IAC-13-A2.5.10

DLR'S MOBILE ROCKET BASE – FLIGHT TICKETS FOR YOUR MICROGRAVITY EXPERIMENTS

Andreas Stamminger
Deutsches Zentrum für Luft- und Raumfahrt (DLR), *Mobile Rocket Base, Oberpfaffenhofen, 82234 Wessling*, Germany, Tel.: +49-*8153-28-1231*, Email: andreas.stamminger@dlr.de

Ludwig Altenbuchner
Deutsches Zentrum für Luft- und Raumfahrt (DLR), *Mobile Rocket Base, Oberpfaffenhofen, 82234 Wessling*, Germany, Tel.: +49-*8153-28-1457*, Email: ludwig.altenbuchner@dlr.de

Josef Ettl
Deutsches Zentrum für Luft- und Raumfahrt (DLR), *Mobile Rocket Base, Oberpfaffenhofen, 82234 Wessling*, Germany, Tel.: +49-*8153-28-2715*, Email: josef.ettl@dlr.de

Marcus Hörschgen-Eggers
Deutsches Zentrum für Luft- und Raumfahrt (DLR), *Mobile Rocket Base, Oberpfaffenhofen, 82234 Wessling*, Germany, Tel.: +49-*8153-28-2172*, Email: marcus.hoerschgen-eggers@dlr.de

Wolfgang Jung
Deutsches Zentrum für Luft- und Raumfahrt (DLR), *Mobile Rocket Base, Oberpfaffenhofen, 82234 Wessling*, Germany, Tel.: +49-*8153-28-2724*, Email: wolfgang.jung@dlr.de

Peter Turner
Deutsches Zentrum für Luft- und Raumfahrt (DLR), *Mobile Rocket Base, Oberpfaffenhofen, 82234 Wessling*, Germany, Tel.: +49-*8153-28-2613*, Email: peter.turner@dlr.de

Mobile Rocket Base (MORABA), a section of DLR's Space Operations and Astronaut Training Department fosters the national and international scientific community to prepare and implement sounding rocket and balloon borne experiments in the fields of aeronomy, astronomy, geophysics, hypersonic and especially microgravity research worldwide. In addition, satellite missions can be supported by mobile tracking radars for trajectory determination as well as with TT&C ground stations. MORABA also supplies a number of mechanical and electrical flight systems for use on rockets, balloons and short duration satellite missions. During the last four decades more than 200 campaigns have been performed in Antarctica, Australia, Brazil, France, Greenland, India, Italy, Japan, Norway, Spain, Sweden and USA. Depending on the scientific aim, an appropriate launch range is selected and complemented or fully equipped with MORABA's mobile infrastructure, such as launcher, telemetry and tracking stations. Converted military or commercial launch vehicles, as well as all necessary mechanical and electrical subsystems are supplied by MORABA. For the launch of rockets, stability and performance calculations are carried out to ensure correct vehicle performance and to meet range safety aspects. This paper will give an overview of the MORABA infrastructure for sounding rocket missions and it will focus on flight tickets for experiments that require perfect microgravity conditions. It will give also a survey of projects with MORABA involvement of the last two years and the next two years.

I. INTRODUCTION

The Mobile Rocket Base (MORABA) was founded in 1967 as part of the Max Planck Society (Arbeitsgruppe für Weltraumforschung) under the initiative of Professor Dr. Reimar Lüst, at that time founding director of the Max Planck Institute for Extraterrestrial Physics. MORABA was later, in 1969, integrated into DLR and is based in Oberpfaffenhofen, Germany.

MORABA's main task is to support the national and international research community in the preparation and execution of sounding rocket- and balloon-borne experiments. These cover a variety of scientific fields, such as atmospheric physics, astronomy, microgravity and linear acceleration experiments, hypersonic research, technology testing and education. By providing and operating mobile infrastructure (TT&C, RADAR and rocket launchers), it is possible to perform complex scientific missions at almost any location that might be required by the experiment. Most frequently, launches are conducted from Esrange (Sweden), Andøya Rocket Range and Spitzbergen (Norway), Natal and Alcântara (Brazil) as well as Biscarosse (France), but remote locations like Antarctica or Woomera (Australia) have also been used. Minimal infrastructure is required to establish a launch site at other desired locations.

The development of new launch vehicle systems to meet the scientific requirements of the various missions constitutes a key capability of MORABA. Military surplus rocket motor systems are converted for the use as sounding rockets and commercially available systems are acquired as necessary. The cost-effective combination of these motors to make up the desired launch vehicle is a key competence of MORABA. A long standing collaboration with our partners in Brazil (DCTA and IAE) offers a unique ability to directly tailor the design of new rocket motor systems for research purposes.

A further objective of MORABA is the development, fabrication and testing of commercially unavailable mechanical and electrical components and systems for sounding rockets and balloons as well as for short duration satellite missions.
The key work areas of MORABA are shown in figure 4. In accordance with its key work areas, MORABA is structured into five groups as shown in figure 1, covering telemetry and RADAR for status and trajectory information, electronic and mechanical flight systems, launch services and flight dynamics as well as business development and tender preparation.

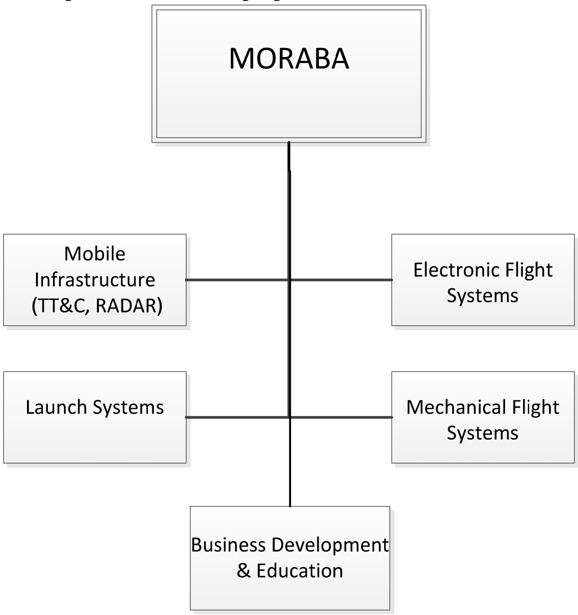

Fig. 1: MORABA Organization.

MORABA is one of a few institutions worldwide which offers the science community all necessary infrastructure and expertise to perform sounding rocket based missions. The mobile infrastructure of MORABA meets highest international standards and enables even very demanding scientific missions. MORABA is ISO 9001 and OHSAS 18001 certified for "Preparation and Conduct of Sounding Rocket Missions for various Scientific Applications" by Bureau Veritas.

Primary customers of MORABA's expertise and facilities are universities and research institutions, DLR institutes, as well as national and international organizations and industry. The majority of the projects with MORABA participation are funded by the German Federal Ministry of Economics and Technology (BMWi), the DLR Space Administration and ESA.

II. MOBILE INFRASTRUCURE AND LABORATORIES

MORABA has all necessary mobile infrastructure to setup and support worldwide sounding rocket and satellite missions. Already during the design of the various stations, special attention was given to mobility and suitability for the extreme environmental conditions encountered at the potential launching sites.

Telemetry and Telecommand

MORABA maintains and operates a fully containerized mobile telemetry, tracking and telecommand stations in the P-, L-, and S-Band frequency spectrum. This station can be set up at any electrical developed site on the globe. It is self-contained and adaptable to a variety of configurations. Multiple telemetry and TV links can be supported simultaneously. All necessary equipment for demodulation and recording of FM, PM, BPSK, PCM and real time TV signals is included in the station. Signal decommutation and conditioning is also performed. Real time quick look and post flight presentations are available. The station is equipped with all necessary instrumentation and support electronics to track and command sounding rockets, stratospheric balloons or satellites.

Fig. 2: New Telemetry, Tracking and Telecommand Station.

RADAR

Beside TM slant-range data and the GPS position data from the rocket, a mobile instrumentation tracking Radar (RIR-774C), which operates in the C-band frequency range, allows precise trajectory determination for scientific and safety related purposes. 10 Hz Tracking data can be used for real-time prediction of the expected impact point during the ascent of a sounding rocket. This information can be vital, for example, in case a range-safety officer has to decide if the self-destruction signal has to be sent to the rocket in case of flight deviations from the nominal trajectory. Sophisticated software packages are available for post flight data evaluation of the 50 Hz tracking data, which is essential for the processing and altitude correlation of many scientific experiments.

Fig. 3: C-Band Tracking Radar RIR-774C Antenna.

Monorail Launcher

For truly independent launch operations at remote locations, MORABA maintains and operates one mobile sounding rocket launcher system. This lately rebuilt monorail launcher is used for rocket vehicles with a mass up to six tons. The launcher is remotely controlled from the launch control room. For weather and wind protection during the preparation phase, the launcher can be covered by a tent which is movable on railway tracks.

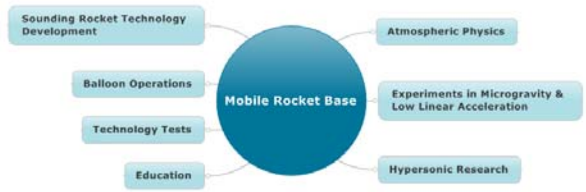

Fig. 4: MORABA Operation, Research & Development Fields.

Laboratory

At its home base in Oberpfaffenhofen, Germany, MORABA maintains a dedicated laboratory area with various technical test facilities (i.e. thermal vacuum test chamber, three-axis air bearing) and checkout systems. Bench tests and flight simulation tests are performed in the MORABA laboratory.

III. SCIENCE ON SOUNDING ROCKETS

The sounding rocket- and balloon-borne experiments cover a variety of scientific fields, such as atmospheric physics, astronomy, microgravity and linear acceleration experiments, hypersonic research, technology testing and education.

Fig. 5: Mobile Launcher at Brazilian Launch Site.

Atmospheric Research

Stratospheric Balloons are used for measurements up to altitudes of ~40 km. Sounding Rockets can perform in-situ measurements in the higher atmosphere up to 130 km. The major programs in this scientific field have been ECOMA and WADIS in the recent years with a number of ten launches.

Microgravity Research

Physical experiments in Earth-based laboratories are frequently influenced negatively by gravity. In the field of material physics, for example, various processes in metallic alloys involve interactions on an atomic scale that can be “masked” or influenced by gravitational driven forces. The corresponding experiments thus require "weightlessness" for high quality results. Experiments are also performed to investigate the influence of gravity on biological processes. The suborbital parabolic trajectory of a sounding rocket offers an experimental time of up to 13 minutes residual accelerations of < 10^-6 g in all axis. Figure 6 shows the achievable microgravity time versus apogee altitude. The different microgravity programs and projects are marked with different colors.

The major programs and projects in the microgravity research field in the last years have been TEXUS, MAXUS, MASER, MAPHEUS and MAIUS.

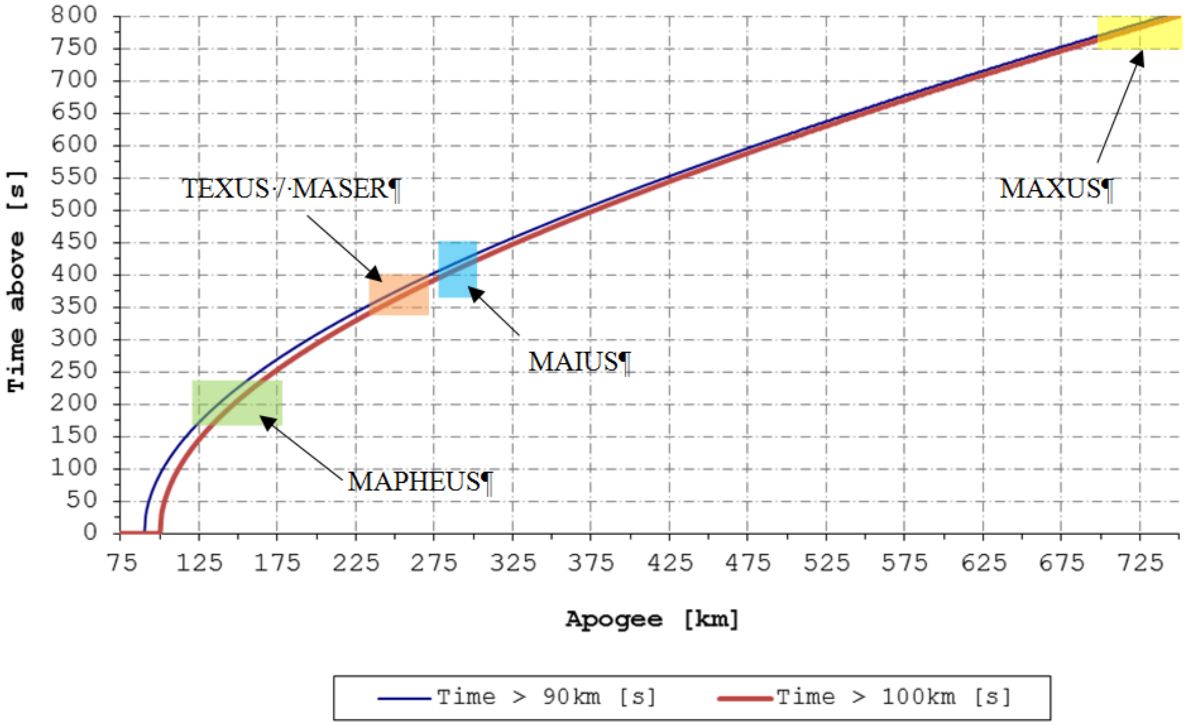

Fig. 6: Achievable Microgravity Time vs. Apogee Altitude of Sounding Rocket Programs.

Hypersonic Research

In addition to the regular microgravity and atmospheric research programs, interest in sounding rockets as a cost-effective test bed for hypersonic research is increasing. The demanding experimental goals result in complex flight experiments which extend the previous operational bounds of sounding rockets. In contrast to hypersonic shock tunnels, sounding rockets can provide re-entry times of one minute in excess of Mach 10 at real aerothermodynamic condition for relatively large experiments. This application requires new classes of vehicles and sub systems which are not readily available on the market as well as innovative approaches to vehicle, payload and trajectory design and control.

The programs and projects with major MORABA involvement in this scientific field are SHEFEX, HIFiRE, SCRAMSPACE.

Education

MORABA is strongly involved in the student education programs REXUS/BEXUS and STERN.

IV. PAST AND FUTURE MISSION

During the last two years more than 18 sounding rockets and 4 balloons have been launched with participation or within a "flight ticket" of MORABA from various locations worldwide.

Fig. 7: WADIS-1 Vehicle consisting of a VS-30 rocket motor and payload.

WADIS

A new atmospheric research program named WADIS (Wellenausbreitung und Dissipation in der Mittleren Atmosphäre) with a single stage rocket was launched in June 2013. The launch of WADIS-2 is planned for Winter 2013/2014. The emphasis of the question is the investigation of gravity waves within the atmosphere as well as the quantification of their contribution to the complete energy budget.

Simultaneously, the atomic oxygen concentration is surveyed with high-precision instruments on board and combined with LIDAR (Light Detection and Ranging) and RADAR (Radio Detection and Ranging) measurements from ground.

MAXUS

The MAXUS long-duration sounding rocket program is a joint venture of EADS and SSC. This program was initiated in 1990 to extend the microgravity duration capability in Europe to 13 minutes. For MAXUS, a single-stage solid-fuel Castor-4B rocket motor is used to launch a gross payload of typically 800 kg to an apogee of about 715 km. The payload diameter is 640 mm.

MORABA provides essential sounding rocket sub-systems as well as the operation of its mobile ground stations. The last rocket in this program, MAXUS-8, has been launched in 2010.

TEXUS

The TEXUS sounding rocket program (Technologische Experimente Unter Schwerelosigkeit) with until now 50 missions was initiated in 1976 by the German Ministry of Research and Development. Beginning with TEXUS launches in 1988 the program was commercialized and EADS Astrium has taken the overall responsibility.

MORABA provides essential sounding rocket sub-systems as well as the operation of its mobile ground stations. 3 TEXUS missions have been launched on the IAE/MORABA developed VSB-30 rocket in the last two years. A typical payload has a mass of 400 kg and the achieved apogee is 250 km. TEXUS payload diameter is 438 mm. TEXUS-51 will be the next launch within this program in November 2013.

MAPHEUS

MAPHEUS (Materialphysikalische Experimente unter Schwerelosigkeit), a DLR research rocket program, provides microgravity environment to DLR material physics payloads. On an annual basis, a MAPHEUS rocket is launched into space to approximately 150 km altitude. The payload of up to 270 kg experiences ~3.5 minutes of microgravity before it re-enters the Earth's atmosphere. The first three MAPHEUS missions have been flown on a Nike-Improved Orion, a two-staged vehicle. MAPHEUS-4 has been launched in 2013 on a single stage VS-30 rocket. The payload diameter is 356 mm but design changes for the upcoming launches are under investigation.

MAIUS

MAIUS, a matter-wave interferometer that will be launched on a sounding rocket, will generate the first BEC (Bose-Einstein-Condensate) in space and investigate it over a lengthy period of time. Carried by a research rocket especially configured by MORABA, see figure 8, MAIUS is scheduled to be launched from Esrange near Kiruna in the north of Sweden in November 2014. During the microgravity phase of the flight, which will last for six minutes, researchers expect to enter territory that has not been explored so far in quantum physics experiments. To put the matter in perspective - under normal gravity, a BEC can be maintained in a laboratory for no longer than a few fractions of a second. This is why physicists regard this rocket flight as a milestone. During the prolonged phase of microgravity, they will be able to generate not only one but several BECs in succession and study them for a period that is much longer than anything that has been achieved so far – a project that is unique worldwide.

Fig. 8: MAIUS-1 Vehicle consisting of a VSB-30 rocket motor assembly and payload [6].

MASER

MASER is a Swedish SSC microgravity sounding rocket program with an international participation of industry and science community, financed by ESA. MORABA provides essential sounding rocket sub-systems as well as the operation of its mobile ground stations. One MASER missions has been launched on a VSB-30 rocket within the last two years. The payload mass and dimensions are very similar to the TEXUS payloads.

SHEFEX

The goal of the SHEFEX (Sharp Edge Flight Experiment) program is to test and qualify cost effective re-entry thermal protection technology in a flight experiment. To perform the test, the experiment is mounted at the front of a sounding rocket. SHEFEX-1 was launched in 2005 from Norway on an S-30/Improved Orion motor combination. With the launch of SHEFEX-1, MORABA demonstrated its capability to provide a cost-effective platform for hypersonic research during the re-entry phase of sounding rocket vehicles.

With a length of 12.6 meters and mass of 6.8 tons, SHEFEX-2 was launched in 2012 from Andøya on a modified Brazilian two-staged VS-40 rocket to achieve a higher velocity and longer re-entry time. Apart from the thermal protection experiment, SHEFEX-2 also included an experiment to investigate aerodynamic vehicle control during re-entry using small moveable wings known as canards. SHEFEX-2 included a precession control on the second stage motor and payload system which provided a flatter and longer re-entry trajectory with a range of more than 800 km and corrected drift and dispersion.

Fig. 9: SHEFEX-2 Vehicle consisting of a modified VS40 rocket motor assembly and payload [3].

For the researchers, the interesting part began when it re-entered the Earth's atmosphere with a velocity of more than Mach 10 at an altitude of 100 km. All data down to an altitude of 30 km was received by multiple telemetry stations which lead to a very successful mission even though it was not possible to recover the payload due to strong winds, low cloud altitude and very high waves in the Norwegian Sea in the impact area.

Fig. 10: SHEFEX-2 launch in Andøya rocket range [3].

As a further development in the SHEFEX program, MORABA is supporting the development of the Brazilian rocket VLM-1 (Veículo Lançador de Microsatélites) which is capable of launching the SHEFEX-3 vehicle to a near orbital trajectory. The SHEFEX-3 vehicle will be separated from the payload in the heterosphere and autonomously re-enter the atmosphere.

HIFiRE And SCRAMSPACE

MORABA and other DLR institutes are collaboration partners in the two international hypersonic research programs HIFiRE (Hypersonic International Flight Research Experimentation) and SCRAMSPACE. The HIFiRE program is a hypersonic propulsion research program jointly led by the Australian Defence Science and Technology Organisation and the US Air Force Research Laboratory. It entails the launch of up to nine research payloads with sounding rockets, to which MORABA's contribution is the provision of launch vehicles and campaign operations for four sounding rockets. Negotiations for an extension of this collaboration for further launches are currently under way [2].

MORABA is also part of the international consortium for the conduct of the SCRAMSPACE flight experiment. This program is led by the University of Queensland in Brisbane, Australia, and involves the launch of one sounding rocket to lift a free-flying, unguided scramjet payload to its experimental window. As with the HIFiRE collaboration, MORABA's contribution entails the procurement, preparation and launch of the rocket motor systems and the necessary hardware and flight safety support.

The special requirements for the experimental payloads and trajectory parameters in missions for hypersonic research result in non-typical vehicle configurations where special attention must be paid to launch vehicle stability and integrity as well as performance. As research in this field progresses, experimental requirements become increasingly demanding and require elaborate trajectory design and control, similar to that of the SHEFEX 2 flight experiment.

REXUS/BEXUS

The REXUS/BEXUS program allows students from universities and higher education colleges across Europe to carry out scientific and technological experiments on research rockets and balloons. Each year, two rockets and two balloons are launched, carrying up to 20 experiments designed and built by student teams. In the last two years MORABA has been involved in 4 REXUS and 4 BEXUS launches.

REXUS experiments are launched on an unguided, spin-stabilized rocket powered by an Improved Orion motor with 290 kg of solid propellant. It is capable of taking 40 kg of student experiment modules to an altitude close to 100 km. The vehicle has a length of approximately 5.6 m and a body diameter of 356 mm.

BEXUS experiments are lifted by a balloon with a volume of 12 000 m³ to a maximum altitude of 35 km, depending on the total experiment mass (40-100 kg). The typical flight duration is 2-5 hours.

The REXUS/BEXUS program is realized under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Board (SNSB). The Swedish share of the payload has been made available to students from other European countries through a collaboration with the European Space Agency (ESA). EuroLaunch, a cooperation between the Esrange Space Center of SSC and MORABA, is responsible for the campaign management and operations of the launch vehicles. Experts from ESA, SSC, ZARM and DLR MORABA provide technical support to the student teams throughout the project. REXUS and BEXUS are launched from Esrange, Sweden.

STERN

In winter 2010, DLR launched the support program STERN (Studentische Experimental-RaketeN) for university students to develop, build and launch their own rockets. The program addresses at all German universities which offer courses in aerospace technology. The rockets should have a small telemetry system to transmit key trajectory and housekeeping data back to Earth during flight. The rockets may be propelled by a solid-fuel, liquid-fuel, hybrid or steam motor. In order to teach students engineering and science and to put their technical knowledge to the test as early as possible in their studies, there are no altitude restrictions except the normal range restrictions. The program will run for up to three years, depending on the university and the scope of the project. At the end of the project, the result should be a flight-capable rocket. Some of the rockets will be launched from the Esrange Space Center at Kiruna, in Sweden. To break the European altitude record could be a long-term objective of the DLR program.

V. SOUNDING ROCKET FLIGHT TICKET

MORABA is usually contacted by the primary investigator in the early stage of a project. MORABA provides assistance in defining the mission objectives, selecting suitable sounding rocket vehicles and optimum launch locations. The necessary electrical and mechanical subsystems that are required to meet the mission objectives (e.g., telemetry, recovery) are identified as vital components for the mission scenario. Finally, MORABA provides preliminary costing and implementation plans as input for the scientist's project proposal to the funding agencies. This section describes the usual workflow for the preparation and conduct of a typical sounding rocket or balloon mission from project acquisition to vehicle launch.

Mission Management and Range Coordination

Prior to any mission, negotiations with range authorities are conducted to obtain the necessary launch permissions, to define the local infrastructure facility requirements and to determine logistics requirements. Depending on the range location and existing instrumentation, an optimal ground station configuration and ground support equipment setup is defined. Any deficiencies are supplemented by MORABA mobile equipment. Where required, comprehensive self-contained launch facilities are made available for deployment at remote locations, requiring only minimal on-site preparations.

A major part in the preparatory phase of launching sounding rockets is the pre-flight mission analysis. Depending on the physical properties of the payload and the selected launch vehicle, an iterative analytical process is started to tune and verify the required flight performance with regards to trajectory, stability, heating and re-entry. The MORABA rocket portfolio is shown in figure 11. For range safety and recovery purposes, a dispersion analysis is also performed.

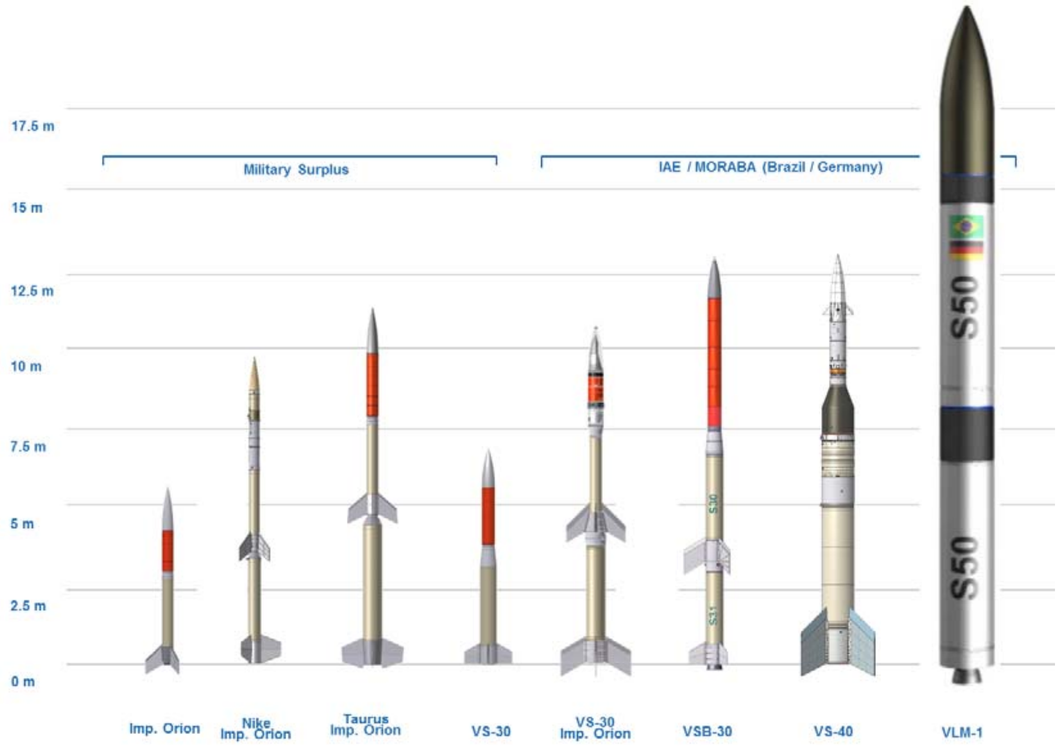

Fig. 11: MORABA Rocket Family.

Electrical and Mechanical Manufacturing

MORABA has a broad experience in the design and manufacturing of complete vehicle systems and is able to provide ready-to-fly solutions to sounding rocket- and balloon-borne scientific experiments. Depending on the capability of the participating organization or industry, the necessary components for a complete vehicle are designed, manufactured and qualified to the needs of the mission. The spectrum ranges from onboard processor systems, pyrotechnic ignition systems to all kinds of mechanical flight systems.

Fig. 12: MAPHEUS-4 System Bench Test.

Assembly, Integration and Testing

A large variety of sounding rocket payloads and components can be assembled, integrated and tested in the MORABA laboratories, see figure 12. All necessary equipment and test setups are available to verify transmitter and receiver systems as well as scientific and support system data integrity. Facilities are available to test rate or attitude control systems for a wide range of payloads, including three axis air bearing systems. This allows realistic calibration and verification of the pointing accuracy and the required manoeuvers during the ballistic flight phase in the heterosphere (> 100 Km). To facilitate the testing process, dedicated or generic electric ground support equipment is built. For environmental testing, payload balancing and determination of the payload's physical properties, MORABA uses industrial test facilities (EADS Astrium, IABG and the University of the German Armed Forces in München, Germany).

Launch Campaign

After the successful completion of the bench test, flight simulation test and the environmental tests, all necessary equipment, mobile stations and flight hardware are transported to the selected launch location. Station assembly, motor preparation and payload integration are performed in parallel to reduce the time-to-launch. After completion of the preparation phase, an intensive test period follows to ensure the readiness of all participating organizations and flight systems. After the test countdown, one or more so called "hot" countdowns are needed to launch the rocket vehicle. The number of countdowns is, besides potentially appearing technical problems, dependent on the weather conditions and scientific constraints. For ionosphere research, certain phenomena like aurora borealis are necessary, to provide the proper scientific conditions for the deployed experiments. In the case of microgravity missions, the launch opportunity is mainly influenced by local weather conditions. After the parachute recovery system sequence and the safe landing of the payload, it is retrieved by helicopter or ship and brought back to the range.

Post-Flight Mission Analysis

After the flight, all available flight data from various sources, such as RADAR, slant-range, housekeeping data inclusive inertial platform navigation and GPS data are processed and compared to the predicted values. Any deviations and anomalies are investigated and if necessary design and procedure changes are implemented.

VI. SOUNDING ROCKET TECHNOLGY DEVELOPMENTS

Major achievements in recent years have been the implementation and qualification of the new rocket vehicle VSB-30, a joint development of the Brazilian institution IAE (Instituto de Aeronaútica e Espaço) together with DLR MORABA, which was successfully introduced in the European microgravity programs TEXUS and MASER. New recovery and service systems were developed in cooperation with Kayser-Threde GmbH. In cooperation with SSC, a new service system was developed and implemented into the REXUS (Rocket Experiments for University Students) and MAPHEUS program. These modern sounding rocket systems together with the Brazilian VSB-30 vehicle enable cost effective and short lead time access to a microgravity environment in order to qualify and flight test experiments for the International Space Station (ISS) in parallel to independent missions. With the joint development of the VLM-1, MORABA will be capable to offer a launch vehicle for complex hypersonic re-entry missions. The next subchapters will explain some developments in detail.

European Recovery System (ERS)

Up to the TEXUS-44 microgravity research mission, successfully launched in February 2008, the payloads of the TEXUS vehicles were exclusively equipped with the Magellan (former Bristol Aerospace Ltd.) ORSA recovery system, integrated into the ogive nose cone. With the intention to gain more independency from the North American market and the inherent procurement and ITAR regulations problems, the European Space Agency (ESA) has taken initiative to contract industry for the development and built-up of a new European Recovery System (ERS) in 2006. For the design, manufacturing and qualification task sharing, a cooperation of MORABA and the Kayser-Threde GmbH has been initialized.

The ERS is designed to recover payloads of up to 450 kg mass and 438 mm (17 inch) diameter by a two-stage subsonic parachute system. It features a separating ogive nose tip with a forward deploying recovery parachute. The assembly incorporates a 3:1 fineness ratio ogive whose forward portion is ejected within the heterosphere to permit subsequent parachute recovery system operation. The aft ogive houses the parachute system, autonomous redundant electrical pyrotechnic ignition system, housekeeping electronics, TM interface, beacon system, camera system and pyrotechnic and electronic batteries.

The parachute system activation is controlled by barometric switches on the descent trajectory at a nominal altitude of 4.6 km (15 kft) in the combination of an electronic timing activation unit (ignition unit). Together with the heat shield ejection the drogue parachute is deployed and the payload is mainly stabilized from flat spin and decelerated. After complete stabilization the drogue parachute is separated and extracts the main parachute out of the deployment bag. At fully opened main parachute the final sink rate is around 8 m/sec [4].

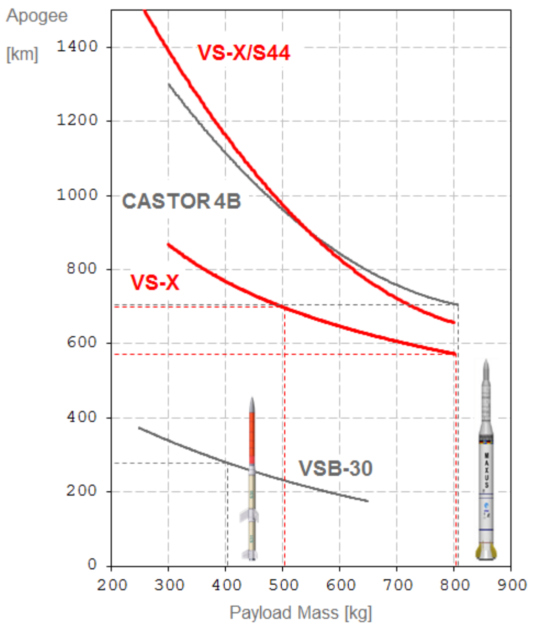

Fig. 13: Performance of the Possible New Sounding Rocket VS-X

Guidance, Navigation & Control

In the field of Guidance, Navigation and Control, a capability has been developed to shape trajectories by repointing of an upper stage rocket motor. Initially driven to serve the scientific requirements of SHEFEX-2, where a re-entry into the atmosphere with small inclination had to be realized, the successful mission was followed by additional inquiries from hypersonic research groups (HEXAFLY, HIFiRE-8, SHEFEX-3). The attitude control system consists of a cold gas system and control logics that where developed in-house and have the unique ability to control spinning vehicles. In conjunction with this new system, a dispersion reduction capability was developed and flight-proven that allows for an unrivalled impact point precision. This facilitates telemetry coverage prediction, recovery operations and, most important, flight safety issues that usually accompany long range missions. The core of this capability consists of an algorithm that evaluates the real-time flight state during 1st stage burn and accordingly corrects target coordinates for the repointing of the upper stage.

Sophisticated microgravity missions like MAIUS-1 do require additionally attitude control to align the payload in a certain attitude in reference to the gravitational field.

Operations

MORABA has extended its abilities to provide full launch support by the development and qualification of a flight safety tool. The software receives flight status data (position, velocity and attitude) from all available sources (GPS, RADAR, Inertial Navigation System, Telemetry). The data are processed and displayed to the Flight Safety Officer in real time. This is a requirement for mission risk minimization.

Flight Dynamics

In collaboration with Astos Solutions GmbH Stuttgart, MORABA enhanced the six degree of freedom dynamic simulation capabilities of the ASTOS software and validated the tool against MORABA’s already operational dynamics code ROSI. This expands MORABA’s trajectory prediction capabilities to more complex mission scenarios that involve guidance systems (SHEFEX-2, VLM, HEXAFLY). Existing codes were continuously validated against real flight data and, in case of need, updated, resulting in high reliability predictions.

Development of a New Versatile Rocket Vehicle

DLR MORABA initiated a study for the development of a new versatile sounding rocket as a new working horse for the European and international microgravity research program on sounding rockets. The need for such a new sounding rocket is given by new constraints on the future sounding rocket programs the sounding rocket community is faced with:

1. Stagnating financial resources in the major sounding rocket programs.

2. Strong dependency on high tensile steel cased VSB-30 and VS-40 vehicle family
3. Increasing safety and critical dispersion requirements by rocket ranges
4. Limited altitude range for unguided vehicles from ESRANGE
5. Microgravity time > 6 minutes only available with the CASTOR 4B rocket motor

The new sounding rocket shall be a single stage rocket that shall be launched vertically. It shall have trajectory control by using a thrust vector control system which necessitates the implementation of a flight termination system. Very important is the use of a carbon fibre motor case to reduce the aforementioned dependency on steel and to increase the payload capacity. Future rocket developments have also to regard that due to environmental restrictions thermal protection systems have to be designed without asbestos. Figure 13 shows the performance of the new sounding rocket, named VS-X, compared to the VSB-30 and the CASTOR 4B which are used in the microgravity programs TEXUS, MASER and MAXUS. In combination with a S44 motor the VS-X can lift an 800 kg payload to an apogee of 700 km.

VII. SUMMARY & OUTLOOK

Sounding rockets and balloons will continue to provide a flexible, cost and time effective platform for various fields of scientific research for experiments qualification and for verification measurements. Beside the development of new vehicles for microgravity experiments another challenge is the continuously increasing data rate of new experiments and the bandwidth of the telemetry and telecommand systems. The need of teleoperations on experiments during a flight mission and the provision of real time telemetry data on flights with high apogees or long range will become more important in the coming years. Improvements on the ground equipment and telemetry stations are necessary to serve the demands of future experiments.

VIII. ACRONYMS

BEC	Bose-Einstein-Condensate
BEXUS	Balloon Experiments for University Experiments
BMWi	Bundesministerium für Wirtschaft und Technologie
BPSK	Binary Phase Shift Keying
DCTA	Departamento de Ciência e Tecnologia Aeroespacial
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EADS	European Aeronautic Defence and Space Company
ECOMA	Existence and Charge State of Meteoric Dust Grains in the Middle Atmosphere
ERS	European Recovery System
ESA	European Space Agency
ESRANGE	European Space and Sounding Rocket Range
FM	Frequency Modulation
GmbH	Gesellschaft mit beschränkter Haftung
GPS	Global Position System
HIFiRE	Hypersonic International Flight Research Experimentation
IABG	Industrieanlagen-Betriebsgesellschaft mbH
IAC	Internation Astronautical Congress
IAE	Instituto de Aeronaútica e Espaço
ISO	International Organization for Standardization
ISS	International Space Station
MAIUS	Materie Interferometrie Unter Schwerelosigkeit
MAPHEUS	Materialphysikalische Experimente unter Schwerelosigkeit
MORABA	Mobile Raketenbasis
OHSAS	Occupational Health and Safety Assessment Series
ORSA	Ogive Recovery System Assembly
PCM	Pulse Code Modulation
PM	Phase Modulation
RADAR	Radio Detection and Ranging
REXUS	Rocket-borne Experiments for University Students
RIR	Range Instrumentation RADAR
SCRAMSPACE	Scramjet-based Access-to-Space System
SHEFEX	Sharp Edge Flight Experiment
SNSB	Swedish National Space Board
STERN	Studentische Experimental-Raketen
TC	Telecommand
TEXUS	Technologische Experimente Unter Schwerelosigkeit
TM	Telemetry
TT&C	Telemetry, Tracking & Command
TV	Television
USA	United States of America
VLM	Veículo Lançador de Microsatélites
VSB-30	Veículo de Sondagem Boosted – 30
WADIS	Wellenausbreitung und Dissipation in der Mittleren Atmosphäre

IV. REFERENCES

1. Boyce R.R. / Tirtey S.C. / Brown L. / Ogawa H.: *SCRAMSPACE: Scramjet-based Access-to-Space Systems*, AIAA-2011-2297, 17th International Space Planes and Hypersonic Systems and Technologies Conference, 2011
2. Dolvin D.J.: *Hypersonic International Research and Experimentation (HIFiRE) Fundamental Sciences and Technology Development Strategy*, AIAA-2008-2581, 15th AIAA / AAAF International Conference on Space Planes and Hypersonic Systems and Technologies, 2008

3. Huber F. et al: *DLR Raumflugbetrieb Status Report 2005-2013*, DLR Report 2013
4. Hörschgen M. / Pfeuffer H. / Janke T.: *European Recovery System (ERS)*, 19th ESA Symposium on European Rocket and Balloon Programmes and Related Research, Bad Reichenhall, Germany, 2009
5. Stamminger A. / Altenbuchner L. / Ettl J. / Jung W. / Kirchhartz R. / Turner P.: *MORABA – Overview on DLR's Mobile Rocket Base and Projects*, SpaceOps 2012 Conference Proceedings. 12th International Conference on Space Operations, 11.-15. June 2012, Stockholm, Sweden, 2012
6. Stamminger A. / Ettl J. / Jung W. /Grosse J.: *MAIUS User Manual*, DLR 2012-04-20