SUBORBITAL SPACEFLIGHT

Space Operations and Astronaut Training

DLR

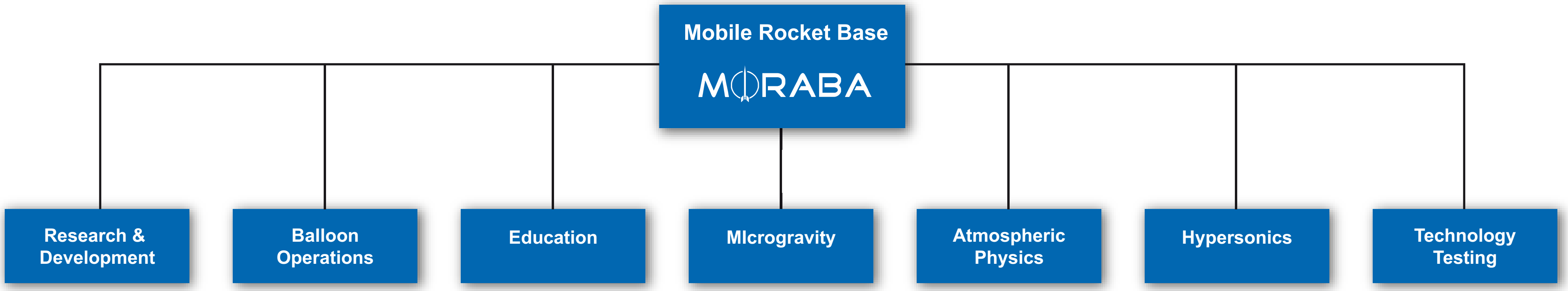
MORABA

MOBILE RAKETENBASIS


MORABA
MOBILE RAKETENBASIS

Research Platform Sounding Rockets

Since its founding more than 50 years ago, DLR RB/MORABA has been successfully providing suitable environments and conditions as well as supporting services in the realm of sounding rockets for the conduct of scientific experiments. Sounding rockets are an integral component of experimental research for a multitude of scientific areas, such as microgravity, atmospheric physics or aerothermodynamics. Alongside the drop tower and parabolic flight experiments, sounding rockets allow cost effective precursor experiments for subsequent applications on orbital and other spaceborne systems. The preparation time and costs are relatively low whereas repeatability and the frequency at which experiments can be conducted are high. The insights and findings of experiments conducted on these platforms therefore allow adjustments for follow-on missions. For the demonstration of new technologies and their stepwise introduction into more and more applied research and subsequent utilization, sounding rockets provide an ideal research platform for crucial steps from fundamental to applied research and development. The MAIUS project (first Bose-Einstein-Condensate in space) showcases the most prominent advantages of sounding rockets employed for microgravity research and in-space testing. Their long exposure time to the experimental conditions outside of the atmosphere allowed researchers of the MAIUS mission to conduct a multitude of experiments, thereby populating the experimental dataset and drawing conclusions with high impact for the upcoming development and research into atom interferometry in space. This will ultimately lead to new technologies for precise clocks, with direct applications, for instance in guidance and navigation. Sounding rockets are furthermore the only platform that allows in-situ measurements in the atmosphere at altitudes above that of sounding balloons, which float at up to 40 km above mean sea level. Recently supported missions include WADIS, PMWE, MaxiDusty and ICI with target altitudes between 100 km and 350 km. In the field of carrier technology development and hypersonics, they are irreplaceable, either for hypersonic aerothermodynamic and propulsion experiments (HIFiRE), reusability (ReFEx), or technology testing (ROTEX-T, ATEK, STORT).



MORABA research fields and operations

DLR's internal, programmatic projects alongside with many national and international cooperation agreements and science support services contracts form the basis for a large variety of projects. Since 2014, MORABA thereby launched 47 sounding rockets and supported the launches of 12 balloons. An up-to-date overview of all missions supported by MORABA can be found here. A long lasting cooperation agreement with the Department of Aerospace Science and Technology (DCTA) of the Brazilian Aeronautics and Space Institute (IAE) , as well as the Brazilian Space Agency (AEB), provided the foundation for the joint development of different types of rocket motor vehicles, the most prominent being the VSB-30 as the standard vehicle for microgravity missions. The European Range Network EASP (Esrange Andøya Special Projects Agreement) allows scientists of five ESA member states facilitated access to the European rocket ranges Esrange (Sweden) and Andøya (Norway). Additionally, the EuroLaunch cooperation between MORABA and the Swedish Space Corporation (SSC) is an enabler for joint missions and launches from Esrange and allows the coordination of efforts and competences for missions at other launch sites. Within the HIFiRE Program, a cooperation agreement with DST Group Australia intensified bilateral scientific collaboration, resulting in the support of three launches from Woomera, Australia.Currently, negotiations are ongoing to further establish this collaboration beyond the end of the HIFiRE program in 2018. Likewise, the strengthening of the cooperation with the NASA Sounding Rockets Program Office is currently being established and is sought to enable the exchange of technology, hardware and subsystems. Strong national cooperation with the Institute of Atmospheric Physics (IAP), Kühlungsborn, Material Physics in Space, as well as internal teaming with the department for High Speed Flows, DLR Cologne, are of great importance for permanent research programs and the evolutionary development of launch vehicles. Achievements and developments are presented in this chapter on the basis of different research missions.

Introduction of new launch vehicles

Within the last five years, the MORABA rocket family was extended by qualifying new launch vehicles within operational research projects. The approach to couple launch vehicle development with operational missions and programs offers synergies between technology and research as well as cost benefits and unique research conditions at acceptable mission risk levels. However suitable evolutionary development strategies have to be selected carefully and cross-influencing of launcher development and experimental requirements has to be limited.

O-STATES – S31/Improved Orion

In a Swedish national project for atmospheric physics, the new launch vehicle S31/Improved Orion was qualified. By use of several solid body electrolysis sensors, density profiles of atomic and molecular oxygen was measured between 60 and 245 km altitude. The S31/Improved Orion vehicle provides less total performance when compared to the established S30/Improved Orion combination, but accelerates faster and thus shows better wind resistance. An apogee of 245 km was reached. The possibility of on-range refurbishment of service and recovery modules was another significant achievement of the mission, allowing cost reduction in future mission concepts. The S30 and S31 are now available as boosters for the Improved Orion upper stage and can be selected as needed, following MORABA's mix & match concept for rocket motor vehicles.

ROTEX-T – Terrier/Improved Orion

The qualification of the Terrier Mk12/Improved Orion launch vehicle was a joint effort between Esrange Space Center (ESC) and MORABA. The vehicle was launched in 2016 for the ROTEX-T project, a hypersonic boundary layer transition experiment, reaching an apogee of 185 km, resulting in a maximum airspeed of Mach 5.2 during re-entry.

MaxiDusty – Improved Malemute Qualification

The Improved Malemute military surplus motor's performance attributes have proven to be very attractive for the conduct of atmospheric physics missions. It closes the performance gap between the frequently used Improved Orion rocket motor and the motors of Brazilian production, where the propellant mass is 2.5 to 3 times that of the Improved Orion. In a joint effort with Andøya Space Center (ASC) and NASA Sounding Rocket Program Office, MORABA qualified this new rocket motor as a single stage launch vehicle with two test flights carrying the MaxiDusty 1 and 1b payloads in 2016. MaxiDusty is an atmospheric physics project that investigates dust particles in the mesosphere. Before and after reaching the apogee of 115 km, measurements in the atmospheric layers of interest were carried out. New flight hardware such as tailcan, fins and motor adapter, tools and work procedures were designed and constructed for this rocket motor.

The testing of new high-temperature resistant fins was of great success. With their leading edge impregnated with phenolic resin and cork as thermal protection material for the fin area, the ablative and hazardous material FIREX™ could be replaced completely (see section about MAPHEUS 6, MAIUS-1 & IMQ). Modifications of the ignition system allow this rocket motor to be used as a second stage for further new vehicle combinations. The developments conducted for the introduction of this rocket motor have been and will continue to be introduced step by step and where appropriate to other vehicles of MORABA.

Hypersonics and technology testing

MORABA's support of hypersonics research started with the SHEFEX I mission in 2005. Since that time, interest in this research field increased and technology testing in regimes of Mach 5 to above Mach 10 at real aerothermodynamic conditions for experimental bodies at a meaningful scale is well in demand. Hypersonic laminar to turbulent flow transition experiments are necessary for improved accuracy in thermal loads prediction in access-to-space technology as well as planetary entry vehicles. Sounding rockets can be regarded as research infrastructure in the fashion of a flying windtunnel, with the significant difference, that the test gas is not processed by compression, expansion, combustion, arc heating or any other process that changes chemical, thermal or physical properties of the gas as it would be the case with ground based facilities.

A further advantage of using sounding rockets as a research platform is the possibility of using full scale vehicles and thus the aerothermodynamic phenomena can be observed directly. Presently, mission design and vehicle capabilities begin to enable testing of flight vehicles at near thermal equilibrium.

HIFiRE

The "Hypersonic International Flight Research Experimentation" (HIFiRE) program lasted from 2009 to 2018 and was supported by MORABA with the conduct of six launch campaigns (5, 3, 7, 5b, 4, 7b). The research program was aimed at exploring the fundamental technologies required to achieve practical hypersonic flight. Being able to fly sustainably at hypersonic speeds would revolutionize high speed, long distance flight and provide more cost-effective access to space. Suppressed trajectories were used for the last missions, allowing maximum atmospheric test time and resulting in more thermally demanding launch vehicle and experiment conditions. Mission-specific thermal protection systems (TPS) were developed and employed on the VSB-30 vehicles on an experimental level.

BOLT and HIFLIER

The objective of the "Boundary Layer Transition" (BOLT) project is to experimentally investigate the hypersonic boundary layer transition mechanisms from laminar to turbulent flow on a low-curvature concave surface with a swept leading edge. This shall be achieved during a captive-carry flight experiment on a sounding rocket at speeds between Mach 5 and 7 in 2020. The BOLT project is coordinated by the US Air Force Research Laboratory (AFRL) and funded by the US Air Force Office of Scientific Research (AFOSR). It will be carried out by MORABA in collaboration with the Air Force Research Laboratory Aerospace Systems Directorate (AFRL/RQ) and MORABA's contribution is funded by a research grant. MORABA will customize the S31-Improved Orion launch vehicle system, coordinate Esrange Space Center in Sweden as the test range and manage the launch mission. On the payload side, MORABA provides the despin- and separation system, the main service system as well as the cold gas attitude control system. The BOLT experimental payload, consisting of the flight geometry and payload support module, is provided by AFOSR Performers.

HIFLIER 1 is a follow-up project planned in 2021 with a new payload stack, but conditions and requirements stay the same as for BOLT. These two flights are intended to be developed into an ongoing series of experimentation with international collaboration opportunities.

HEXAFLY-INT

The HEXAFLY-INT project is run by ESA and funded by the EU as well as EU partner countries. It aims at the development of a hypersonic glider and its test flight. An international consortium of research institutes, universities and industry partners is involved in the development of the 4 m long flight body to be used in speeds exceeding Mach 7. Aerodynamic efficiency, thermal protection materials and structures, flight control and the testing

HIFiRE 5b launch vehicle at Woomera test range of high-speed propulsion systems on ground are key topics that are investigated. MORABA is introducing its expertise in cold gas-, telemetry-, telecommand-, and GPS-systems, and acts as a service provider for the launch vehicle, service system and the launch campaign. The currently developed VS-50 rocket motor vehicle is planned to be used for this mission in 2021.

STORT

The STORT project aims to conduct a relatively simple flight experiment with hot structures and high enthalpy flow. The idea is to leverage sounding rocket technology and enhance it with smart sensor strategies in order to fly a three stage rocket motor vehicle with an upper stage ignition of the third stage such that the apogee dispersion is reduced. This combination of an unguided rocket with an adaptive ignition timeline results in improved insertion accuracy and thus higher experimental condition reliability compared to normal unguided sounding rockets, where the upper stage ignition is dependent on time only. The three stages allow the 200 kg payload to be propelled to a speed greater than Mach 8 and the suppressed trajectory results in heat loads that are close to or representing thermal equilibrium at that speed. Interactions between flow and hot walls can be investigated and hot structures will be thermally soaked.

The mission design approach makes use of the experiences of HIFiRE and combines this experience with new elements such as the attitude sensing's input to the ignition time of the upper stage. The project thus carries on the evolutionary development strategy of MORABA that aims to generate significant advances in capabilities with small increases in risk.

ATEK

The ATEK project utilized the second stage rocket motor system itself as an experiment platform. An S30 rocket motor from Brazilian production was used as a second stage with a heavily instrumented tailcan and fin assembly. Experiments were conducted pertaining to the pressure and temperature distribution on the fins as well as the temperature and gas composition of the exhaust plume. Experiments were conducted on the motor adapter in order to determine the efficiency and necessity of thermal protection systems – generating data for future decisions on applicability and suitability of protected and unprotected structures. Data of this sort facilitates the concept of evolutionary changes in the vehicle and provides the basis for informed decisions with acceptable mission risks for the generated advances in sounding rocket technology. For the ATEK mission, the evolutionary development approach was utilized to allow technology testing with the testing of materials in a highly demanding high temperature and high density abrasive particle loaded flow of a composite solid propellant rocket motor.

CRYOFENIX

Orbital launcher technology development is actively being supported by direct technology testing such as during the CRYOFENIX project. A sounding rocket experiment carrying a cryogenic liquid (hydrogen) was performed for the first time in Europe, launched in 2015 from Esrange. The main objective for the mission was to study the global behavior of liquid hydrogen under controlled linear acceleration conditions, generated by a derivative of MORABA's rate control system using a cold gas thruster module. Liquid propellant experimentation under weightless conditions was supported with controlled moderate linear acceleration (thrust <28 N for approx. 400 kg payload). The experiment data obtained during the flight in terms of high resolution videos, pressure and temperature data are well in line with the expected results. The experiment data will support future development of liquid propellant management systems for future European launcher systems.

Evolutionary development in atmospheric physics

Recent developments within the last five years in the research field of Atmospheric Physics showcase the evolutionary approach of MORABA to further develop and enhance systems and capabilities. A highly complex and integrated sensor platform evolved within three succeeding programs, and diverse subsystems could be improved.

From ECOMA to WADIS to PMWE

After the end of the Norwegian-German ECOMA program in 2010, German atmospheric physicists concentrated their studies in the program WADIS. The aim of the program was to quantify gravity waves within the atmosphere as well as their contribution to the complete energy budget. Simultaneously, the atomic oxygen concentration was surveyed with high-precision instruments on board. The in-situ measurements were enhanced by ground-based LiDAR and RADAR measurements. Two launches in 2013 and 2015 with a newly developed and customized measurement platform in combination with several meteorological rockets were performed from Andøya Space Center (ASC) within this program. The emphasis of the follow-up program PMWE is the study of polar mesospheric winter echoes and turbulences in altitudes of 70 to 90 km, as well as the quantification of meteoric dust particles and negative ions. The first two of four PMWE sounding rockets were launched in 2018. The WADIS and PMWE mission operations and payload integration were managed completely by MORABA and all experiment support, data acquisition and handling and timeline command subsystems were developed by MORABA. Therefore, a measurement platform concept was designed as well as a waterproof service module including a high precision inertial measurement unit and GPS as well as transponder-based trajectory tracking by Radar. The recovery system was improved and equipped with a newly developed localization system using the Iridium communication network, making recovery localization fully independent from all other onboard telemetry systems. The new measurement platform was adapted in a way that it could be equipped with significantly more sensor units at the front end for measurements during the ascent phase and at the aft end during reentry when compared to previous capabilities during the ECOMA and WADIS programs. Additionally, the platform carries a "guest module" for different in-house or guest technology testing experiments. During the WADIS flights, GPS receivers were tested and subsequently developed, and an active free falling sphere was ejected, requiring a unique ejection mechanism. For the first two PMWE flights, this guest module was used for the fusion of a strap-down inertial platform with a commercially available, but never flown, GPS receiver, as well as an in-flight data fusion algorithm to improve positioning accuracy. The latter was only possible because of massively improved on-board computing power provided by MORABA's MFC2 main processor card, used for the first time on a sounding rocket. The telemetry bandwidth was increased continuously from at most 0.833 Mbit/sec (ECOMA) to 3.333 Mbit/sec (WADIS) and further to 5.0 and 8.0 Mbit/sec (PMWE1/2). Finally, a new floatation device for water recovery of the PMWE payload was developed and tested by MORABA. Additionally, for the salvo launch of PMWE sounding rockets, a novel mission concept was elaborated in cooperation with ASC, incorporating simultaneous operation of four telemetry tracking stations and two Radar stations as well as a new recovery vessel. To meet budgetary requirements, the mission logistics concept was revized and both payloads were assembled and completely tested at MORABA facilities in Germany and then shipped launch ready to ASC. The so-called ship-and-launch concept is believed to offer significant cost advantages and will be further investigated in the future. A salvo launch of PMWE 3 and 4 is planned for autumn 2020.

PMWE launch vehicle at Andøya Space Center

First of their kinds

ROTEX-T – Crash resistant onboard data storage

The ROTEX-T flight in 2018 has enabled flight testing with very high data rate sensors, allowing investigations into heat transfer and pressure fluctuations in hypersonic boundary layers. This highly complex and demanding experiment was made possible by onboard data storage in a crash resistant container, without the need to transmit telemetry data to ground, which was developed by DLR Cologne (AS-HYP) based on MORABA hardware. Further, complex and costly reorientation systems to align the body axis with the flight vector were omitted for simplicity of the mission and higher flight velocities, yet resulting in valuable high speed data at more than Mach 5. The experimental body impacted in the Esrange Space Center impact area after separation from the stabilizing aft end and was successfully recovered without the use of a parachute system. Such approaches to high speed flight testing open the opportunity to gather large amounts of high speed flow data at low cost. From a mission design point of view, the aim of this mission was to demonstrate the viability of low complexity and thus low risk flight opportunities to highly complex experimental questions.

QUANTUS/MAIUS-1 – First Bose-Einstein condensate in space

In 2011, the QUANTUS consortium started their activities to perform fundamental research on matter wave interferometry in weightlessness for long-term atomic clock developments. Three sounding rocket missions (MAIUS-1 to 3) have been planned to demonstrate Bose-Einstein condensate creation and atom interferometry with rubidium and potassium atoms. Two different payloads MAIUS-A and MAIUS-B are being designed, qualified and integrated in the time frame from 2011 until 2020. The MAIUS-A scientific payload demonstrated the first Bose-Einstein Condensates in Space in the challenging environment aboard a 2-staged VSB-30 sounding rocket in 2017. In order to achieve this ambitious scientific goal, the experiment used various sensitive instruments imposing strong requirements on the thermal and mechanical design of the scientific payload. The large required volume leads to an increased payload diameter, resulting in static stability problems that were solved with an unconventional aerodynamic layout of the launch configuration. Combining a rate control optimization with a highly accurate attitude control yielded the ability to conduct cold atom interferometry under free-fall conditions for the first time. The MAIUS-2 flight is planned for 2021.

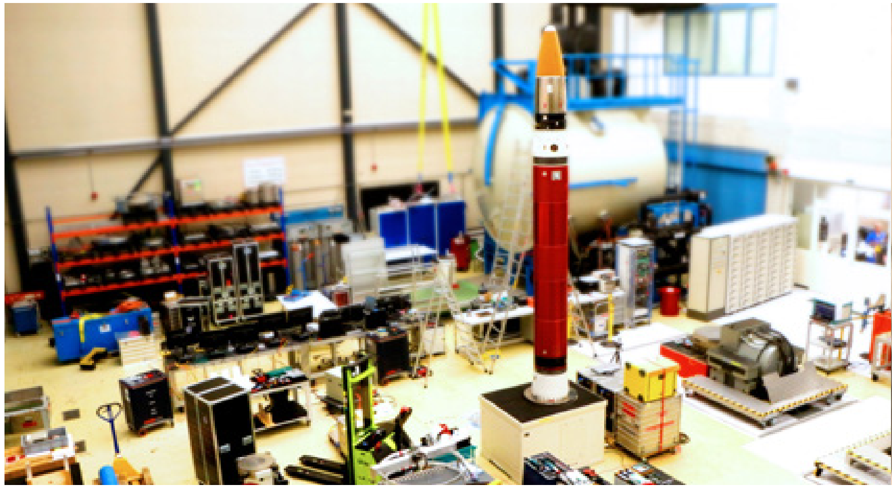
MAPHEUS 6, MAIUS-1 & IMQ – Cork as a Thermal Protector

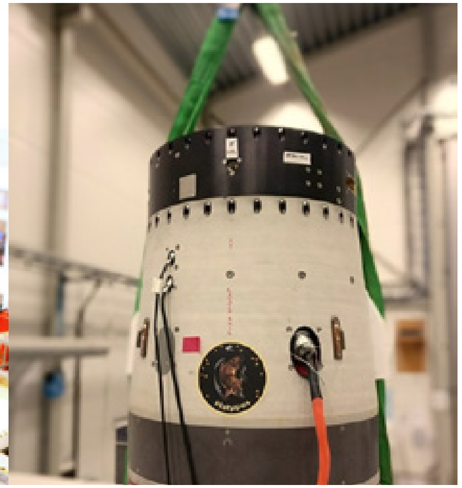
The application of aerospace thermal protection systems (TPS) is not limited to orbital flight and re-entry vehicles. Although less critical in terms of the thermal load's magnitude, it is also an essential part of sounding rocket primary structures. For a large variety of launch vehicles, MORABA uses thermal protection systems on primary structures such as fin, nose cone, conical adapter and heat shield assemblies. An ablative, epoxy based, two component thermoset coating has been the material of choice over several decades. Using relatively simple manufacturing methods, it can be sprayed onto almost any geometry. However, its difficult quality control properties, noxious fumes released during the spraying process, its limited shelf life, its extensive storage requirements and above all, its residues polluting adjacent payload components during the ablation phase, are the key drivers for the development

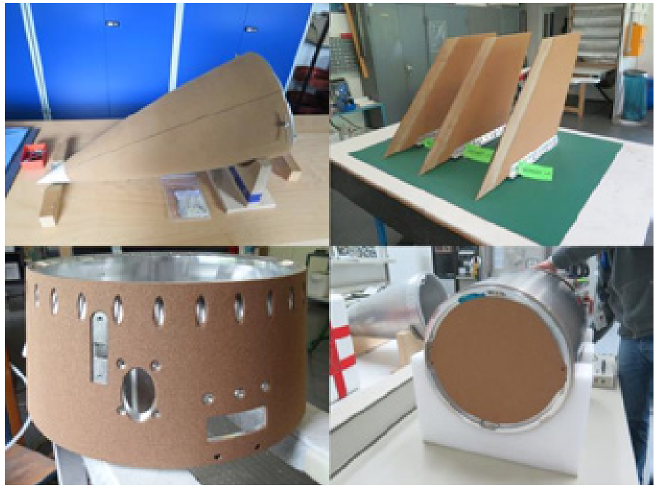
Left: MAIUS environmental test (Credit: Stephan Seidel)

Middle: MAIUS service system

Right: Cork-based TPS applied on various primary and secondary sounding rocket structures







of a new thermal protection system using a special aerospace material based on cork. The new material was successfully tested in the scientific missions MAIUS-1, MAPHEUS 6 and IMQ and replaced step by step the FIREX™ material of all primary structures.

ReFEx – Reusability Flight Experiment

The recently established project ReFEx plans to make use of a VSB-30 sounding rocket platform to bring its lifting body vehicle to flight conditions resembling those that can be experienced by a potentially reusable first stage of an access-to-space system. The sounding rocket is intended to be unguided and the entire vehicle is planned to be scaled to small size for this type of research, with the payload mass being less than 600 kg. This payload shall be brought on a “flattened” trajectory with an apogee of less than 85 km. This is achieved by a prolonged coast phase after first stage burn-out and before second stage ignition, resulting in a significant gravity turn of the free-flying second stage and payload. The planned delivery point provides the experiment with a Mach number of 5.5, at an altitude of 75 km. Key technologies for reusable booster systems will be tested by the demonstration of a controlled, autonomous reentry. To increase stability of the reentry body, foldable wings are planned.

Spherical nose of the SPIDER experiment launched in 2016

Return of the spherical nose

For the two missions SPIDER (atmospheric physics, investigation of plasma characteristics within the electronic jet of an Aurora by means of 3D in situ multipoint measurements) and MAIUS (microgravity, first Bose-Einstein-Condensate in Space), a spherical nose cone was used. The bluntness was a means to control the apogee and the center of pressure. Additionally, a better balance of performance and stability could be created, and the bending loads of the vehicle were reduced.

Records in educational programs

MORABA is involved in two different student programs. In the STERN program, students built their own rockets. The REXUS/BEXUS program opens two different research platforms (rockets and balloons) to students from various scientific fields.

STERN – Amateur Hybrid Rocket altitude record

The STERN program (STudentische Experimental-RaketeN) exists since 2010 and addresses all German universities offering courses in aerospace technology. The students develop, build and launch their own rockets (solid, liquid or hybrid) with the support of experienced DLR staff of MORABA, Space Propulsion and Space Administration. The TU Braunschweig launched the first hybrid rocked at Esrange within the experiment FAUST. With the ZEpHyR rocket, ZARM Bremen was able to launch the first paraffin/liquid oxygen sounding rocket in Europe. And finally, the European altitude record of student rockets was achieved in 2016 by the University of Stuttgart with the rocket HEROS 3 (32,3 km).

REXUS/BEXUS – More than 1.000 students participated

The REXUS/BEXUS (Rocket/Balloon Experiments for University Students) 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. Since 2004, MORABA has been involved in 26 REXUS and 27 BEXUS launches. By now, more than 1,000 students participated in these missions, gaining valuable insights and experience while passing through a complete project cycle in a typical spaceflight experiment.

REXUS experiments are launched on an unguided, spin-stabilized single stage 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 90 km. BEXUS experiments are lifted by a balloon with a volume of 12.000 m³ to a maximum altitude of 35 km, depending on total experiment mass (40 - 100 kg). The typical flight duration is 2 - 5 h. The REXUS/BEXUS program is realized under a bilateral Agency Agreement between DLR and the Swedish National Space Agency (SNSA). The Swedish share of the payload has been made available to students from other European countries through collaboration with the European Space Agency (ESA). EuroLaunch, a cooperation of MORABA and Swedish Space Corporation (SSC) is responsible for the campaign management and operations of the launch vehicles. Experts from ESA, SSC and DLR provide technical support to the students teams throughout the project. REXUS and BEXUS are launched from Esrange Space Center.

Exploration

MORABA has introduced its expertise also in the field of exploration during the last five years.

MIRIAM-2

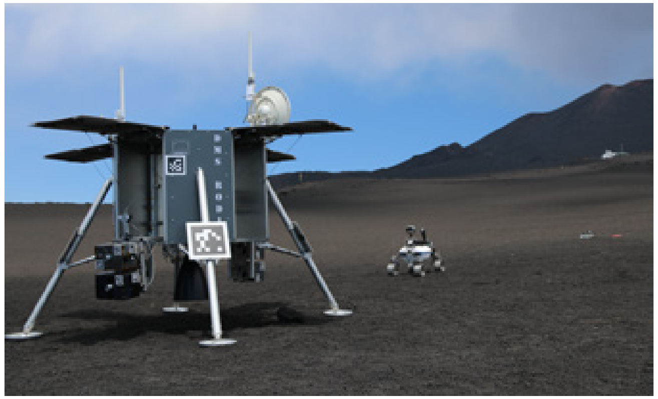
The successor experiment of the MIRIAM mission (launched in 2008) aims at the testing of a reentry balloon for the landing of an ARCHIMEDES Mars probe. In the mission of 2008, the balloon was not inflated completely due to delayed separation between payload and rocket motor. Nevertheless, the complex systems for storage, deployment, inflation and release of the balloon functioned well. The design and concept of the balloon probe shall now be tested by releasing a 4 m diameter balloon including sensor package in an appropriate altitude. The experiment allows to further increase MORABA's expertise in this particular kind of recovery systems and extends the application of sounding rockets to supporting exploration technology development.

CORSAIR

CORSAIR was a proposal for the NASA New Frontiers program and ended in 2018. Out of 12 submitted proposals, CORSAIR was unfortunately not selected, but yielded a high quality mission concept nonetheless, with MORABA extending its capabilities to comet sample return applications. The concept belonged to the Comet Surface Sample Return mission theme which focused on acquiring a macroscopic sample from the surface of a comet nucleus and returning it to Earth. CORSAIR used a harpoon-based Sample Acquisition System with the spacecraft hovering several meters above the comet surface. This stand-off strategy overcomes disadvantages of other systems such as drills. Within the study, MORABA was responsible for the development, testing and numerical analysis of the pyro-driven launcher.

ROBEX – Robotic Exploration

Within the Helmholtz Alliance's project ROBEX, many different research groups and their expertise in space and deep-sea exploration were brought together for the testing of robotic exploration scenarios. During the demonstration mission at Mount Etna in Italy, MORABA set up parts of the simulated ground segment and the entire network infrastructure including a 23 km radio link between the ground segment and the demonstration site on Mount Etna.



Lander (left), rover (center) and base camp (right, background) of the ROBEX demonstration mission on Mount Etna

Permanent programs for diverse scientific areas

There are permanent microgravity programs financed by ESA, DLR Space Administration as well as DLR Program Directorate "Space".

MAPHEUS

MAPHEUS (Materialphysikalische Experimente unter Schwerelosigkeit) is a DLR research rocket program providing microgravity environment to DLR material physics payloads. On an annual basis, a MAPHEUS rocket is launched into space to approximately 250 km altitude. The payload then experiences 6 min of microgravity before it re-enters Earth´s atmosphere. Four MAPHEUS missions have been launched since 2014.

TEXUS

The TEXUS (Technologische Experimente Unter Schwerelosigkeit) sounding rocket program with so far 56 missions was initiated in 1976 by the German Ministry of Research and Development. Beginning with TEXUS launches in 1988, the program was industrialized and Airbus has taken the overall responsibility as the main contractor. MORABA provides essential sounding rocket sub-systems as well as the operation of its mobile ground stations. Six TEXUS missions have been launched on the VSB-30 rocket developed by IAE (Instituto de Aeronaútica e Espaço, Brasil) and MORABA since 2014.

MASER

MASER is an SNSA sounding rocket program with participation of international industry and science community. MORABA provides essential sounding rocket sub-systems as well as the operation of its mobile ground stations. Since 2014 two missions were launched on VSB-30 rockets.

MAXUS

The MAXUS long-duration and heavy payload microgravity program was a joint venture between Airbus and SSC (Swedish Space Corporation).It was initiated in 1990 to extend the microgravity duration capability in Europe to 13 min. With the launch of MAXUS 9 in 2017, the last available Castor-4B rocket motor for typical payload masses of 800 kg to reach an apogee of more than 700 km was used. Currently, no solid rocket motors in this class are available.

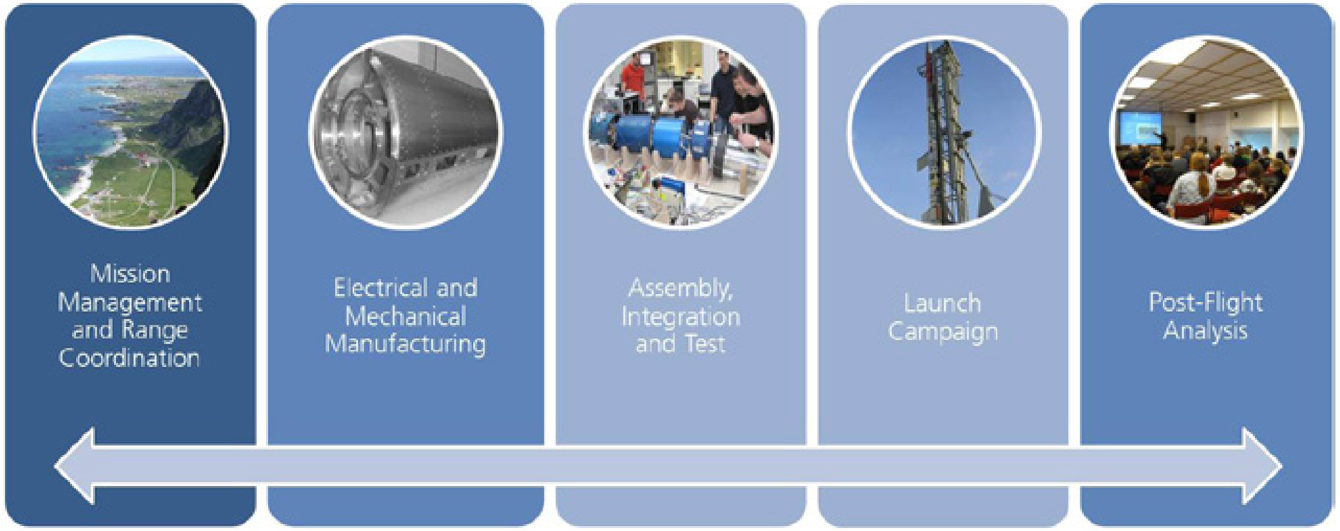
Modular Services

End-to-end service for the research community

A suborbital flight mission requires a broad variety of tasks to be completed in preparation and conduct of the launch mission itself, all culminating in the ignition of the first stage rocket motor. A post-flight report summarizes the main flight characteristics and performances – it is generally the last deliverable to the user.

Dependent on the experimenter's needs, MORABA is either taking over parts of a mission or is responsible for the planning and conduct of the entire mission in an approach called "flight ticket". The MAIUS project is an example where MORABA's responsibility extended to the mission management and range coordination, the electrical and mechanical manufacturing of all systems for the launch vehicle and payload support systems as well as the assembly, integration and all tests in advance to the launch campaign. Finally, the launch campaign and post-flight analysis of the sounding rocket platform was in MORABA hands.

For the TEXUS program for example, industry is responsible for mission management and all payload-related systems and MORABA acts as a subcontractor for launch service, tests, recovery- and service-system and post-flight analysis. MORABA therefore adapts its services to the requirements of the partners and customers and offers support in all parts concerning the launch vehicle, but is also available to provide services with a clear interface that is limited to the launch vehicle only. MORABA is not however acting as a reseller of systems or rocket motors. Launches are conducted as a service which utilizes rocket motor systems owned by MORABA and spent in the service effort.



MORABA End-to-End Service for clients and partners in a flight ticket approach

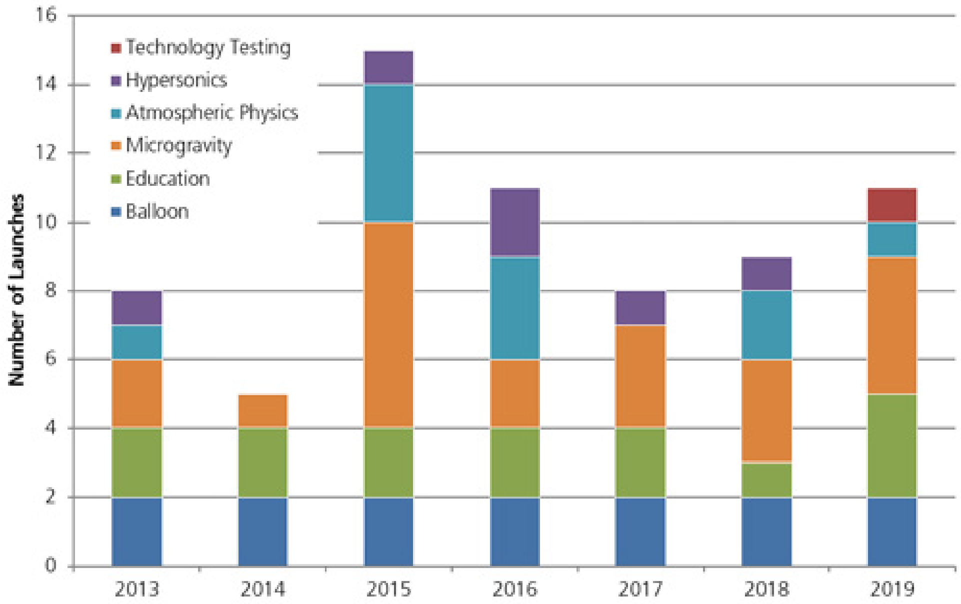
Evolution of services by broadening the field of applications

MORABA is an enabler for suborbital flights for a large variety of research fields. MORABA actively explores new areas of applications in order to broaden the user and customer base.

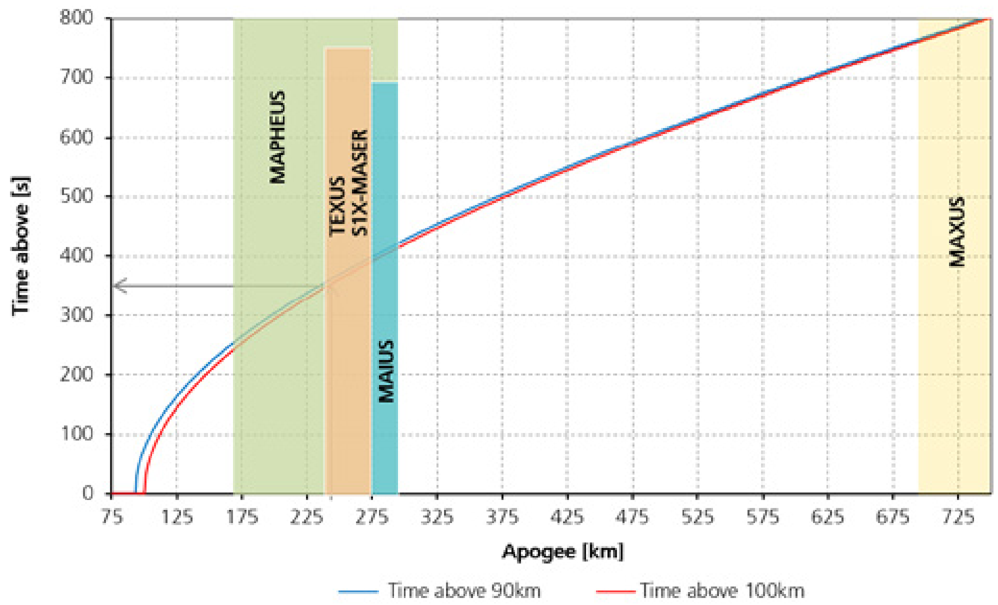
The first missions in the sixties were in the field of Astronomy to study solar eclipse. However, earth-based and balloon-borne telescopes improved and allowed longer observation times and at the same time satellite based observatories came into operation, so that European sounding rocket based astronomical research disappeared over the years. Atmospheric physics is another research field for which sounding rockets are continuing to be a valuable research platform since the early days. Stratospheric balloons are used for measurements in altitudes up to 40 km. As a supplement, sounding rockets can perform in-situ measurements in the higher atmosphere up to several hundreds of kilometers to investigate for example dust and ion particles, the composition of the atmosphere and its interaction with the solar wind and the magnetic field. Physical or biological experiments in Earth-based laboratories can generally only be conducted under the influence of gravitational acceleration. Some experiments however aim at the investigation of phenomena that are heavily influenced or masked by this gravitational acceleration. In the field of material physics for example, various processes in metallic alloys involve interactions on an atomic scale that cannot be observed on ground due to that reason. High-quality results can thus be obtained on suborbital parabolic trajectories providing experimental time in microgravity for up to 13 minutes. Due to the current lack of availability of solid rocket motors in the class of >10 to (MAXUS class), long-duration microgravity missions cannot be supported at present, but 6 minutes of microgravity are standard for current missions, utilizing the Brazilian made VSB-30 vehicle.

With the launch of the two SHEFEX experiments in 2005 and 2012, the new field of hypersonics was introduced at MORABA. The interest in sounding rockets as a test bed for hypersonic research and technology testing, for example supporting the development of aerothermal protection systems, is increasing permanently. The demanding experiment's goals result in complex flight experiments which expand the previous operational bounds of sounding rockets. In contrast to ground based hypersonic wind tunnels where a finite mass of a test gas is heavily processed in order to achieve testing times of a few milliseconds, sounding rocket based "flying wind tunnels" can provide experiment times of one minute in excess of Mach 10 at real aerothermodynamic conditions for relatively large experiments. This application requires new classes of vehicles and sub systems which are not readily available commercially as well as innovative approaches to vehicle, payload, trajectory and mission design and control. Competences that have been gained within these ambitious missions in the field of hypersonics and technology testing are now used for the development of a microlauncher for orbital assets. The VLM-1 microlauncher, which is currently developed in cooperation between DLR Stuttgart, Braunschweig and Oberpfaffenhofen together with DCTA/IAE and AviBras in Brazil will comprise a 3-staged vehicle consisting of two S-50 solid motors and a solid upper stage (S44). The use of these rocket motors in a 2-staged version (S-50/S44) introduces the highly performant suborbital launch vehicle VS-50. This vehicle will be suitable for large payload mass and very high apogee and is even more powerful than the MAXUS motor. It will therefore not only close the current gap for long microgravity exposition times, but is also offering observation times of around 30 minutes to the research field of astronomy. It is expected that this capability will generate renewed interest in sounding rocket based astronomy in Europe and also enable cooperation with US based researchers of that field. Used as a powerful carrier for hypersonic experiments, the VS-50 is also a valuable test bed for reentry- and reusability-scenarios. The VLM-1 carrier finally could be used for orbital assets to be operated, e.g. by DLR, GSOC.

Number of launches per research field supported by MORABA since 2013



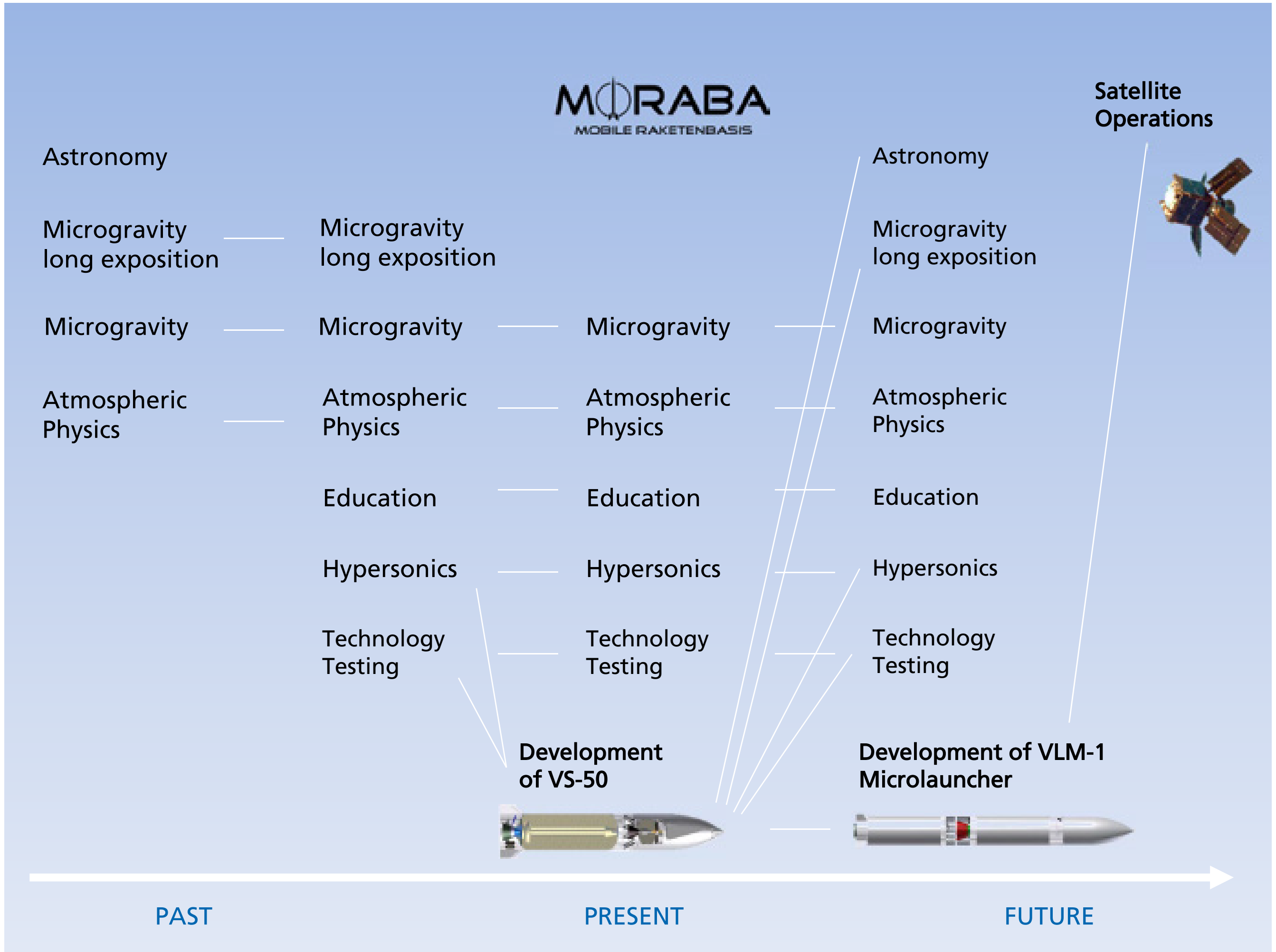
Achievable microgravity time vs. apogee altitude of different sounding rocket microgravity programs



Since the early years of the current millennium, MORABA is strongly involved in student education programs. The REXUS/BEXUS and STERN programs are not only a valuable contribution in many students´ preparation to their professional career in space-flight industry, but are also an important source for DLR to recruit enthusiastic young staff. Supporting all the diverse research fields, MORABA represents a competence center for suborbital space-flight in Germany and Europe.

Commercially independent advisor for governmental institutions

MORABA has been introducing its expertise in suborbital flights into studies for various national and international governmental institutions recently. Commercially independent, MORABA is providing advice and evaluation in the field of responsive space capabilities or hypersonic threats.



Evolution of research fields

Ground Infrastructure

The mobile infrastructure of MORABA allows worldwide setup and thus support of sounding rocket, balloon and satellite missions even at remote locations. As a consequence, already during the early design phase of the various stations special attention was paid to mobility and suitability for the extreme environmental conditions encountered at the potential launching sites, such as extreme temperatures or salt water.

Telemetry and Telecommand

MORABA maintains and operates a fully containerized mobile telemetry, tracking and telecommand station in the S-band frequency spectrum. The station which was designed by MORABA is composed of CSC standard ISO containers and as such can be set up around the globe with minimal requirements on the site. The 1.5 m Secondary Antenna can be stowed in boxes and used as an acquisition aid antenna together with the 5 m Primary Antenna, or as an independent and highly flexible receiving station. The Antenna Pedestals are designed for high angular velocities and accelerations in order to maintain a reliable tracking for the highly dynamic sounding rocket vehicles. The control station is equipped to simultaneously receive, record and support several Telemetry and TV streams with various modulation schemes. It is self-contained and adaptable to a variety of configurations.

Above: Mobile S-band TM Station with two antenna dishes (5 m and 1.5 m radius)

Below: Mobile C-band Tracking Radar (RIR-774C)

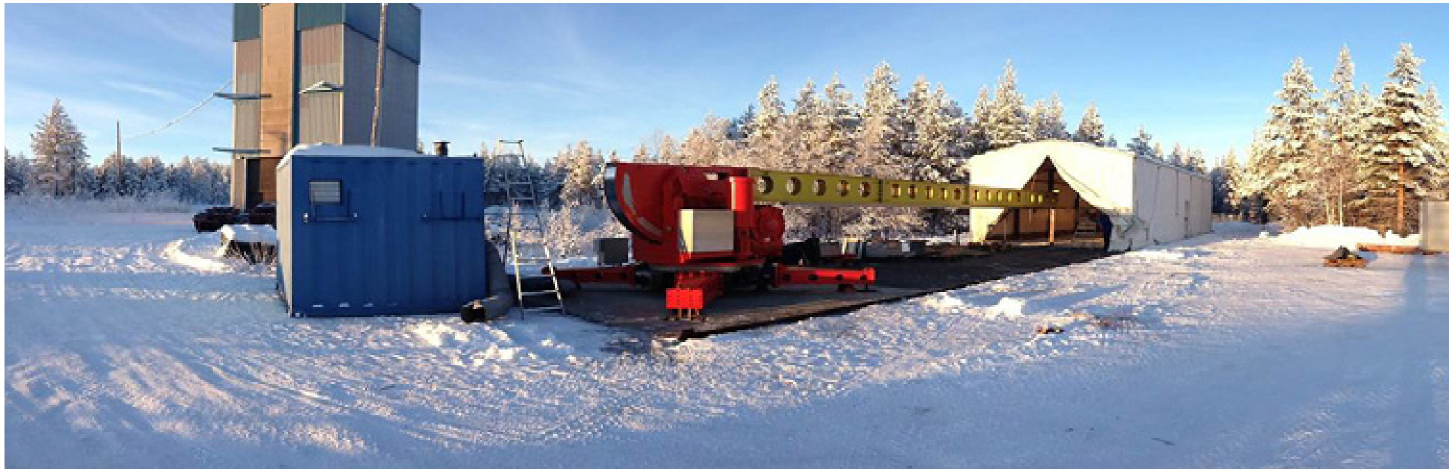
Mobile Tracking Radar

Accurate position determination of sounding rockets and balloons in flight is mandated by flight safety regulations and often also by scientific requirements. MORABA determines position through TM slant-range data and the GPS position data telemetered to ground from the rocket, but in addition operates a fully independent position tracking source, a mobile instrumentation tracking Radar (RIR-774c).

This radar operates in the C-band frequency range and allows independent, redundant and precise trajectory determination for scientific and safety related purposes, with and without transponders aboard the flight vehicle. 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 crucial, for example in case of flight deviations from the nominal trajectory, when a range-safety officer must come to a decision on the termination of a flight by sending the self-destruction signal to the rocket. 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. By the end of 2019, a major upgrade of the main computer will be conducted, allowing higher data output rates.

Monorail Launcher

The mobile sounding rocket launcher system of MORABA (MAN II) allows fully independent launch operations at remote locations. The 13 m rail length of the monorail launcher, maintained and operated for rocket vehicles with a mass up to 3 t, is remotely controlled from the launch control room. Final adjustments can be made during countdown as late as ten minutes prior to launch, when final wind weighting measurements are extrapolated into trajectory predictions. For weather and wind protection during the preparation phase, the launcher can be covered by a tent which is movable on railway tracks.



Mobile launcher with movable tent

Capability Development

Microsatellite launcher VLM-1 (under development)

MORABA employs an evolutionary development strategy in order to develop its competences and capabilities while keeping mission risk at an acceptable level. Safety is compromised under no circumstances and every new flight item is scrutinized for its function and possible impact on flight safety. The idea to evolve developments in small steps rather than in big chunks results in relatively foreseeable changes in flight performance as well as flight profile, both determining directly mission and safety risk. Thus, changes to fin structures for instance are introduced in small steps, i.e. the leading edge is changed in one flight and only in subsequent flights further modifications such as the thermal protection on the fin blade are added. Instrumentation, often in collaboration with other DLR departments (BT-RSI, AS-HYP), allows the identification of advantages of individual technologies and allows thorough assessment of the performance in flight.

This approach is taken in all subsystems that are under MORABA control and especially those that are related to rocket motor or payload support systems. Higher mission risk is deemed acceptable for experimental payloads when compared to rocket motor and payload support systems, due to the fact that the latter are considered a service to the experiment.

The demonstrated increase in capabilities, such as suppressed trajectories or improved recovery systems, subsequently allows a broader portfolio to be offered to the science community and the utilization of sounding rockets by a wider range of scientific disciplines. Unguided sounding rockets are presently blurring the boundaries between the classic unguided systems and capabilities that would be traditionally addressed only by guided and much more costly systems. It is MORABA's strategy to leverage the advantages of cost efficient sounding rockets with the addition of carefully selected technology options to enhance the sounding rocket use case to those that would not be generally reachable. One example of this shall be the mission STORT where a very low apogee trajectory shall be flown and good accuracy is required in order to meet the science requirements. Another example is the microlauncher VLM-1, a joint development between the Brazilian DCTA and AEB with DLR, where the experience and technologies of sounding rockets are employed to construct an orbital launch system. This approach from the lower end into the orbital market is thought to generate simpler and thus more cost efficient solutions when compared to the downsizing of established orbital launcher technologies.

VS-50 – Microlauncher VLM-1

The goal of the German-Brazilian collaboration VS-50 / VLM-1 is the development of the VS-50 launch vehicle, suitable for hypersonic aerothermodynamics, re-entry and reusability research utilising scaled experiment vehicles of up to 1.3 m diameter. It can also be used as replacement for the MAXUS motor for heavy payloads on µg research missions. Ultimately, the VS-50 vehicle will be further developed into the VLM-1 microsatellite launcher capable of delivering payloads of 50 to 150 kg into orbit.

Currently, Brazil develops the high-performance rocket motor S50 together with AviBras. DLR is responsible for most structures and electronics as well as guidance, navigation and control. The rocket motor consists of a carbon fiber composite case (~ 1.5 m diameter) and 13 t of ITAR free solid propellant.

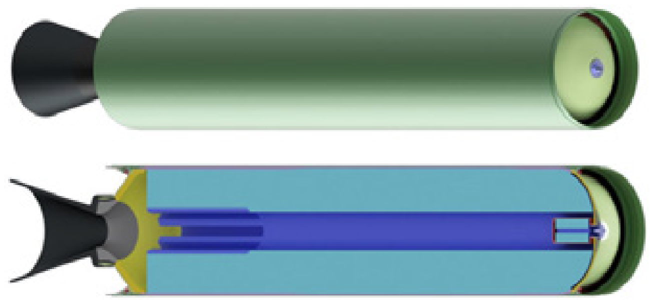
Development of solid as well as gel-based rocket motors with Bayern-Chemie GmbH

Within a study with Bayern-Chemie GmbH, the joint development of gel-based as well as solid rocket motors was evaluated. The study resulted in the assessment that the energy density of hybrid and gel based rocket motors was insufficient to replace the existing solid propellant based systems for the standard microgravity mission. Their increased size resulting from the lower power density means that these approaches are not compatible with existing ground systems. The solid rocket motor was expedited to a concept within a feasibility study.

A preliminary design of a particular solid rocket motor was performed. Due to the thrust profile, it can be used as first or second stage of a two-stage vehicle with a similar performance as the VSB-30 and mechanically compatible to latter motor systems. The development of the rocket motor takes approximately three years. Steps have been taken in order to undertake this joint development from 2019 onwards.

By developing rocket motors within Germany, the design can be influenced much more easily than if the motors were directly purchased. MORABA will take an active part in the development process and further DLR institutes are invited to verify numerical tools such as the coupled numerical solver AHRES for the internal ballistics of solid rocket motors.

The gel-based rocket motor concept was subsequently taken to concept level for a small upper stage for atmospheric physics sounding rockets. The technology would allow the throttling of thrust and thus in principle the hovering of the vehicle in a certain location or altitude. For atmospheric physics, it could be of interest to hover in a particular altitude in order to measure the spatial distribution of particles, ions and atmospheric composition. This can become possible with such technology and in altitudes where no lifting or floating body can fly.



Solid propellant stage preliminary design

Imprint

Publisher
Deutsches Zentrum für Luft und Raumfahrt e.V.
German Aerospace Center
Space Operations and Astronaut Training
Mobile Rocket Base

Address
Münchener Str. 20, 82234 Weßling
Telefon + 49 8153 28-2701

MORABA.de

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag