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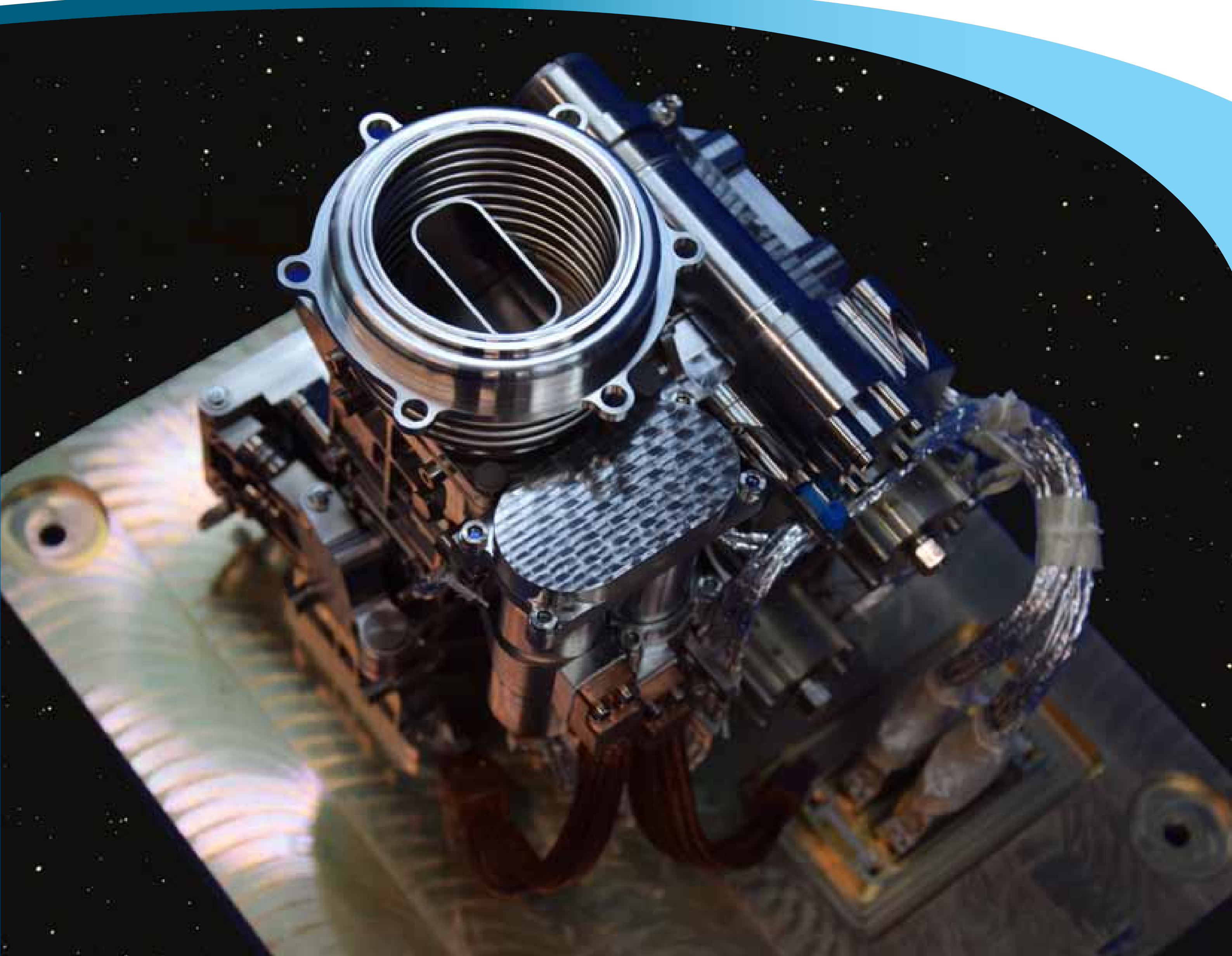


SPACE SYSTEMS

ROBOTICS AND MECHATRONICS

ROBOTICS AND MECHATRONICS
INTRODUCTION

OHB System AG is one of the leading independent forces in the European space business. We are developing and manufacturing some of the key space missions of our times such as the Galileo navigation satellites, the SARah reconnaissance system, the MTG meteorological satellites, the EnMAP environment satellite, the TET-1 technology demonstration mission and the Hispasat 36W-1, ELECTRA and EDRS-C telecommunication satellites.

OHB traditionally combines in-house technologies with current developments of leading national and international institutions and companies to commonly develop new solutions for its customers. Among those, high-precision robotic and mechatronic systems represent key units of present and future space missions, not only for Earth observation, navigation and telecommunications, but also for challenging planetary exploration and space science missions.

OHB has been engaged in the development of high-precision robotic and mechatronic systems since more than two decades and has built up strong expertise in the design and development of:

- high-precision mechanisms and integrated mechatronic systems for optical instruments
- robotic systems for planetary exploration
- payloads and systems for orbital servicing and de-orbiting.

The company experience in these activities is covering different roles:

- acting as Prime Contractor (at system or payload level), i.e. generating the requirements specification documents and managing/supervising the design, development and validation of space systems performed under sub-contract
- acting as Supplier, i.e. receiving the requirements specifications from its customers and designing, developing and validating space systems accordingly in-house.

OHB has recently established a company-wide robotics working group to define an internal roadmap for development of robotic technologies for planetary exploration, orbital servicing and de-orbiting which covers OHB in Germany and all European OHB sister companies. All OHB activities in the field of space robotics are coordinated by this group.

ROBOTICS AND MECHATRONICS
KEY COMPETENCES

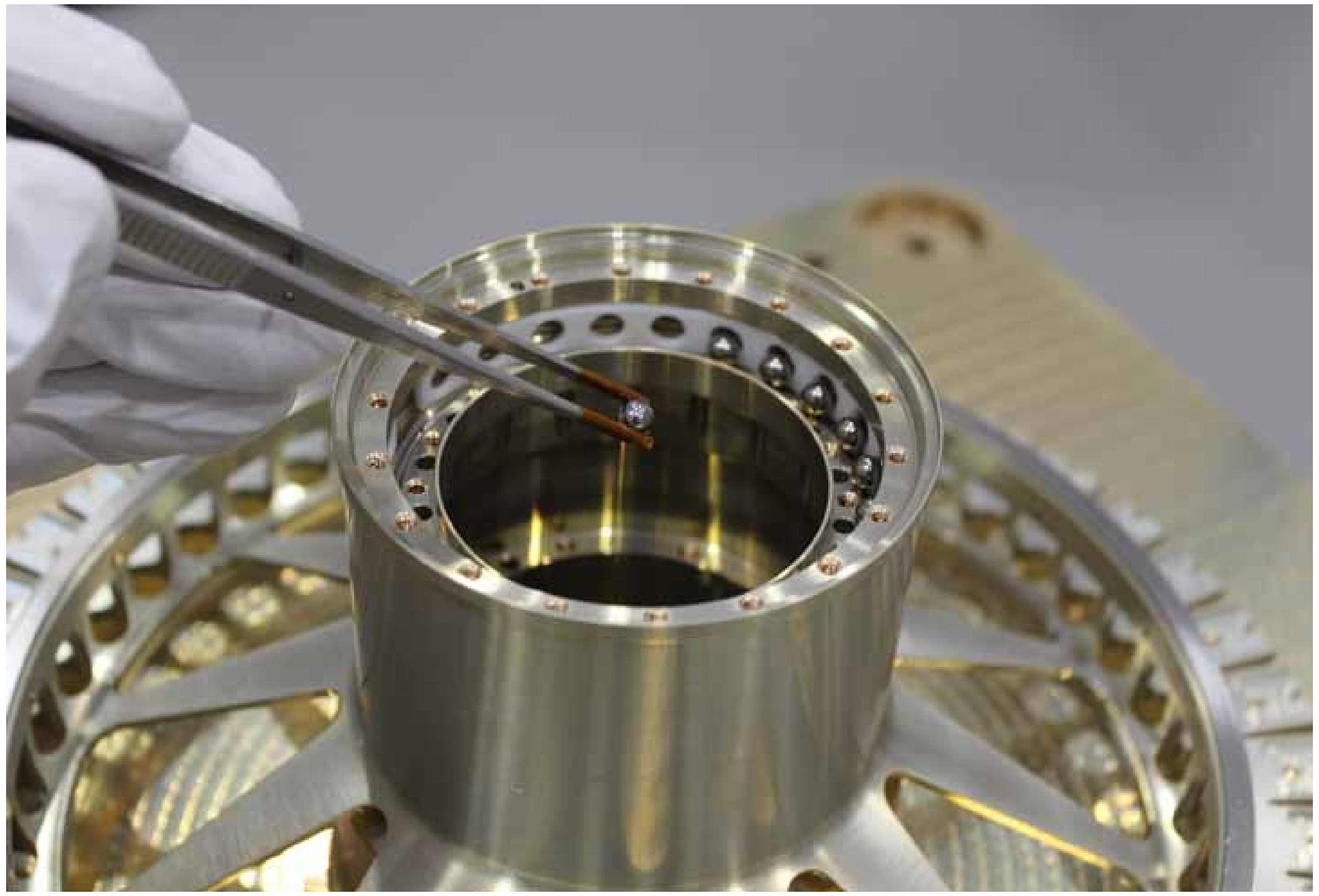
OHB's ambition is to maintain and further promote the company's position as one of the leading European players in robotics and mechatronics, and to serve as a reliable provider of integrated mechatronic systems and payloads. The key competences of OHB are therefore:

- in-house design and development of mechatronic and robotic systems including control systems and algorithms
- contribution to systems engineering and design at unit, instrument, payload and satellite level, based on a profound understanding of the mission objectives, requirements and system architectures
- system engineering and technical management of mechatronic sub-systems and equipments developed in-house
- management of sub-contractors for robotic and mechatronic systems in all technical matters
- competence and service center for all mechanical manufacturing processes
- production engineering, manufacturing and finishing planning as well as material flow management covering all steps performed by OHB's own workshop and by external manufacturing partners.

OHB is actively taking part in the discussions with ESA and DLR, the scientific community and various commercial customers to identify technology needs for future missions. Robotic and mechatronic technology development programs are planned and pursued in collaboration with partners in industry and academia, with a focus on:

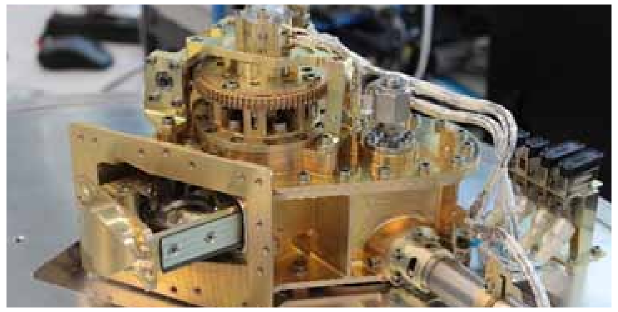
- high-precision mechanisms and control systems for next-generation optical instruments and payloads for Earth observation, astronomy and science
- precision tools and orbital robotic systems, e.g. for capturing of and docking to cooperative and non-cooperative targets in orbit
- in-orbit robotized assembly of (very) large structures and telescopes
- advanced systems for planetary exploration, e.g. for autonomous mobility as well as sample acquisition and processing
- payload and satellite automation.

Based on two decades of heritage and the broad experience and excellence of its high-qualified staff, OHB is able to define and develop each of the above mechatronic space systems in-house.



ROBOTICS AND MECHATRONICS
ROBOTIC SYSTEMS FOR PLANETARY EXPLORATION

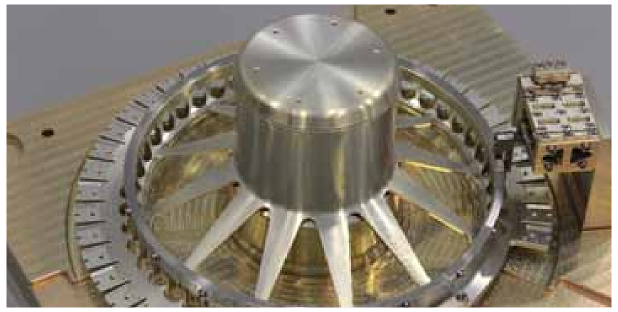
Sample Acquisition, Handling and Processing Systems



The ExoMars rover, which is a key element of ESA's ExoMars 2020 mission to Mars, is equipped with a central science laboratory („Pasteur") for the autonomous analysis of Mars soil samples. The samples are drilled from the Mars soil down to 2 m below surface and fed autonomously into the ultra-clean zone of the rover lab by the SPDS (Sample Preparation and Distribution System). OHB designed and developed the complete SPDS, which consists of four different sub-units that interact with each other:

(1) the Core Sample Handling System (CSHS) which accepts the samples discharged from the drill and forwards them – exploiting Mars gravity – to the subsequent CS mechanism;

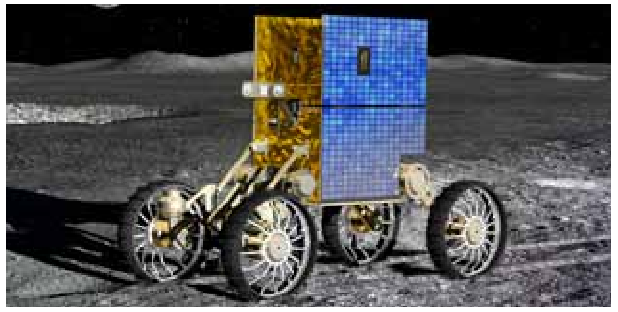
(2) the Crushing Station (CS), operating as a jaw crusher to comminute granular and massive samples to smaller grain sizes and to powder as required by the Pasteur science instruments;



(3) the Powdered Sample Dosing and Distribution System (PSDDS, not shown), positioned below the CS and receiving the sample powder falling out of the CS. The powder is dosed by the PSDDS dosing mechanisms and thus dispensed into sample receptacles located below the PSDDS;

(4) the Powdered Sample Handling System (PSHS), which essentially is a carousel-type wheel carrying a number of ovens for thermal and chemical processing of the powder samples as well as a 'refillable container' to present a larger amount of sample powder to several other science instruments inside Pasteur.

Advanced Mobility Systems



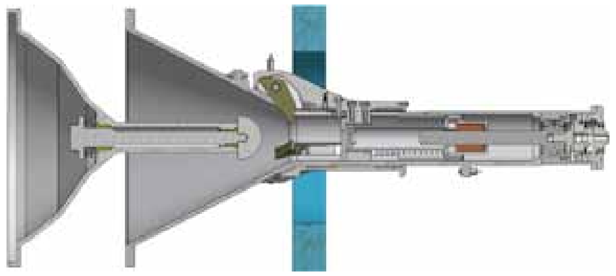
Under contract of the German Space Agency OHB has carried out a feasibility study of a sample fetching rover called MPE for the planned Lunar Lander Mission, in collaboration with Von Hoerner & Sulger GmbH and the DLR Centre for Robotics and Mechatronics.

The MPE rover has four wheels with active suspension and can be tele-operated or can navigate autonomously. It is able to actively adapt each single wheel to the surface. All subsystems and payloads are grouped around a central body, which provides the thermal, mechanical and electrical interfaces to the landing vehicle.

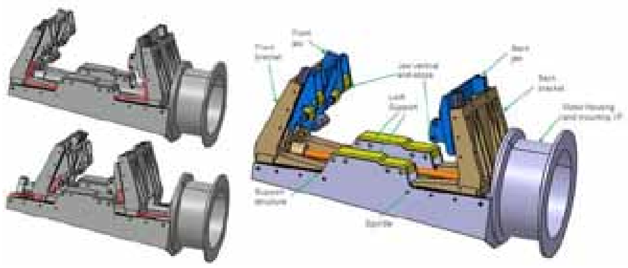
The ExoMars CSHS is developed in collaboration with HTS GmbH, Coswig.

ROBOTICS AND MECHATRONICS
CONCEPTS AND PRODUCTS FOR ORBITAL ROBOTIC SYSTEMS

Gripping and Docking Systems



A high potential is seen in future robotic servicing missions to (a) extent the functionality of existing satellites beyond their originally envisaged lifetime and (b) assemble very large space systems, e.g. deep-space telescopes for astronomy or planetary exploration. Another important application is seen in the collection and reduction of space debris, up to active de-orbiting of LEO satellites which failed or reached the end of their lifetime. OHB is strongly involved both in mission studies in these fields and the development of the required robotic systems.



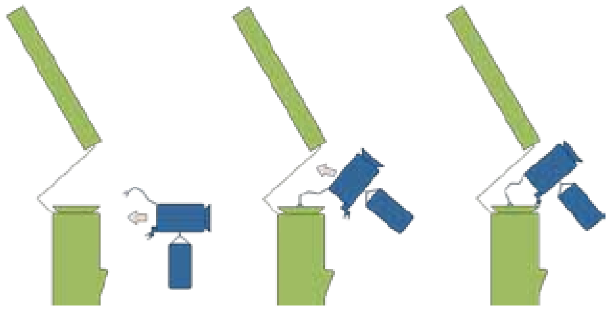
For different types of gripping and docking systems, OHB design concepts are available for the most relevant components:

- a Gripper Mechanism used as end-effector of a robotic arm to capture cooperative or non-cooperative satellites. The gripper is designed to compensate an initial angular and position misalignment (±5deg / ±20mm) and is self-adapting to the geometry of the launch adapter ring of the target satellite. It requires only one actuated degree of freedom (spindle drive)
- a Berthing and Docking System to establish and maintain a strong and stable connection to the target satellite during servicing and de-orbiting.

Robotic Arms

The ROKVISS robotic arm, developed by an industrial team led by OHB, was installed on the outer shell of the International Space Station (ISS) end of 2004 and was operated there flawlessly for more than three years. The ROKVISS components successfully used and validated in this project are today forming the basis for OHB's robotic and mechatronic systems which are will be used for maintenance and repair tasks within manned and un-manned space applications.

Deorbiting Systems

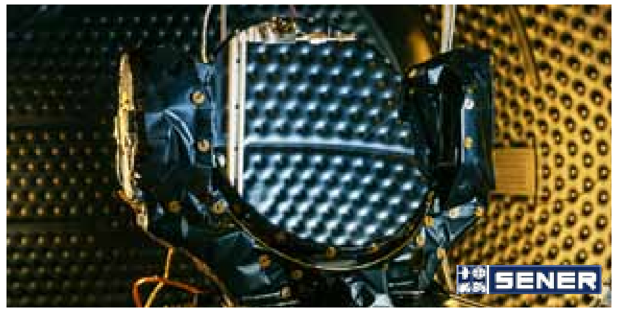


For active de-orbiting of unusable satellites, safe and reliable capture technologies have to be designed. A planned mission is e.Deorbit whose objective is to remove ESA's ENVISAT satellite from the LEO protected zone. During the e.Deorbit Phase A and subsequent Phase B1 studies led by OHB, various mission options and concepts have been traded. The conclusion is a dedicated de-orbit maneuver sequence with a rigidly connected target using the launch adapter ring of ENVISAT for both mission challenges, the safe capturing and the rigid connection.

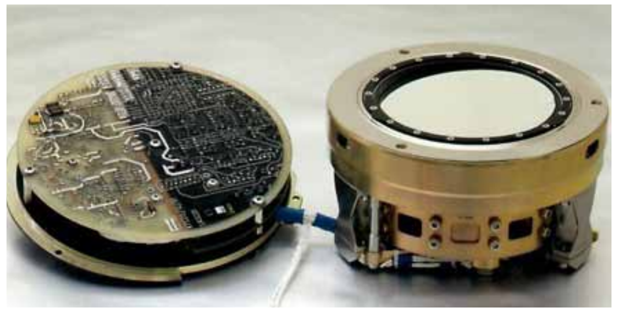
ROBOTICS AND MECHATRONICS
HIGH-PRECISION MECHANISMS FOR OPTICAL INSTRUMENTS

One of OHB's main business areas is the development of optical instruments for Earth observation and astronomy. These usually require reliable high-precision mechanisms like steerable mirrors, scanners, focus mechanisms and filter wheels. As they are of key importance for the end-to-end performance of the instruments, OHB has built up particular competences in the development of such mechanisms, including full numeric modelling and simulation of all electro-mechanical components and control systems.

Steerable Mirrors and Scanners



The next generation of weather forecast and Earth observation instruments, which will be launched with the Meteosat Third Generation (MTG) satellites starting in 2020, requires ultra-high precision scanners to cover the European landmass with adequate spatial resolution. The MTG Scanner Subsystem is developed by Sener, Spain, under OHB subcontract and in close collaboration with OHB's mechanism specialists, for a total of more than 10^6 operation cycles in orbit and an absolute pointing accuracy of less than 100 µrad. The scanner is one of the key elements driving the performance of the MTG instruments.

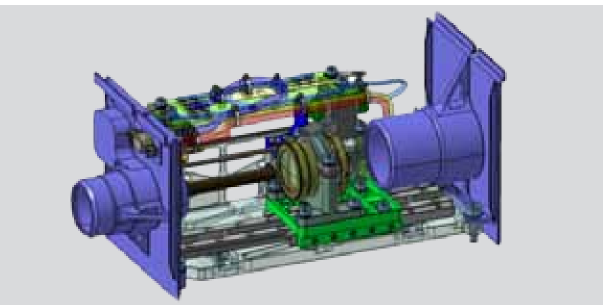


A high precision two-axis steering mirror mechanism has been developed by OHB for the LASCO coronagraph flown on the ESA/NASA mission SOHO. The primary mirror is mounted on a 'quasi-cardanic' mechanism such that it can be tilted in each direction by 1 arcmin at an accuracy of 5.6 arcsec, allowing for correction of potential mispointing of the telescope as well as for dynamic imaging, which results in significant improvement of the instrument's spatial resolution.

Filter and Calibration Wheels

OHB's generic Filter Wheel mechanism design, originally developed for the PACS instrument on ESA's Herschel mission, can accommodate up to five different filters and has been qualified for up to 40.000 operation cycles in a temperature range between 1 and 350 K. The multi-functional EnMAP Shutter and Calibration Mechanism is derived from this generic design and developed by HTS GmbH under OHB subcontract. With an accuracy of 5 arcmin, it combines the functions of instrument calibration and shutting/clearing of the light path in a temperature range between 270 and 317 K.

Linear Focus Mechanisms



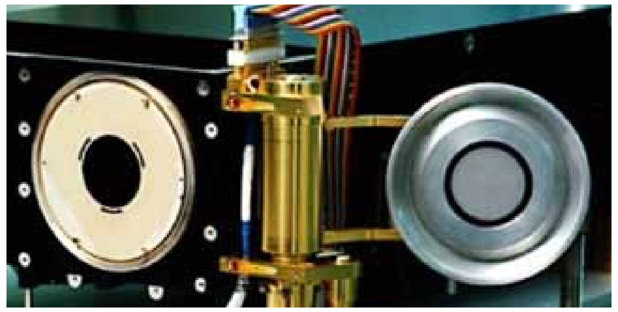
Linear focus mechanisms are required for different purposes in cameras and optical instruments. OHB has developed a linear focus drive for the High-Resolution Camera on the Mars rover of the ExoMars 2020 mission. This mechanism provides a linear resolution of less than 1 µm. It is controlled in closed-loop based on algorithms evaluating real-time camera data, using a controller developed by OHB's partner, the DLR institute of Planetary Research in Berlin.

EnMAP is developed by OHB on behalf of the German Space Agency DLR with funds of the German Federal Ministry of Economic Affairs and Technology under grant No. 50 EP 0801.

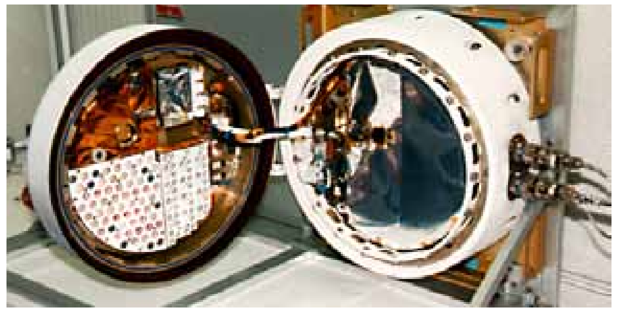
ROBOTICS AND MECHATRONICS
SHUTTERS, COVERS AND DEPLOYMENT MECHANISMS

OHB has several scalable design concepts available for release and deployment mechanisms for different applications, such as instrument covers, deployable sunshields or deployable booms for scientific instruments. Either realized as in-house development directly for our customers, or as sub-contract given to one of our European mechanism technology partners, OHB is in a position to serve many technology requests even for sometimes exotic challenges in terms of robustness, precision or reliability.

Motorized Covers for multiple operations

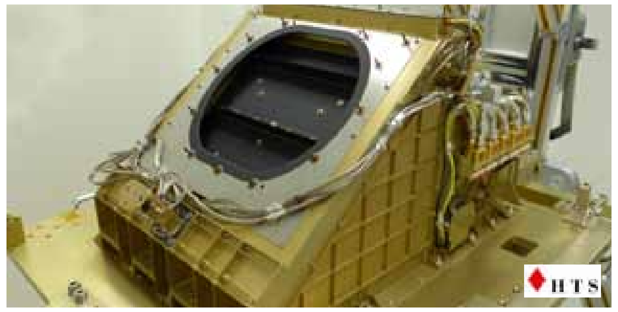


Release and deployment mechanisms for multiple operations at regular intervals or upon dedicated telecommand are used to seal space instruments against contamination during storage and launch. In a typical configuration, as developed by OHB for the LASCO instrument on ESA's SOHO mission, opening and closing of the instrument aperture is performed by a gearmotor-driven mechanism designed for at least 1000 operations. In parallel, a 'one-shot' mechanism is implemented to ensure fail-safe operation of the instrument.



Another use case for OHB's cover mechanisms is evident in exposure facilities which are used for performing biological experiments in orbit. Under contracts to ESA and DLR, OHB has built the Biopan multi-purpose exposure facility which has been successfully flown in three multi-week missions with Russian re-entry capsules, and the EXPOSE multi-user exposure facility, which has been installed on the ISS Ceta platform. Both have dedicated cover mechanisms implemented, designed and built by OHB.

Full Aperture Diffuser Assemblies



The Full Aperture Diffuser Assembly (FADA) is a two-degree-of-freedom mechanism positioned at the aperture of the EnMAP instrument. It is fully redundant and comprises a Launch Lock and a Fail Safe Mechanism. It closes the instrument during launch and is opened in orbit allowing entrance of the observed light as reflected from the Earth's surface as well as from the sun for calibration of the instrument. The mechanism has a pointing capability of 4 to 5 arcmin and a very high reliability of 0.999969.

Deployable Booms and Structures

Standard design concepts for different types of deployment mechanisms for booms and complex structures have been established and verified by OHB in several breadboard programs, e.g.

- a standard design for a self-latching hinge for deployable stiff booms
- a mechanism concept for deployment of a 100 m^2 solar sail, based on un-rolling of four flat CFRP shells to form circular-shaped stiff booms by assuming the original shape and thus creating a stiff square structure after un-rolling.

The EnMAP FADA Mechanism is developed by HTS GmbH, Coswig, under OHB subcontract.

Production Engineering and Mechanisms Laboratories

Part of the robotics and mechantronics infrastructure at OHB's Centre for Optics and Science in Oberpfaffenhofen near Munich are the production engineering and the mechanisms laboratories. All labs are equipped with appropriate fittings and devices, such as safety workbenches, extractors, test benches, thermal ovens, etc. The labs are used for preparatory work or specific follow-up examinations that cannot otherwise be performed during the normal integration work in the main ISO 5 area of the centre or that would interfere with the integration work carried out there.

For this reason, the laboratories are also fitted with all necessary technical equipment, such as ESD floors, access control, air-conditioning, nitrogen supply, and emergency power. Some of them are themselves equipped to comply with ISO8 or ISO5. Including further labs for e.g. electronics or thermal-vacuum testing, the laboratory area extends on the second floor of the centre to over 550 m². In addition, the optics laboratory located separately on the ground floor with 100 m² and the analysis laboratories for specifying purity levels measuring 50 m² in total complete the lab infrastructure in Oberpfaffenhofen.

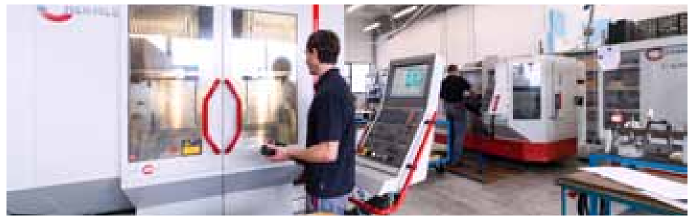
Mechanical Production

The mechanical production area is located about 3 km away in the industrial estate of the neighbouring district of Gilching. Here, a number of automatic 5-axis CNC milling machines along with conventional milling machines are housed in an area of approximately 500 m². The mechanical production area also has different lathes and box column drills in addition to a lapping machine and a Trouvaille cutting machine. The range of machinery is further extended by a high-precision CMM measuring machine to give a total count of about 15 machines.

An additional precise CMM measuring machine clean to ISO 5 conditions is installed in the main ISO 5 integration area in Oberpfaffenhofen. Different storehouse rooms for unfinished and finished products, along with a machine control room, complete OHB's mechanical production facilities in Gilching.

Structural parts for use in a space environment are generally made of high-quality aluminium or titanium. The CAD designs developed and released in the design department located in OHB's main building are transferred directly to the CNC machines in the mechanical production by electronic data link, where the parts are milled and finished within a short time. Additionally for early breadboarding a 3D printing machine is available. In accordance with the requirements of the products to be manufactured, all space structures and structural parts are produced, measured and delivered ready for flight in sizes of up to 0.5 m x 0.5 m x 0.3 m.

In the final stage, the parts are provided back to the integration area in the main building, if no further processing or finishing steps, such as surface treatment, hardening, coating, etc., have to be carried out elsewhere.



ADVANCED SIMULATION OF SPACE MECHANISMS

Model Based Engineering and Systems Engineering

Model-based Engineering (MBE) and Model-based Systems Engineering methods (MBSE) are part of OHB's robotics know-how and are implemented either in specific tasks or in a complete project. The main reasons are that any mechatronic system, like a high precision space mechanism or a robotic arm, has to accomplish multidisciplinary functions under severe environments, and that various engineering disciplines are involved simultaneously in the design and development phase: mechanical, structural, electrical, software and control.

Numerical models are created to deal with complexity, allowing engineers to understand an area of concern and provide unambiguous communication among all technical disciplines.

The relationships reflected by a generic purpose modeling language (e.g. SysML) are mathematically represented by matrices (Design Structure Matrix, Design Mapping Matrix), which are used to execute trade-offs based on the number and type of dependencies (e.g. the less the better for a project).

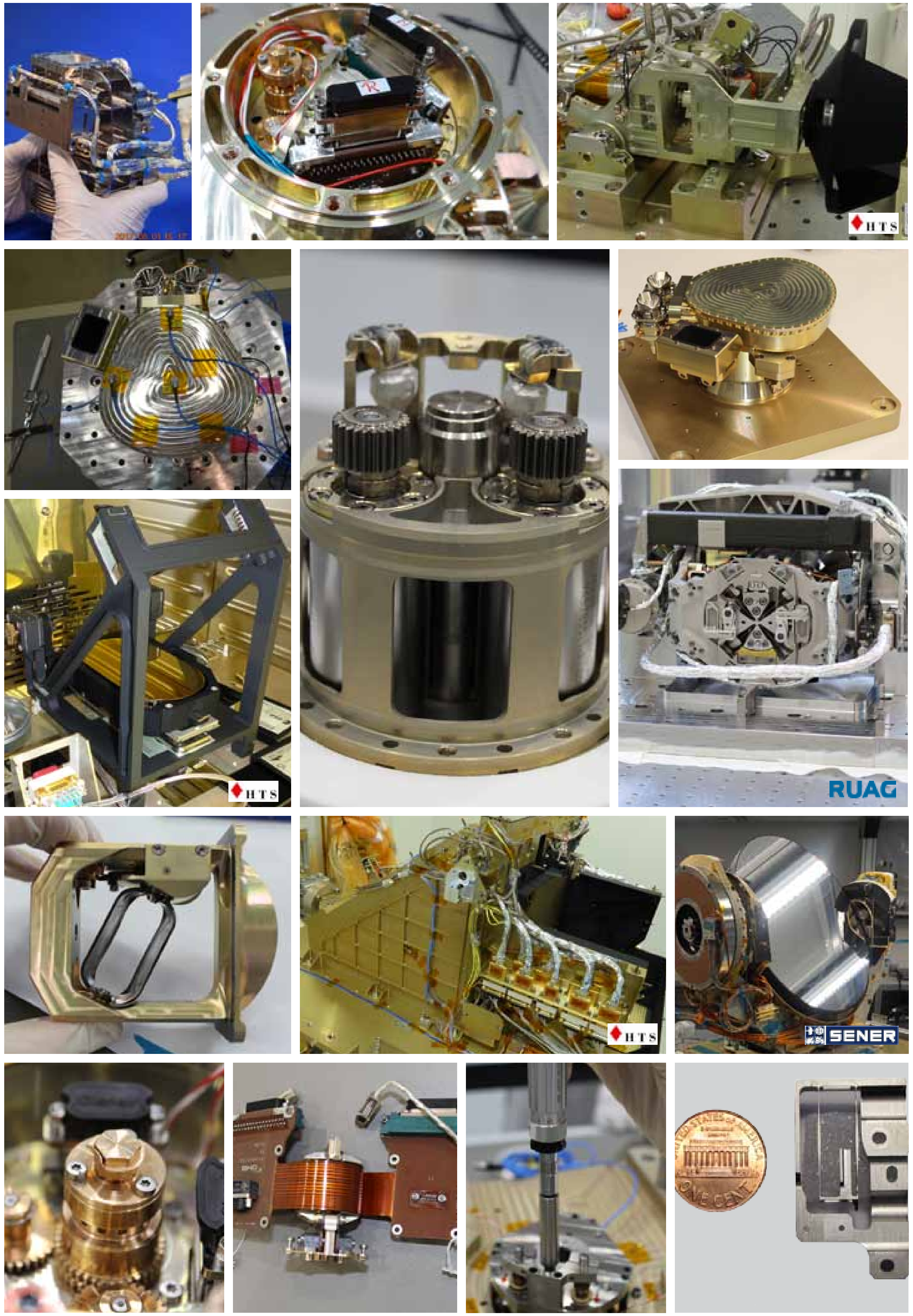
A cross-disciplinary Margin of Compliance chart is generated, and any parameter change can immediately undergo a cascade-effect analysis. MBSE is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout the development and later life cycle phases.

Domain specific concerns (e.g. structural analysis) are tackled with MBE methods. MBE is an approach to engineering that uses models as an integral part of the technical baseline.

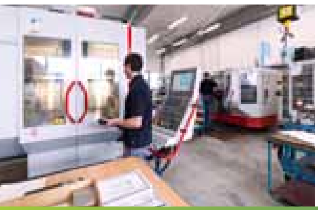
The major challenge is to identify and manage the dependencies among all project entities during the development of a mechatronic system in an early phase. There are direct dependencies (e.g. parameters that are simultaneously impacting two domains) and indirect dependencies (e.g. cross-disciplinary cause-effect relationships not easy to spot with a domain specific approach). MBSE helps identifying all these dependencies, supports early trade-offs and decision making, and reduces risks. It enables defining the architectures of a subsystem considering all mutual impacts (e.g. with the instrument, the test facility, the design and test teams, standards and protocols), and to represent the concepts of its operation.

MBSE and MBE applied simultaneously in one framework bring the following added values:

- improved understanding and traceability of the requirements, including the front-end identification of conflicting requirements
- identification of a sound design, development and verification plan in which all the possible dependencies are elicited and used to drive trade-offs and to identify risks
- improved capability of mapping the variation of the status of compliance to requirements depending on the design choices keeping the multidiscipline overview of the project
- highlighting the systems engineering perspective, i.e. the space mechanism as a system of interest in the frame of its life cycle and in relation to the other systems it operates with.



The Sentinel-4 UVN Scanner Subsystem is developed by RUAG Space, Zurich, under OHB subcontract.





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About OHB System AG

OHB System AG is one of the three leading space companies in Europe. It belongs to the listed high-tech group OHB SE, where around 2,500 specialists and system engineers work on key European space programs. With two strong sites in Bremen and Oberpfaffenhofen near Munich and more than 35 years of experience, OHB System AG specializes in high-tech solutions for space. These include small and medium-sized satellites for Earth observation, navigation, telecommunications, science and space exploration as well as systems for human space flight, aerial reconnaissance and process control systems.

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