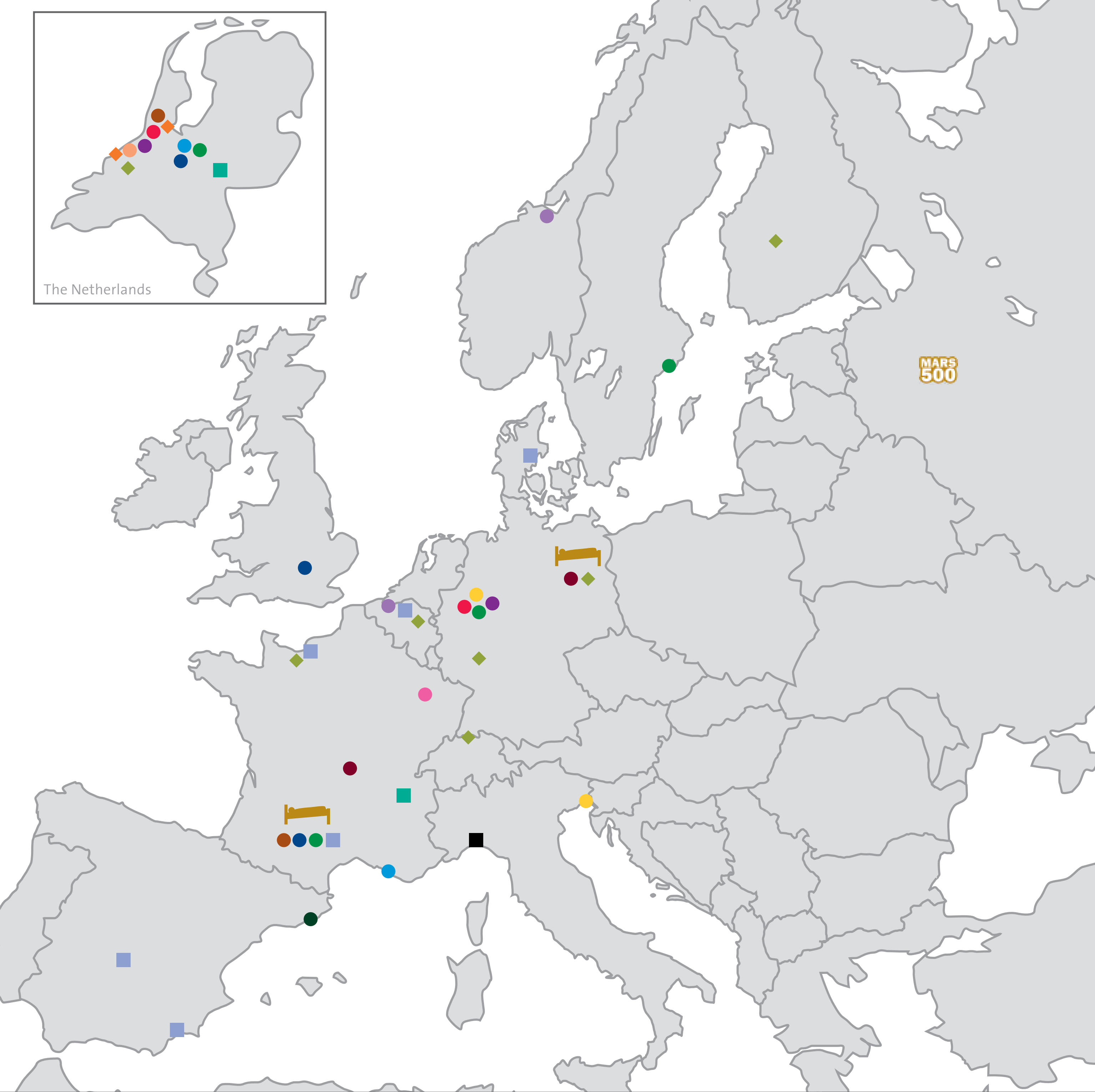

Legend for the above map

Human Research (HR) · Physical Sciences (PS) · HR & PS

- Bedrest
- Concordia
- Mars500
- Pressure and Climate chambers
- Human Centrifuges
- Non-human Centrifuges
- Human-Rated Linear and Angular Accelerators
- Clinostats, Free Fall Machines, and Random Positioning Devices
- Telemedicine, Behaviour and Metrics
- Integrated Bio-Processing, Tissue Engineering
- Magnetic Resonance Facilities
- Movement Analysis, Physical and Skills Training
- Animal Physiology Facilities
- Plant Physiology Facilities
- Magnetic Levitation
- Biotechnology and Life Support Systems
- Extreme Environments
- Radiation Testing
- Fluid Science Facilities: Surface Tension
- Materials Science Facilities

The above map shows the location of Europe's ground-based facilities.

→ 3 GROUND BASED FACILITIES

This chapter is aimed at providing new and experienced users with basic utilisation information regarding the different ground-based facilities.

Image 3-1: Bedrest subject

3.1 Introduction to ground-based facilities

3.1.1 What are ground-based facilities?

Ground-based facilities are research laboratories and institutions that simulate some of the conditions that can be found in the space environment. They allow researchers to test their ideas before flight. They test the influence of gravity, space, planetary and other conditions.

3.1.2 What do ground-based facilities offer?

Using ground-based facilities for experiments under simulated space conditions allows scientists to:

- perform and test preliminary studies;
- test hardware;
- define experiment parameters and protocols.

The access that researchers have to space and microgravity conditions is limited. Ground-based facilities provide a cost-effective way to conduct research programmes to a cross-section of scientists keen to include space-relevant research into their activities.

Examples of scientific disciplines and conditions offered include:

- bedrest;
- metabolic balances;
- hypergravity (centrifuges);
- confinement;
- pressure chambers;
- climate chambers;
- telemedicine;
- behaviour;
- body metrics;
- remote isolation;
- radiation;
- movement analysis (body);
- human-rated linear and angular accelerator;
- magnetic resonance;
- tomography;
- high-resolution echography;
- physical and skills training biofeedback;
- absence of sedimentation (random positioning machines);
- clinostats;
- magnetic levitators;
- phytotron;
- artificial ecosystems;
- extreme environments;
- space power;
- integrated bioprocesses;
- tissue engineering;
- small animals facility;
- crystallisation;
- surface tension.

3.2 An overview of ground-based facilities

3.2.1 Bedrest facilities

Bedrest studies are an invaluable method for simulating the effects of weightlessness on the human body. The physiological effect of lying inactive in bed tilted at 6 degrees for an extended period with the head lower than the feet produces bone/muscle mass loss and fluid shifts similar to those seen in human spaceflight.

As such these studies are a cost-effective means of undertaking an analysis of the underlying mechanisms causing these effects. They test the different countermeasures, which alleviate the negative physiological effects such as nutritional supplements, exercise protocols, equipment or artificial gravity. The confinement of bedrest subjects simulates the confinement experienced by astronauts on mission, and thus makes these studies helpful in testing psychological protocols.

Within ELIPS, ESA offers regular research opportunities for performing bedrest studies.

Both the Institute for Space Medicine and Physiology (MEDES) Clinical Research Facility in Toulouse, France and the German Aerospace Center (DLR) in Cologne, Germany conduct clinical research studies mainly in the areas of physiology, pharmacology and the evaluation of biomedical devices. The institutes undertake experiments, which simulate the effects of the space environment - bedrest, confinement, circadian rhythms, etc. - in order to study its physiological effects and to develop preventive methods.

ESA started to conduct bedrest studies in 2001 to complement its programme of isolation studies that began in the 1990s. The aim was to identify countermeasures – such as exercise and nutrition - to the adverse effects of spaceflight. Short-term, intermediate and long-term studies have been conducted with periods of bedrest ranging from five days to three months.

A 2003 study at the Benjamin Franklin School of Medicine in Berlin, Germany, tested vibration as a form of exercise, while in 2005 female volunteers were given nutritional supplements. The results from these studies have spawned many peer-reviewed papers and increased our understanding of how exercise and nutrition could help keep people on Earth healthy and active. In one 2010 study at MEDES, volunteers were subjected to artificial gravity created by a centrifuge, allowing experiments on volunteers lying horizontally instead of the more common six degrees incline.

For more information on ESA Bedrest studies please visit the following web pages:
www.esa.int/Our_Activities/Human_Spaceflight/Bedrest_studies

Or read the online brochure:
esamultimedia.esa.int/multimedia/publications/Bedrest_Resting_for_science

3.2.2 Isolation and confinement, pressure chambers and climate chambers

3.2.2.1 Isolation studies

Isolation and confinement provide challenges for long-term human spaceflight missions. The psychological effects of being confined, whether alone or alongside a group of people for extended periods, are an important area for study.

In the last twenty years, a lot of experience has been gained from isolation studies, other Earth-based analogue studies and data from human spaceflight missions. Because of this, the European scientific and technology community has gained substantial guidance to risk assessment for humans in the space environment. This experience is helpful in determining psychological aspects of spaceflight such as the psychology of group dynamics and individual performance under isolation and confinement.

The research, combined with knowledge obtained from spaceflight missions has been invaluable in determining human adaptation to conditions in space, as well as in the development of life support systems. Namely the long duration aspect is of major importance.

Previous space-related isolation studies have included:

- the Isolation Study for European Manned Space Infrastructures (ISEMSI) study in Norway in 1990, performed in shore-based hyperbaric chambers;
- the Experimental Campaign for the European Manned Space Infrastructures(EXEMSI) study in 1992 in Cologne, Germany, also performed in shore-based hyperbaric chambers;
- the Human Behaviour in Extended Spaceflight (HUBES) study which modelled aspects of the

long-duration Euromir 95 mission;
- the 'Simulation of the Flight of the International Crew on Space Station' (SFINCSS) from 1999 to 2000.

3.2.2.2 Concordia station

Concordia is a joint French-Italian inland Antarctic research station run by the French Polar Institute and Italian Antarctic Programme. The Concordia base supports remote isolation studies and is open for research groups from all over Europe. ESA's Directorate of Human Spaceflight and Operations uses Concordia's special environment to prepare for future human missions to the Moon or Mars, and ESA supports the French Polar Institute and the Italian Antarctic Programme in medical monitoring, operational validation of life-support technologies and psychological training. Every year Concordia hosts a human research protocol coordinated by ESA and Concordia partners, supplied by universities and research institutions from across Europe. As well as offering around nine months of complete isolation, Concordia is located at around 3200 metres altitude, so the crew has to adapt to chronic hypobaric hypoxia. During the Antarctic winter, the team endures four months of complete darkness - the Sun disappears from the beginning of May, and is not seen again until late August. Living in isolation with a European crew of 13, and in one of the world's most extreme environments, creates an ideal opportunity to conduct research into the adaptation of human psychology and physiology. Space research has been conducted in the polar regions for many years – offering conditions on Earth similar to long-term space travel.

Image 3-2: Concordia station

For more information about Concordia station please visit the following web pages:
www.esa.int/Our_Activities/Human_Spaceflight/Concordia

Or read the online brochure:
esamultimedia.esa.int/multimedia/publications/Concordia_Living_on_white_Mars

3.2.2.3 The Mars500 Isolation Facility

In the light of human exploration of our Solar System ESA undertook a cooperative project with the Russian Institute for Biomedical Problems (IBMP) called Mars500. The Mars500 Isolation Facility is located at the IBMP premises in Moscow, Russia.

A purpose-built isolation facility was outfitted in order to simulate a human spaceflight mission to Mars (see Figure 3-1). The Mars500 isolation facility in which the crew was based is located in a special building, which comprises the isolation facility itself, as well as the operations room, technical facilities and offices. The isolation facility comprised one external module, which was used to simulate the 'Martian surface' and four hermetically sealed interconnected habitat modules, which simulated the spacecraft that took the crew on the simulated journey to Mars and back.

Mars500, the first full-length, high-fidelity simulation of a human mission to our neighbouring planet, started on 3 June 2010, following the completion of an initial 105-day isolation period in 2009, and came to an end 520 days later on 4 November 2011. Mars500 was a fully international mission with a six-person

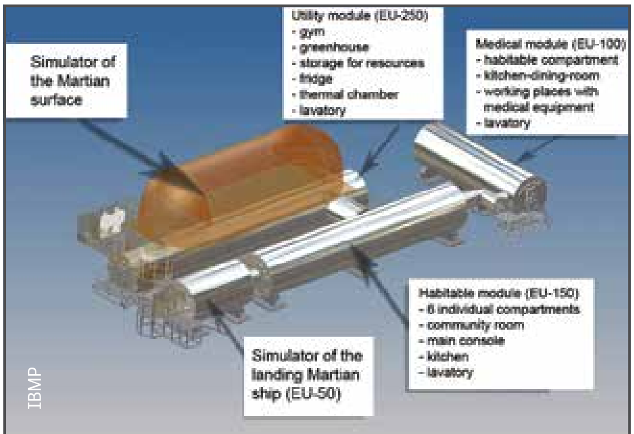

Figure 3-1: The crew's isolation facility in Moscow

crew including two volunteers sponsored by the European Space Agency.

For more information about ESA's participation in Mars500 please visit the following web pages:
www.esa.int/Our_Activities/Human_Spaceflight/Mars500

For more information on the science conducted on ESA's bedrest studies, Concordia station and Mars500 please visit the Erasmus Experiment Archive at
eea.spaceflight.esa.int

3.2.2.4 Pressure and climate chambers

Pressure chambers reproduce the effects of different oxygen and pressure levels. A hypobaric chamber simulates the effects of high altitude on the human body, especially hypoxia (low oxygen) and hypobaria (low air pressure). Hyperbaric chambers on the other hand produce increased pressures. Climate chambers test reactions to temperature and relative humidity.
The COmpagnie Maritime d'EXpertises (COMEX) Hyperbaric Experimental Centre in Toulouse, France features hypobaric and hyperbaric chambers, which can be used for the qualification of equipment, and human intervention methods in hostile environments.

These consist of:

- a neutral buoyancy facility (pool) for undertaking microgravity, lunar gravity or martian gravity training;
- a cellular biology laboratory.

The Netherlands Organisation for Applied Scientific Research (TNO), based in Soesterberg in the Netherlands has different climate chambers for undertaking thermal physiology research of humans in extreme environments.

3.2.3 Hypergravity devices

Hypergravity devices play an important role in many research areas from physiology and biology to materials science and technology.

3.2.3.1 Centrifuges

A centrifuge is a piece of equipment that puts an object in rotation around a fixed axis, applying a force perpendicular to the axis. Centripetal acceleration reproduces the effect of hypergravity.

In a centrifuge, denser substances separate out along the radial direction. Lighter objects will tend to move to the centre. Non-human centrifuges are a key element in, for example, cellular biology - determining the gravisensing mechanisms and tolerances in plants that could impact on cultivation processes here on Earth and on future human spaceflight exploration missions beyond low-Earth orbit.

3.2.3.2 Human centrifuges

Human centrifuges test the capabilities of humans (such as astronauts) to withstand hypergravity in simulations of a spaceflight launch and re-entry. Centrifuges can be used in human physiology research - for example, using them as a means of countering bone mass loss. This type of research can also impact on vestibular-related disorders in space and on Earth.

A number of human centrifuges exist around Europe for undertaking human physiology research in hypergravity. DLR, in Cologne, Germany and the MEDES Space Clinic, in Toulouse, France have similar short-arm human centrifuges which go up to 6 g and are used in countermeasure studies for astronauts.

Image 3-3: Bedrest centrifuge

These human centrifuges can accommodate two reclining or seated subjects. Additional human centrifuges are in place at the Netherlands Aeromedical Institute, in Soesterberg, which can hold up to 175 kg in payload mass, and at the Karolinska Institute, in Stockholm, Sweden which can expose up to 300 kg of payload mass to up to nine times gravity (15 times gravity for equipment alone). TNO, in Soesterberg, also has a facility called Desdemona.

This is a six degrees-of-freedom motion base that is capable of rotation in three axes, linear motion along an 8 m track, and sustained centrifugation up to 3 g.

3.2.3.3 Non-human centrifuges

Non-human centrifuges around Europe vary considerably depending on their purpose. Two larger radius centrifuges are located in the Netherlands at the Academic Medical Centre, in Amsterdam and at ESA-ESTEC in Noordwijk, providing 8 g and up to 20 g environments respectively for a variety of biological, biotechnological, biochemical, physical, material and fluid science, geology and plasma physics experiments. The Large Diameter Centrifuge (LDC) located at ESA-ESTEC, Noordwijk, the Netherlands (diameter of 8 meters) can hold experiments (up to 80 kg) and lasting from one minute up to six months.

DLR, in Cologne, Germany, has the smaller Niedergeschwindigkeits-Zentrifugen-Mikroskop (NIZEMI) Centrifuge which consists of a slow rotating centrifuge microscope for hypergravity experimentation up to 5g and allowing for the observation of small organisms. The Dutch Experiment Support Centre located in Amsterdam has the Medium-sized Centrifuge for Acceleration Research (MidiCAR) which is a dedicated cell/tissue culture centrifuge in which samples may be exposed to accelerations up to 100 g.

Image 3-4: The ESTEC Large Diameter Centrifuge

3.2.4 Linear and angular accelerators

Linear accelerators create changes in velocity in a straight trajectory. Angular accelerators rotate - the speeding up or slowing down of rotation being the angular acceleration or deceleration. Linear and angular accelerators play an important role in understanding how the vestibular system functions in weightlessness. With the human vestibular system relying on Earth's gravity for posture and balance, the understanding of the mechanisms that develop when gravity is reduced in space can help to provide an insight into the problems associated with spatial awareness and orientation there, as well as balance disorders on Earth.

TNO, in Soesterberg, the Netherlands has a vestibular laboratory with a 3-D rotating chair, Linear Track (the ESA Space Sled), Tilting Room, and Ship Motion Simulator while the Medes Space Clinic, Toulouse, France has a Visual and Vestibular Investigation System for investigating the role of the inner ear in detecting changes in motion and orientation. Outside of these two facilities the Centre for Human Sciences Impact Facility in Farnborough, UK, has a Deceleration Track to test the various impacts caused by rapid deceleration.

3.2.5 Clinostats, free-fall machines, and random positioning devices

A clinostat consists of a disc attached to a motor. The disc is held vertically (for simulated weightless research) or inclined (the greater the angle from vertical, the greater the simulated gravity conditions) and the motor rotates it slowly at rates in the order of one revolution per minute. A plant sample/organism is attached to the disc so that it is held horizontally. The slow rotation means that the plant attached specimen experiences a gravitational pull that is averaged over 360 degrees, thus approximating for example a weightless lunar or martian environment.

Plant growth (gravitropism) and development (gravimorphism) can be measured in these conditions. Clinostats have also been used to study the effects of simulated microgravity on cell cultures and animal embryos.

Clinostat facilities are available at DLR in Cologne, Germany, the DESC Laboratory at the Free University of Amsterdam, the Netherlands and at the 'Competence in Aerospace Biomedical Science and Technology' group at Lucerne University of Applied Sciences and Arts.

The principle of a free fall machine (FFM) is based on the gravity-driven free fall of samples fixed to a carriage sliding along a vertical guiding bar. At the bottom of the bar a thrust of compressed air bounces the carriage to the top of the rod. An FFM produces periods of free-fall conditions lasting approximately 800-900 ms which are interrupted by an acceleration of about 20 g for 20-80 ms.

Random positioning machines rotate in a way to simulate weightlessness by removing the effect of gravity in any specific direction.

The DESC Laboratory in Amsterdam has both free fall machines and random positioning machines.

3.2.6 Telemedicine and metrics facilities

Telemedicine can be defined as the delivery of healthcare services where medical staff are not physically present. Professionals use information and telecommunications technologies for the exchange of data for diagnosis, treatment and prevention of diseases and injuries, research and evaluation.

Telemedicine makes the best use of limited and valuable resources. Rapid advances in telemedicine are increasing the scope and possibilities, into areas such as remote surgery.

Capabilities include:

- the Telemedicine Portable Workstation developed at MEDES, Toulouse, France, which collects biomedical patient data and can transmit them to a medical expert for a first aid medical consultation or a second-opinion advice;
- 3-D body scanning, at TNO, Soesterberg, the Netherlands for digitally recording exact shape and body dimensions of humans and objects. This can be used in computer-aided design to construct made-to-measure apparel for example;
- usability Engineering, at TNO Soesterberg where equipment and human-factors know-how are available for the design and test of user interfaces for space applications.

The services (at TNO Soesterberg) include the specification of user requirements, interface prototypes (e.g. storyboards), expert reviews and user tests (in the lab, on location or remotely).

3.2.7 Integrated bio-processing, tissue engineering facilities

Developments in the multidisciplinary field of tissue engineering have yielded a novel set of tissue replacement parts and implementation strategies. Scientific advances in biomaterials, stem cells, growth and differentiation factors, and biomimetic environments have created unique opportunities to fabricate tissues in the laboratory from combinations of engineered extracellular matrices (“scaffolds”), cells, and biologically active molecules. Among the major challenges facing tissue engineering is the need for more complex functionality, as well as functional and biomechanical stability in laboratory-grown tissues destined for transplantation.

The Charité Institute for Transplantation and Organ Replacement, which forms part of the Charité Medical Faculty of the Humboldt University in Berlin offers a scientific environment in the fields of tissue engineering, biomedical technology and transplantation medicine.

Facilities are available at Bio-up, at the Blaise Pascal University, in Clermont-Ferrand, France for the experimental determination of capabilities of various biological transformations, including aerobic and photosynthetic cultures of microorganisms, which are of interest in Life Support Systems for long duration space missions.

3.2.8 Magnetic resonance facilities

Magnetic resonance imaging, commonly known as MRI is an imaging technique used in radiology to investigate the anatomy and functioning of the body. MRI scanners use strong magnetic fields and radio waves to form images of the body. Magnetic resonance techniques are extremely useful within spaceflight-related programmes and projects for determining/imaging some of the physiological effects on soft and hard body tissues. This can either be associated with actual spaceflight missions or in simulated weightlessness such as in bed rest studies. For magnetic resonance techniques related to spaceflight there are facilities within the University of Trieste within the Dept. of Biochemistry, Biophysics and Macromolecular Chemistry (at the Cattinara Hospital in Trieste, Italy) and at the Muscle Lab of DLR's Physiology Laboratory in Hamburg, Germany.

3.2.9 Movement analysis, physical and skills training facilities

3.2.9.1 CAR Centre, Barcelona, Spain

The CAR Centre (Centre d'Alt Rendiment) has been specifically designed to support the improvement of performances of top athletes and to characterise the physiological and general training conditions contributing to such improvement.

In addition to sports, educational and residential facilities, CAR offers:

- services in biomechanics including 2D and 3D videographic analysis of movement and training;
- monitoring of muscle strength using electromyography (recording electrical activity produced by skeletal muscles);
- services in physiology such as analysis of body composition, lactic acid and pH level tests;
- strength/force testing (dynamometry);
- MRI assessment of body/weight distribution;
- muscular metabolism study;
- psychology, nutrition, and physical training and evaluation.

3.2.10 Animal physiology facilities

The Developmental Space Biology Group at the University of Nancy, France offers help for preparation and conditioning of embryos of mostly amphibians for spaceflight. In Germany, the AquaHab, owned by OHB- System AG, in Bremen is an aquatic research module based on hardware developed for DLR and flown successfully in space. Dedicated mainly to ground based research, Aquahab is supported by complex technology and a laboratory facility for operating the modules including a standard biochemical laboratory environment, hardware development and test laboratory, as well as in-house hatchery capabilities.

3.2.11 Plant physiology facilities

In addition to the facilities and equipment mentioned previously (centrifuges, magnetic resonance, clinostats, Aquahab etc.) facilities for plant physiology research related to space applications are listed in the following sections.

3.2.11.1 Plant Biocentre and Norwegian User Support and Operations Centre, University of Science and Technology, Trondheim, Norway

The Plant Biocentre has laboratory facilities for cultivation and analysis for plant biology research, while the User Support and Operations Centre for the European Modular Cultivation System is used for testing the design concept of planned experiment hardware and selected plant material before the implementation of an experiment in space.

3.2.11.2 Multispectral Plant Imaging, University of Ghent, Belgium

At the Multispectral Plant Imaging facility which is part of the Department of Molecular Genetics, the automated thermography setup permits time-lapse thermal imaging of plant leaves. Combined thermographic and video imaging is available to obtain spatial correlation of visible and thermal stress symptoms over time. On the software side, automated generation of overview images and movies for rapid visualisation of changes has been developed.

3.2.12 Magnetic levitation facilities

Every element in the periodic table is magnetic to some extent, from the smallest effect know as diamagnetism which is a property of elements like copper and carbon, to the largest magnetic effect known as ferromagnetism, which in our daily lives is the most common form of magnetism and found in elements such as iron, cobalt, and nickel. Ferromagnetism is a force over one hundred times stronger than diamagnetism. Diamagnetic materials, need a much higher gradient magnetic field strength in order to be levitated (and thus simulate weightlessness). This can be carried out on organic materials or even living biological samples. Such facilities are available at the High Field Magnet Laboratory of the University of Nijmegen, in the Netherlands as part of the Dutch Experiment Support Centre. Similar facilities for fluid sciences, material sciences, and fundamental physics research are present at the French government funded Alternative Energies and Atomic Energy Commission, in Grenoble, France.

3.2.13 Biotechnology and life support systems facility

Activities at the Life and Physical Sciences Instrumentation and Life Support laboratory located at ESTEC, ESA's technical centre in the Netherlands, are focused on research and technology development associated with the impact of the space environment on biological and physical systems, including advanced life support concepts.

Image 3-5: ESA's LIS Laboratory Facilities at ESTEC

The laboratory facilities are able to support biological, physical and life support projects, environmental control, cleanliness, disinfection and sterilisation procedures as well as gravity simulation experiments.

The facility is composed of four main laboratories:

- exploration and life support laboratory;
- Life and Physical Sciences laboratory;
- gravity simulation laboratory;
- ISO class 6 clean room (class 1 planned).

3.2.14 Extreme environments facility

Simulation of environmental conditions in space and on other planets and orbital bodies can be an important precursor in astrobiological experiments in order to determine the survivability of different species under these conditions. It can also help in the planning of future missions, by testing different equipment and technologies to verify that they can deal with the conditions in which they have to function.

The Planetary Simulation facility at the DLR "Mars Complex" in Cologne, Germany provides the following simulated martian environment for physical and exobiological studies:

- atmosphere;
- UV-radiation climate;
- surface/subsurface temperature controlled with regard to diurnal/seasonal fluctuation.

At the Organics under Simulated Interstellar Conditions (OSIC) facility at the University of Leiden in the Netherlands there is a model chamber dedicated to the study of carbonaceous material in ultra-high vacuum at low temperature and under UV irradiation.

3.2.15 Radiation testing facilities

Facilities testing the effects of radiation in different environments are a vital part of planning for future spaceflight, with the testing of different components, equipment and technologies verifying that a mission can deal with exposure to the different levels of radiation in orbit in which it has to function. Developments in this area can also have an impact in areas of medicine such as within heavy ion therapies for cancer treatment.

Numerous facilities are present around Europe:

- ESA operates Internal Radiation Test Facilities at ESTEC, Noordwijk, the Netherlands, which has both a Co-60 gamma source for testing and the CASE (Californium-252 Assessment of Single Event Effects) laboratory test system, which is an alternative to the conventional heavy ion accelerator;
- the GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany can simulate cosmic radiation, in particular the galactic cosmic radiation, and has the accelerators UNILAC and SIS-18 that deliver ion beams of high quality of many chemical elements (including iron) in the energy range of 1 MeV–1 GeV per nucleon and can accelerate light ions (up to neon) to 2 GeV per nucleon;
- DLR's Integrated Space Environment Factors Simulator KOBE in Berlin, Germany offers interstellar and planetary environment simulation such as high vacuum, martian climate conditions,

solar irradiation and ultraviolet radiation;
- the Grand Accelerateur National d'Ions Lourds (GANIL) in Caen, France offers production of accelerated ions from helium to uranium of medium energy (20–100 MeV/amu), which can be used for studies in fundamental physics. It can also be used in radiobiology and material sciences for simulating the exposure of biological systems or materials to cosmic heavy ions;
- the accelerator facility at the Paul Scherrer Institute in Villigen , Switzerland is used to accelerate protons which can be used for research into the smallest fundamental constituents of matter, the investigation of innovative materials, the development of new products for medical diagnosis and unique methods of treating tumours;
- the Heavy Ion Irradiation Facility, at the Centre de Recherches du Cyclotron, Louvain-la-Neuve, in Belgium is used for studies in Single Event Effects in collaboration with ESA;
- the RADiation Effects Facility (RADEF), which is located in the Accelerator Laboratory of the University of Jyväskyä, Finland includes beam lines dedicated to proton and heavy ion irradiation studies of semiconductor materials and devices.

3.2.16 Fluid science facilities: surface tension

The Sider Metro Test (SMT) laboratory at the University of Genoa, Italy is composed of a number of dedicated pieces of equipment, which allow measurement to be made from near ambient temperatures up to 1500°C. Measurements relevant to fluid and materials science can be made at both the liquid-gas interface and liquid-liquid interface.

Special real-time software processes data so that rapid interfacial phenomena like those governed by adsorption, or by diffusion can be traced. Surface and interfacial tension data, both at equilibrium and in dynamic conditions are of basic importance for studies related to solidification, crystal growth, joining, detergency, foams and emulsion stability.

3.2.17 Materials science facilities: crystallisation

The Universidad Autónoma de Madrid, Spain offers:

- equipment for sample preparation and growth of single crystals at high temperature, in air or controlled atmosphere, melt and vapour techniques;
- capabilities for cutting, polishing and orientation of single crystals;
- and methods of sample characterisation techniques.

The timescale for performing an experiment is from three to 12 months depending on the adaptation of equipment as required.

3.2.18 Materials science facilities: solar power

In operation since 1991, the Solar Furnaces in Almeria, Spain have been fully devoted to materials treatment in the framework of European Union-funded research programmes. The main components are:

- the mirrored, mobile heliostats, which reflect sunlight;
- the mirrored parabolic concentrator onto which sunlight from the heliostats is reflected;
- a louvered shutter to control sunlight concentration;
- a movable test table which concentrates sunlight onto the focal spot where specimens are held.

DLR in Cologne, Germany has a 25 kW solar furnace, a high power radiation source (20 kW) and further solar test facilities. Well-equipped laboratories, workshops and simulation tools in Stuttgart and Cologne allow for thermal, chemical, optical R&D activities as well as system analyses.

3.2.19 Materials science facilities: wind tunnels

At the COmplexe de Recherche Interprofessionnel en Aérothermochimie (CORIA), at the University of Rouen, France three wind tunnels have been built to simulate the re-entry conditions of differing planetary atmospheres. Numerous measurement techniques, in particular optical diagnostics, have been developed to study high enthalpy flows and supersonic plasma flow can also be generated.

A similar wind tunnel exists at the Von Karman Institute, Sint-Genesius-Rode, Belgium. Temperatures up to 10 000 K can be achieved.

At the University of Aarhus in Denmark simulation of the martian aerosol is performed in a unique re-circulating wind tunnel enclosed in a low pressure atmospheric chamber. Importantly, such a system allows the atmosphere to be carefully controlled and monitored, and the dust to be stored for long periods of time compared to flow-through systems. Typical wind speeds up to 10 m/s can be reproduced with variable dust density. A liquid nitrogen cooling system allows the extreme low temperatures on Mars to be achieved, this also allows the low humidity to be reproduced. In the two years of research it has been found that dust sticks readily to any and all surfaces invariably forming aggregates as the dust sticks to itself.

3.2.20 Erasmus Centre High Bay

The Erasmus Centre is located in the Erasmus Building at ESA's Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands. The centre is a showcase for the programmes and missions of the Directorate of Human Spaceflight and Operations. Its role is to inform and advise institutional and commercial users interested in making use of the Directorate's space platforms and ground-based facilities.

The Erasmus Centre hosts a 900 square metre exhibition area - High Bay - in which potential users and researchers can familiarise themselves with various experiment facilities. The display includes a 1:10 scale model of the complete International Space Station, and full size models of ESA's Columbus laboratory and Russia's Zvezda module. Also in the High Bay are a Russian Foton capsule and a TEXUS sounding rocket, which have both flown in space, a parabolic flight demonstrator, and training modules for practical demonstration and familiarisation of the main Columbus experiment facilities.

One of these experiment facilities is the Microgravity Science Glovebox (MSG), on ISS since 2002. A ground model of the MSG, located in the Erasmus Centre, provides a training facility for astronauts performing a wide variety of materials, combustion, fluids and biotechnology experiments and for experiment developers to make fit checks and functional tests in Europe prior to the final MSG integration activities in the Unites States.

Image 3-6: The Erasmus Centre High Bay

Image 3-7: Dutch ESA astronaut André Kuipers being trained on the engineering model of the MSG, in the Erasmus Centre

Image 3-8: Virtual Reality Theatre

Complementary to the High Bay exhibition area the Erasmus Centre offers potential users a realistic 3D graphic representation of the International Space Station in combination with unique high-resolution 3D pictures in the Erasmus Centre Virtual Reality Theatre. The theatre can host up to 25 visitors.

3.2.20.1 Drop Tower demonstrator

In November 2004, the Erasmus Centre inaugurated a Drop Tower demonstrator, erected in its High Bay area, built with the objective of familiarising visitors and potential users with the drop tower concept (see chapter 4), as well as to provide a tool for demonstrating a weightless environment to students and school pupils (see chapter 2).

The tower is a 13 metre woven metal structure, providing 1.4 seconds of microgravity. Drop tests can be carried out in the inner payload bay of a cylindrical capsule, surrounded by an aerodynamic protective outer shield. During the hoist to the top of the tower, the outer shell is lifted by the inner capsule. Once the payload is released, the shell and the capsule are no longer connected. The outer shell is to reduce the effects of drag on the capsule caused by the surrounding air.

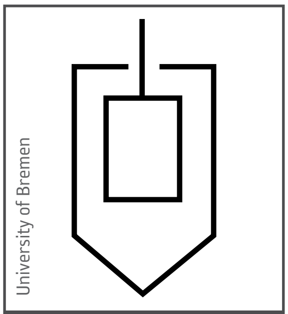

Figure 3-2: Schematic diagram of the capsule & outer shell

The payload is released by a spring loaded 'kick' mechanism that allows experiments to be jolted as the capsule is dropped, important for particle agglomeration experiments.

At the base of the tower, a 1.75 metre deep pit filled with PVC lentil-shaped objects breaks the fall of the experiment capsule that is exposed to 25 g impact upon deceleration.

Experiments are hosted on a circular aluminium platform, provided by the user, and should be mounted directly onto 8 mm aluminium base plates to avoid damage by vibration upon deceleration. Rubber or plastic mounts should not be used as these prolong the 25 g effect.

The maximum payload weight is 2 kg excluding the host platform. Full technical specifications of the platform and capsule can be found in the figures 3-3, 3-4 and 3-5.

For the data analysis of a drop in the Drop Tower demonstrator, ESA can provide torque data specific to each drop. The accelerometer primarily uses one axis but can also detect sideways movements due to small voltage changes. The accelerometer uses a frequency of 500 MHz for data collection.

ESA also provides a high speed GO PRO Hero 3 camera. It operates at a speed of 120 frames per second resulting in a 4x reduction in speed upon playback. This effectively converts the playback time of the experiment from 1.5 seconds to 6 seconds.

For more information on each of the ground-based facilities please visit the following web pages:
www.esa.int/Our_Activities/Human_Spaceflight/Research

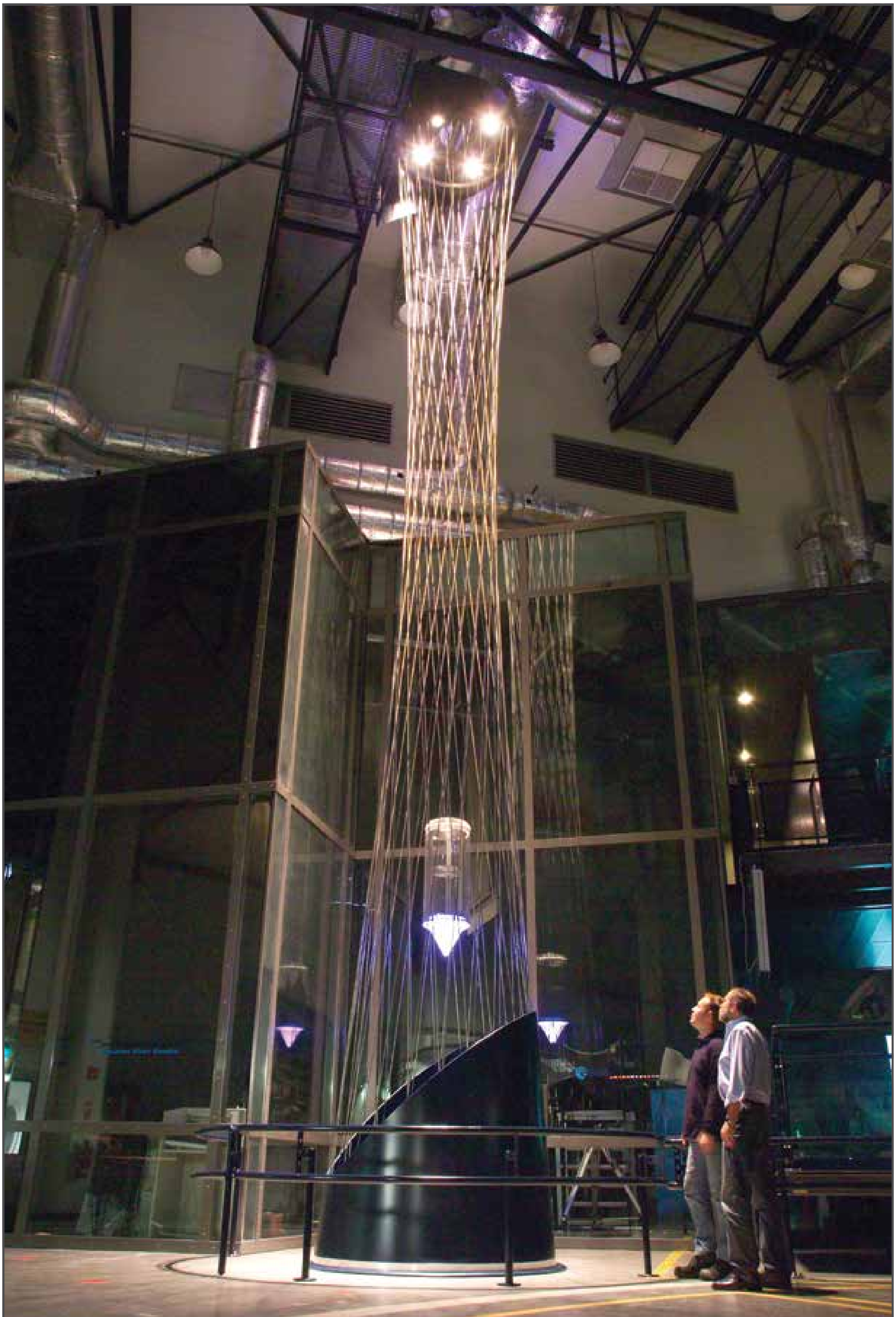

Image 3-9: Erasmus Centre Drop Tower demonstrator

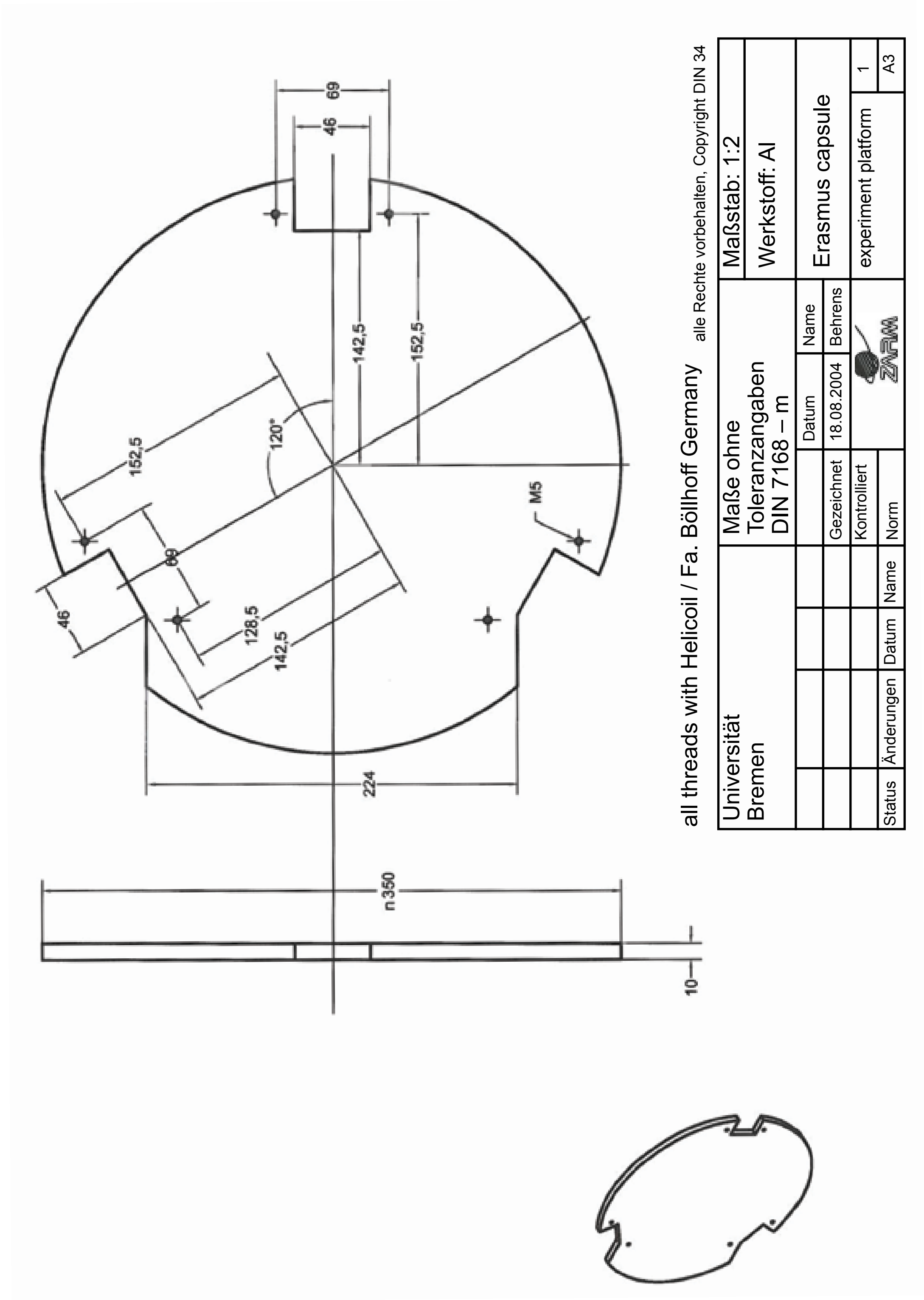

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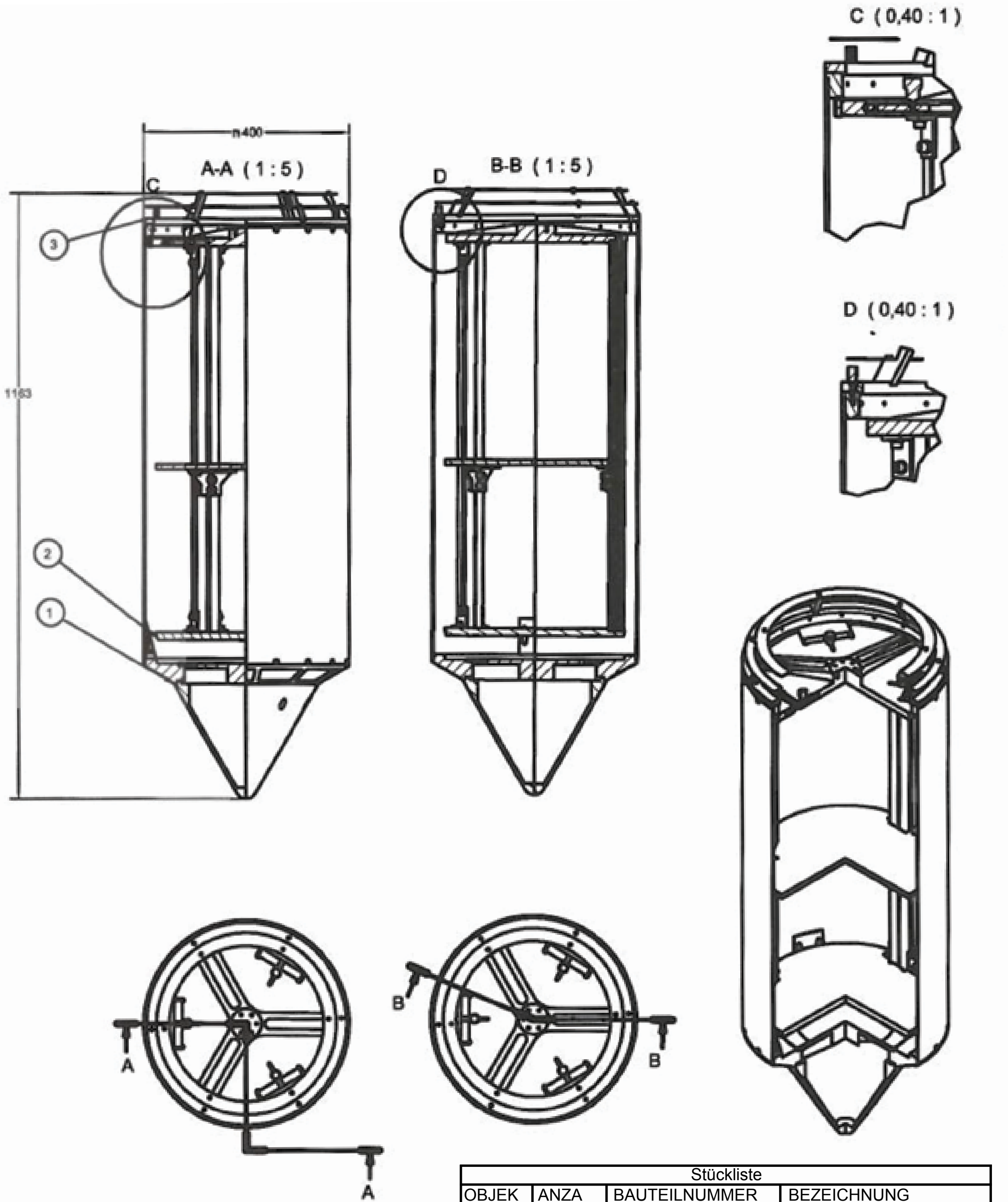
Figure 3-3: Drop Tower platform specifications



Stückliste			
OBJEK	ANZA	BAUTEILNUMMER	BEZEICHNUNG
1	1	drag shield	
2	1	free flyer	
3	1	spoiler	

Universität Bremen				Maße ohne Toleranzangaben DIN 7168 – m			Maßstab: / Werkstoff:
					Datum	Name	Erasmus capsule
				Gezeichnet	18.08.2004	Behrens	
				Kontrolliert	ZARM		experiment platform · 1
Status	Änderungen	Datum	Name	Norm			A3

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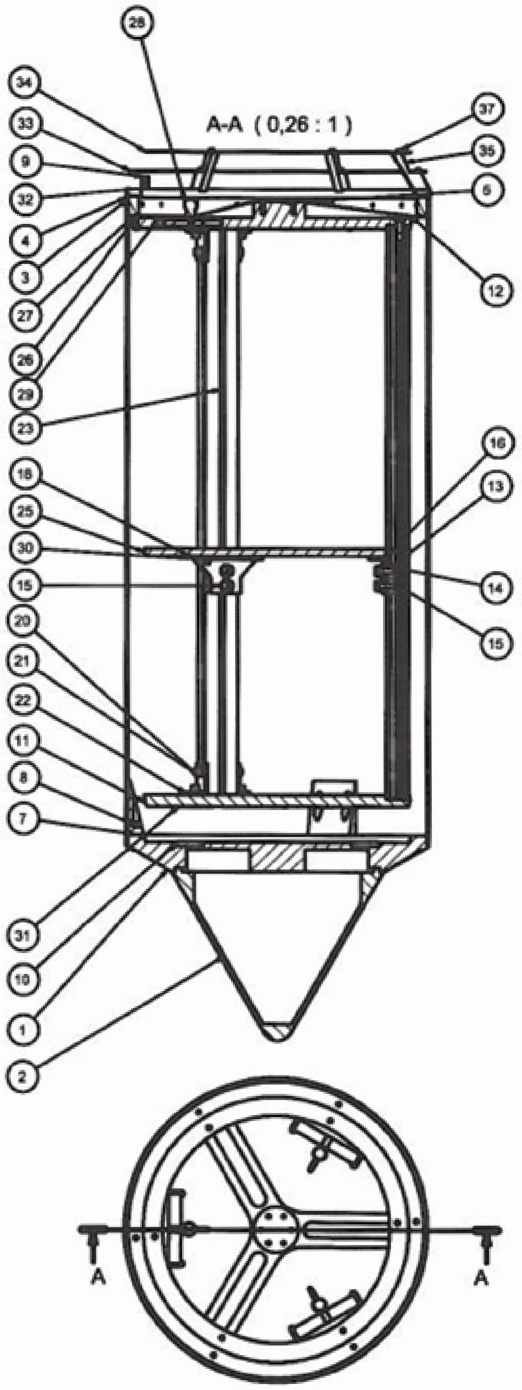
Figure 3-4: Drop Tower capsule specifications (1)



Stückliste			
OBJEK	ANZA	BAUTEILNUMMER	BEZEICHNUNG
1	1	dragshield base plate	
2	1	dragshield nose cone	
3	1	dragshield shroud	
4	1	dragshield suspension ring	
5	36	DIN 7991 – M4 x 12	Senkschraube
6	8	DIN 912 – M6 x 30	Zylinderschraube
7	3	guide rail	
8	12	DIN 912 – M5 x 16	Zylinderschraube
9	2	spoiler crew	
10	1	dragshield shock absorber	
11	1	free flyer base plate	
12	1	free flyer top cover	
13	6	sliding block	Bosch 3842242113
14	6	DIN 125-1 – B 8.4	Scheibe
15	6	DIN 912 – M8 x 16	Zylinderschraube
16	1	platform bracket 1	
17	1	platform bracket 2	
18	1	platform bracket 3	
19	3	DIN 7991 – M8 x 30	Senkschraube
20	24	DIN 912 – M6 x 12	Zylinderschraube
21	24	DIN 125-2 – B 6.4	Scheibe
22	12	stringer bracket	
23	3	stringer	Bosch 342992431/..
24	12	sliding block M6	Bosch 3842518408
25	1	experiment platform	
26	3	centering screw	
27	3	centering device	
28	3	pin screw	Fa. Kipp Nr: 24L170412N
29	3	pin	
30	6	DIN 125-2 B 5.3	Scheibe
31	12	free flyer shock absorber	
32	1	spoiler suspension ring	
33	1	spoiler ring 1	
34	1	spoiler ring 2	
35	6	spoiler bracket	
36	6	DIN 912 – M4 x 6	Zylinderschraube
37	12	DIN 912 – M3 x 6	Zylinderschraube

Universität Bremen				Maße ohne Toleranzangaben DIN 7168 – m			Maßstab: Werkstoff:	
					Datum	Name	Erasmus capsule	
				Gezeichnet	18.08.2004	Behrens		
				Kontrolliert	ZARM		experiment platform	1
Status	Änderungen	Datum	Name	Norm				A3

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Figure 3-5: Drop Tower capsule specifications (2)

3.3 References

1. ESA Bedrest studies web pages:
   www.esa.int/Our_Activities/Human_ Spaceflight/Bedrest_studies

2. ESA Concordia station web pages:
   www.esa.int/Our_Activities/Human_ Spaceflight/Concordia

3. ESA Ground-based facilities web pages:
   www.esa.int/Our_Activities/Human_Spaceflight/Research

4. ESA Mars500 web pages:
   www.esa.int/Our_Activities/Human_ Spaceflight/Mars500

5. "Laboratory Science with Space Data:
   Accessing and Using Space-Experiment Data", D. Beysens, L. Carotenuto, J.W.A. van Loon, M. Zell, Springer, 2011.