

In addition two new experiment module developments are initiated:

- **EUGRAPHO** - a biological experiment with two scientific objectives:
  1. New determination of the gravitaxis threshold in *Euglena gracilis* after pre-exposure to microgravity
  2. Investigation of the role of cAMP in the interplay between gravitaxis and phototaxis in *Euglena gracilis* based on experiments previously flown on TEXUS and MAXUS (Astrium)
- **PERWAVES** - a material science / combustion experiment for the investigation of “Percolating Reactive Waves in Particulate Suspensions”

The questions pursued by the Canadian group of scientists are:

- What is the concentration propagation limit of the percolating discrete flame?
- How does it correlate with “thermodynamic” or regular lattice model predictions?
- What is the flame speed value and behavior in the vicinity of the propagation limit?
- What are the percolation fractal dimensions of the flame front when the flame approaches the propagation limit?

The main challenges for the implementation of these requirements in an experiment module are:

- the homogeneous dispersion of the metal powders (Fe, Al)
- the accurate measurement of the dispersion process
- the safe and reliable ignition of the gas/powder mixture

The verification and validation of the selected design requires tests under micro-gravity conditions and could be performed either in the drop tower at the ZARM in Bremen or in a parabolic flight campaign with ESA and the Canadian Space Agency CSA.

5. SUMMARY

In 35 years the technologies implemented in the TEXUS and later the MAXUS rockets have advanced significantly. By introducing 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. For biological experiments the laboratories with their modern equipment are essential for the preparation and post-processing of their unique samples. The well established and efficient communication between all involved parties is a key parameter for the success of demanding logistic challenges.

Our main focus is and will remain the implementation of the scientific, technical and logistic requirements by researchers and scientists in an optimal and efficient way to provide also in the future the best service to our customers.

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