3 DROP TOWER

This section provides a guide to the ZARM (Zentrum für Angewandte Raumfahrt Microgravitation) Drop Tower, located in Bremen, Germany, which was officially declared an ESA External Facility on 2 October 2003. The section begins with a brief introduction to drop towers and drop tubes.

3.1 Introduction

3.1.1 What Are Drop Tubes and Drop Towers?

Drop tubes and *drop towers* are ground-based research facilities with which up to ten seconds of free-fall (weightless) conditions can be achieved.
Drop tubes are dedicated to containerless processing for fundamental studies of material properties and solidification microstructures. Samples (usually liquid metal drops) are released from the top of the *drop tube* and allowed to fall freely. The aerodynamic drag, which creates friction and subsequently convection in samples, can be eliminated by operating the tube under vacuum, thus creating weightless conditions.
Drop towers are multi-purpose facilities, which enable autonomous experiment packages to be submitted to true free-fall conditions. In most cases, *drop tower* experiments are performed in an evacuated chamber to eliminate the effects of drag force. Their high degree of flexibility permits investigations in different research areas. A series of experiments can be conducted over a period of a few days, enabling scientists to screen ranges and parameters. *Drop towers* are very useful for obtaining quantitative data on physical phenomena with short characteristic times in the absence of gravity-driven disturbances.

3.1.2 What Do Drop Tubes and Drop Towers Offer?

Drop tubes and drop towers provide:

- Facilities for experiments that require less than 10 seconds of weightless conditions;
- Precursor opportunities for carrying out research in preparation for long-duration missions;
- Low-cost access to research in weightless conditions;
- A short experiment planning-development-execution cycle;
- A fast turn-around time;
- The possibility of executing a series of experiments within a few days;
- Direct intervention by research teams to make modifications between drops;
- Minimal safety requirements;
- A high quality low gravity environment ($< 10^{-5}$ g);
- A platform for new ideas in the field of microgravity research.

3.1.3 Why Use Drop Tubes and Drop Towers?

The main reason for using drop tubes and drop towers is that they are extremely useful to students and scientists new to the field of microgravity research, as well as to experienced researchers wishing to execute numerous, short, low-cost tests before (when foreseen) moving on to costly, long-duration missions. Even though the time of weightlessness to perform experiments is of the order of seconds, the level of microgravity obtained is of extremely high quality, providing good scientific data.

3.1.4 Principal Characteristics of the ZARM Drop Tower

The ZARM drop tower is a 146 m tall concrete shaft (Figure 3-1), which provides near weightlessness up to 3 times a day, for experiments dropped from the top of the tower (4.74 seconds of microgravity) or catapulted upwards from below the tower (9.48 seconds), respectively. In September 2004, a catapult system was inaugurated at the ZARM drop tower (Figure 3-2), which doubles the standard drop microgravity time, and is located in a chamber 11 m below ground under the tower. This catapult throws the capsule upwards from the bottom of the tower, accelerating it by a pneumatic piston driven by the pressure difference between the vacuum inside the drop tube and the pressure inside the tanks. The acceleration level is adjusted by means of a servo hydraulic braking system controlling the piston velocity. This catapult system accelerates capsule masses from 300 kg up to 500 kg to a speed of 48 m/s within 0.28 seconds.
The microgravity lab system itself is a cylindrical capsule with a diameter of 800 mm and a length of 1.6 m or 2.4 m depending on the space required. Inserted platforms, held in aluminium frames, form the modular drop capsule structure. After integration of an experiment prior to a drop or a launch, the whole capsule is closed pressure-tight with an aluminium cover. When performing a drop, a winch pulls up the capsule to the maximum internal height of 120 m. The specially designed release mechanism serves for low induction of disturbances during free fall. The internal drop tube is evacuated before every drop or launch and the capsule is released/catapulted at a residual pressure of 10 Pa. The internal tube, which has a volume of 1700 m^3, stands detached at a height of 13 m on the 2 m thick roof of the deceleration chamber. The detachment of the tube from the tower itself is necessary to assure quiescent conditions even during stormy weather. During the free fall period of a drop or launch, an ultimate microgravity quality with residual accelerations less than 10^{-5}g can be detected. At the end of the experiment, an 8 m high deceleration unit, filled with polystyrene pellets, decelerates the vehicle.

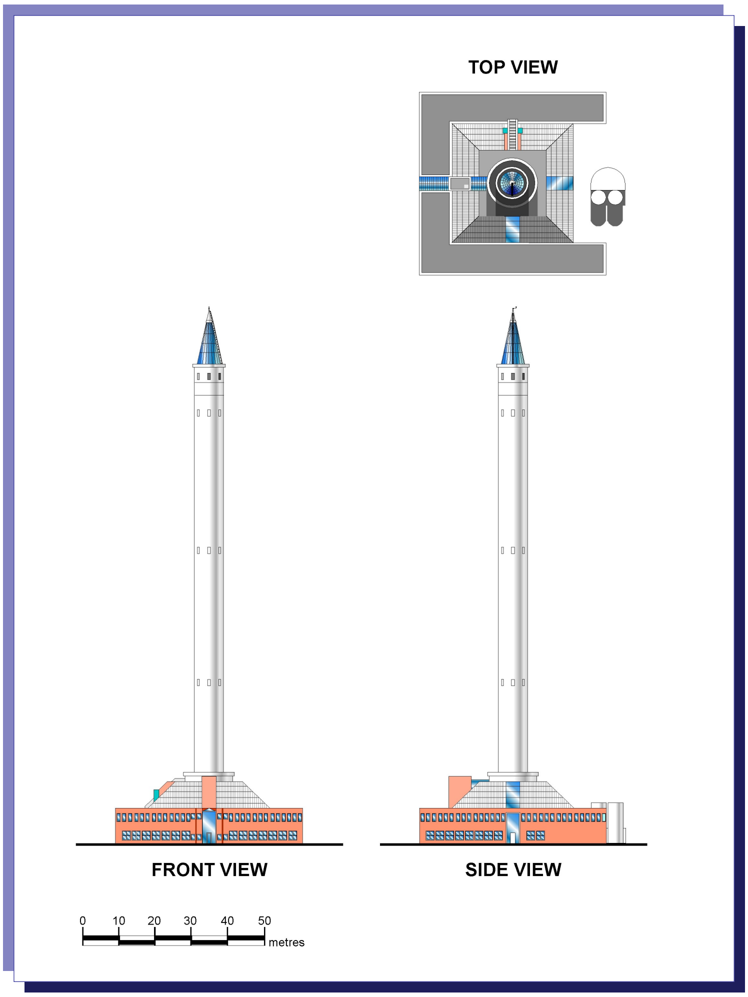

Figure 3-1: ZARM Drop Tower External View

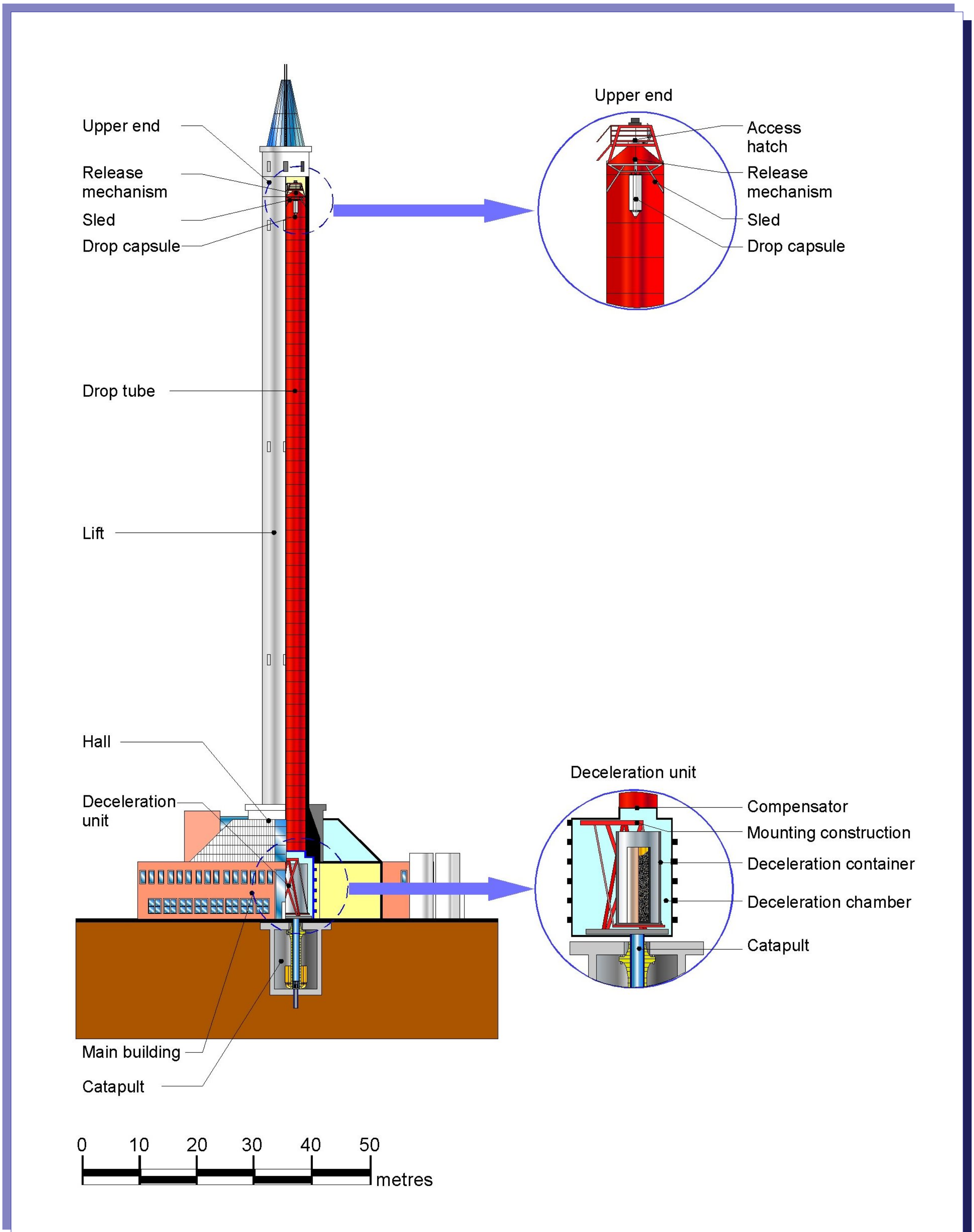

Figure 3-2: ZARM drop tower interior layout

3.2 Physical Environment

3.2.1 Pressure Environment

The drop capsule is a gas-tight pressure vessel, sealing the interior from the outer drop tube vacuum. The interior is kept at atmospheric conditions throughout the whole procedure, and the inner pressure is continuously monitored as part of the housekeeping data. Pressure deviations may result from a temperature shift due to differences of ambient temperature between the integration area and the top of the tube. In case of pressure increases due to outgassing of experiments or high power consumption values, the pressure is released to the surroundings only during the evacuation process. If the internal capsule pressure drops to less than 980 hPa, the experiment procedure is stopped. The drop is initiated when the tube pressure is below 10 Pa. The actual values are monitored together with the other tower data in the control room.

Table 3-1: Drop tower environment pressure parameters

PARAMETER	VALUE
Nominal capsule pressure (p)	1.013 hPa
Pressure loss (dp)	< 1 % in 3 hours
Safety range (p)	980 hPa – 1.300 hPa

3.2.2 Thermal Environment

The temperature of the interior of the capsule is continuously monitored and is in general maintained at room temperature (RT). In winter, during the evacuation process, the temperature can drop to 0 °C. Therefore, for sensitive experiments the inside of the capsule can be heated up to RT. Experiments can be connected to a thermal liquid circuit, which is connected to a thermostat outside of the tube. Through closed loop regulation, the temperature can be adjusted to between –20 °C and +60 °C. The circuit is disconnected about 90 seconds prior to the drop command. An onboard heat exchanger with about 1 kW power can be made available.

Table 3-2: Technical data of the thermostat

PARAMETER	VALUE/CHARACTERISTIC
Temperature range	-20 °C to +60 °C
Liquid	Glycol/Water-Mixture
Heating power	Max. 2 kW
Cooling power at +20 °C	2.3 kW
Cooling power at –20 °C	1.2 kW
Volume of bath	19-27 litres
Maximum pressure	0.6 bar

3.2.3 Accelerations

3.2.3.1 Transition From 1g to 0g

Users who wish to initiate their experiments before the drop begins should keep in mind that the transition from 1g to 0g might create disturbing effects for the experiment. The release mechanism has been designed and revised over the years to achieve a relatively smooth transition, but for some experiments it might still create relevant disturbances (e.g. for levitation systems, experiments with long relaxation times, hardware like interferometers, etc.). Figure 3-3 shows typical accelerations immediately after release of the capsule.

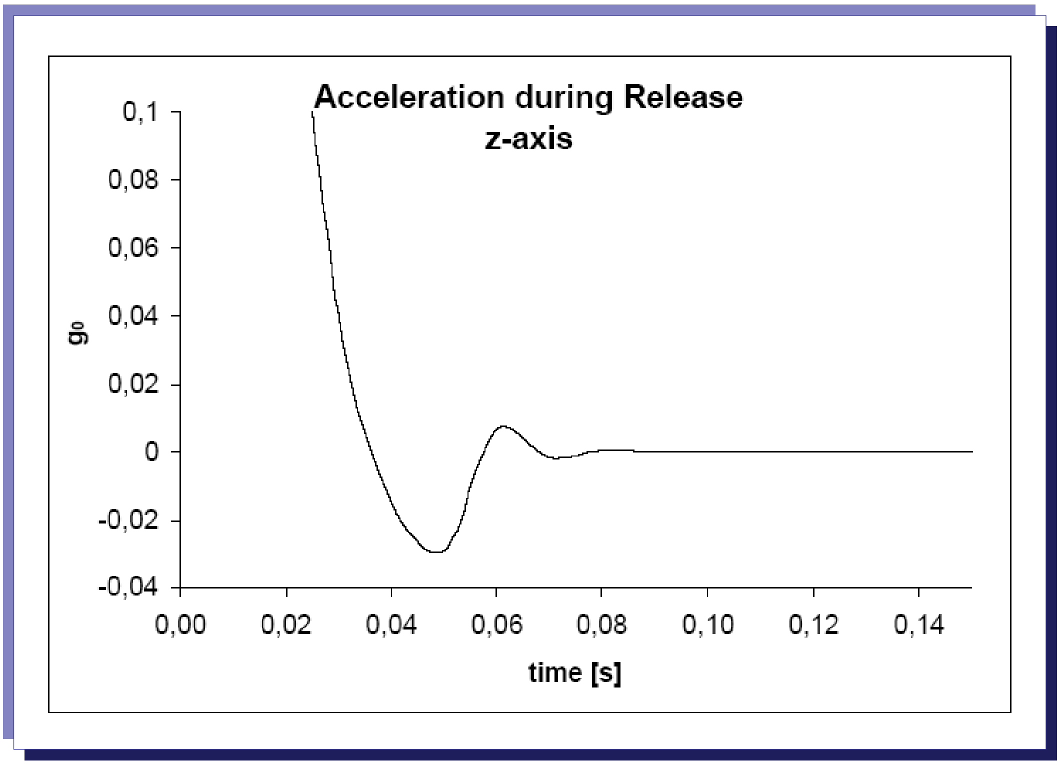

Figure 3-3: Typical accelerations immediately after release of capsule (Image: ZARM)

3.2.3.2 Residual Accelerations

The residual accelerations during the flight are generally as low as 10^{-6}g to 10^{-5}g. Figure 3-4 depicts the residual accelerations during the drop of the experiment. The data in Figure 3-4 and Figure 3-5 were recorded during a test drop of a capsule not containing an experiment. The capsule was equipped with batteries, a running Capsule Control System (CCS), data transmission system, sensor platform and platforms loaded with screwed steel plates to provide an experimental equivalent mass. The data presented is meant to provide the user with a reference data set.

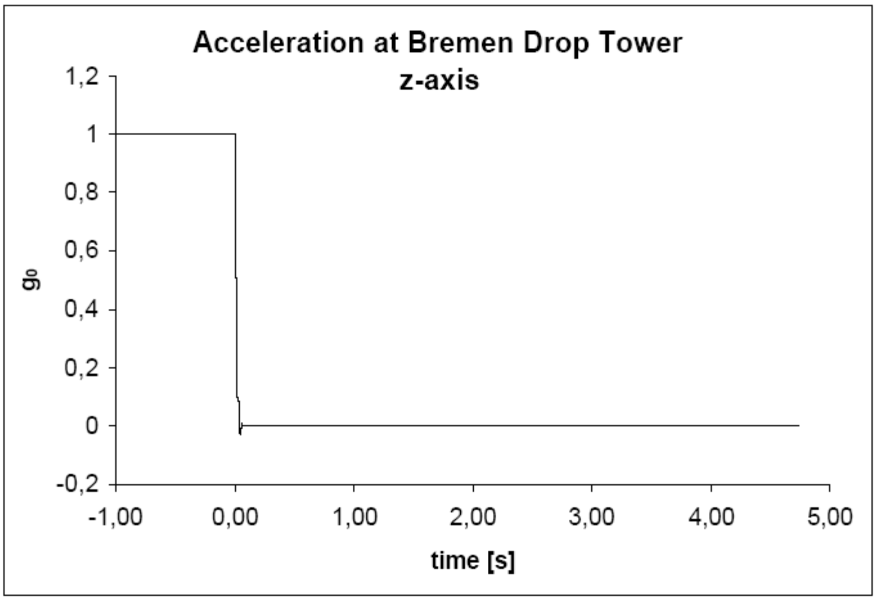

Figure 3-4: Residual accelerations during the drop (Image: ZARM)

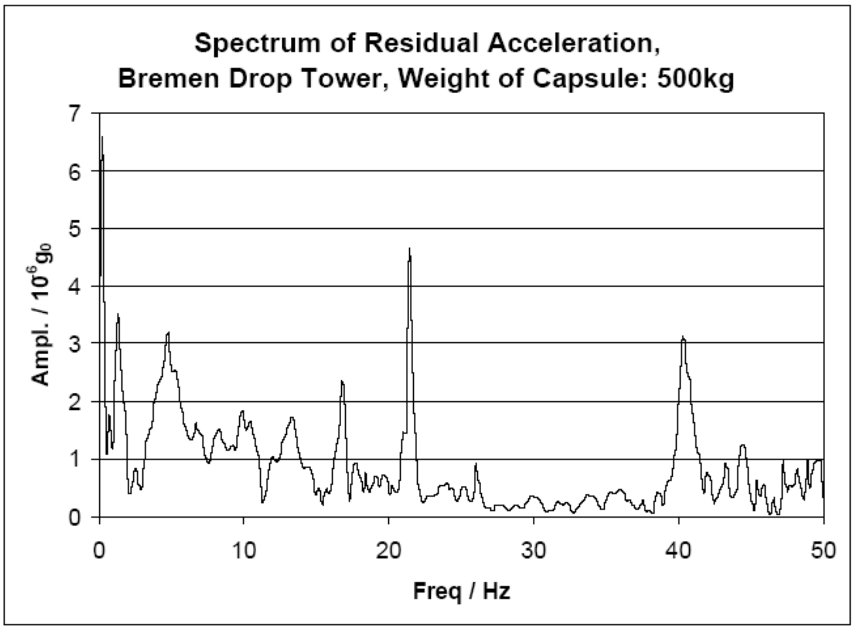

Figure 3-5: Fourier spectrum of accelerations (after end of release transition) (Image: ZARM)

3.2.3.3 Deceleration Forces

The experimental hardware must be designed and mounted to withstand the deceleration forces encountered at the end of a drop. Figure 3-6 is a typical deceleration curve of the ZARM drop tower. As can be seen, the deceleration lasts for about 0.2 seconds. The average deceleration value is approximately 25 g, and the peak value reaches about 50 g. For design purposes, these values must be considered as quasi-steady accelerations. The introduction of a safety factor of 2 is strongly recommended. Therefore, the experiment must be designed to withstand a deceleration of up to 100 g.

N.B. No damping elements are recommended: shock absorbers might lead to an amplification of accelerations. Therefore, the best design is to fix all elements together (and to the platforms) as rigidly as possible.

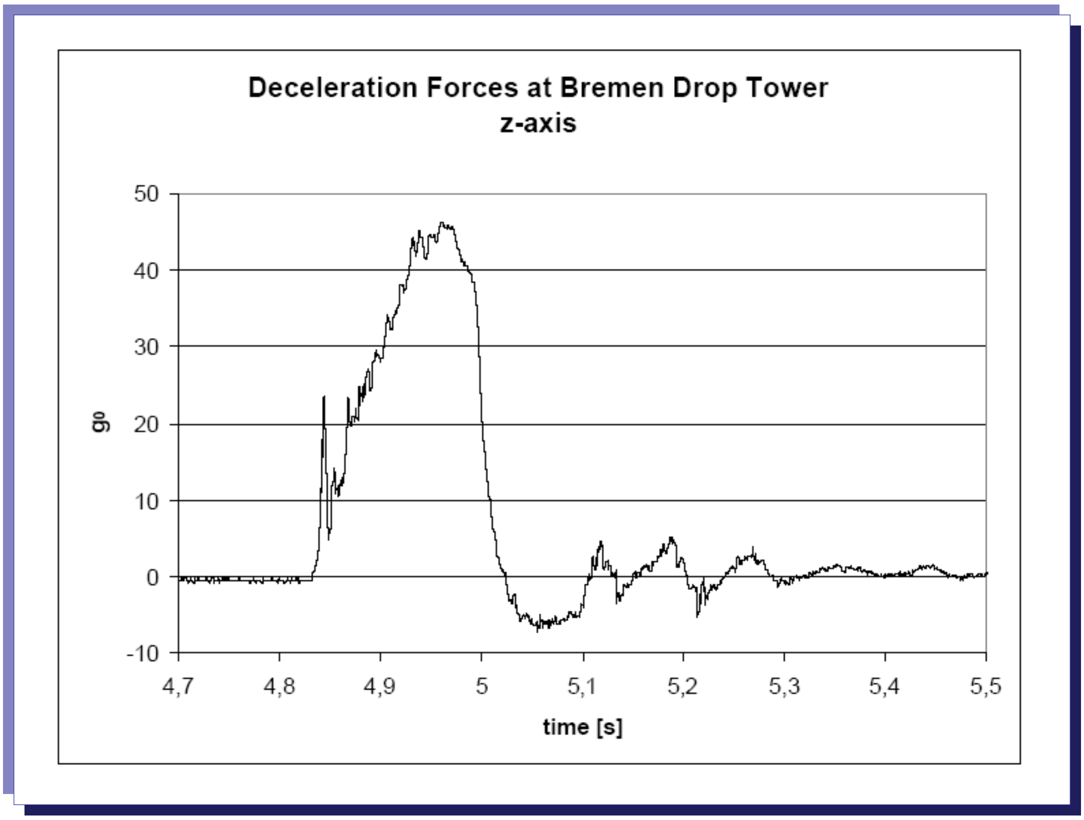

Figure 3-6: Typical deceleration plot **(Image: ZARM)**

3.3 Scientific Research Suitable to the ZARM Drop Tower

The following blocks (Figure 3-7) highlight the various scientific fields, which are suitable for research in the ZARM drop tower. It is important to note, however, that these fields are based on the data from current and past research carried out at ZARM, and should therefore NOT be considered exhaustive by the user. Scientists should view the fields presented below as a guide, and are encouraged to propose new research areas, as long as their experiments can be executed within the limitations of the ZARM drop tower, i.e. microgravity duration, payload volume and mass, costs, available support equipment and diagnostics, etc.

FUNDAMENTAL PHYSICS

Complex plasmas and dust particle physics
- Aerosol particle motion
- Frictional interaction of dust and gas
- Thermophoresis

FLUID AND COMBUSTION PHYSICS

Combustion
- Droplet and spray combustion
- Soot concentration
- Combustion synthesis
- Laminar diffusion flames
- Flame vortex interaction
- Fuel droplet evaporation

Structure and dynamics of fluids & multiphase systems
- Pool boiling
- Multiphase flows
- Heat and mass transfer
- Dynamics of drops and bubbles
- Thermophysical properties
- Interfacial phenomena
- Isothermal capillary flows
- Extensional flows
- Dynamics and stability of fluids
- Liquid bridges
- Evaporation
- Ferrofluids
- Electromagnetics
- Complex dynamic systems
- Thermomagnetics
- Surface forces and adhesion

MATERIALS SCIENCE

Thermophysical properties

New materials, products and processes
- Polymers
- Melt processing
- Metallic foams

BIOLOGY

Cell and developmental biology
- Gravitaxis and gravikinesis

Figure 3-7: Research fields carried out in the Drop Tower, based on past experiments

3.4 Payload Accommodation

3.4.1 Mechanical Aspects of the Drop Capsule

The user experiments are accommodated in a specially designed drop bus, which is pressurised to atmospheric pressure and is shockproof to withstand the deceleration forces.
The base structure (see Figure 3-8 and Figure 3-9) consists of the Capsule Control System CCS (the electronic interface between experiment and experimenter), the switchable power supply EPC (Experiment Power Control unit) and the radio telemetry/telecommand system with parabolic microwave antenna mounted within the nosecone.
The different parts of an experiment are assembled on platforms (shipped to the user's lab prior to a campaign for experiment pre-assembly), which are then successively connected to the four stringers of the rig (two possible heights). Finally the stringer rig is set onto the base structure and fixed. Once at the drop tower, all electrical and electronic connections are positioned between the platforms and the base structure along the stringers.

At the beginning of the mechanical design of a drop tower experiment, the following technical data and limitations must be kept in mind:

- The overall weight of a platform (including the platform itself) may not exceed 100 kg;
- The point load of a platform (at the centre) may not exceed 50 kg;
- The distribution of mass should be even;
- The distance between the lower end of the stringers and the underside of the lowest experiment platform may not be less than 420 mm;
- Ensure that all platform holders of one platform are exactly on the same level;
- The overall height of the experiment may not exceed 980 mm (short capsule) or 1730 mm (long capsule). See Figure 3-9;
- The maximum overall mass of the drop capsule is 500 kg. (Maximum payload mass – short capsule = 274 kg, Maximum payload mass – long capsule = 234 kg).

Table 3-3: Masses and dimensions of drop capsule

PARAMETER	SHORT CAPSULE	LONG CAPSULE
Stringer length (mm)	1545	2310
Mass of base structure including CCS and batteries (kg)	110	110
Mass of lid plate (kg)	36	36
Mass of pressurising cover and connection elements (kg)	32	54
Mass of 4 stringers (kg)	42	60
Mass of nose-cone with antenna (kg)	6	6
Mass of 1 platform with connectors (kg)	15.5	15.5
Net mass of capsule (kg)	226	266
Maximum capsule gross mass (kg)	500	500
Maximum payload mass (kg)	274	234

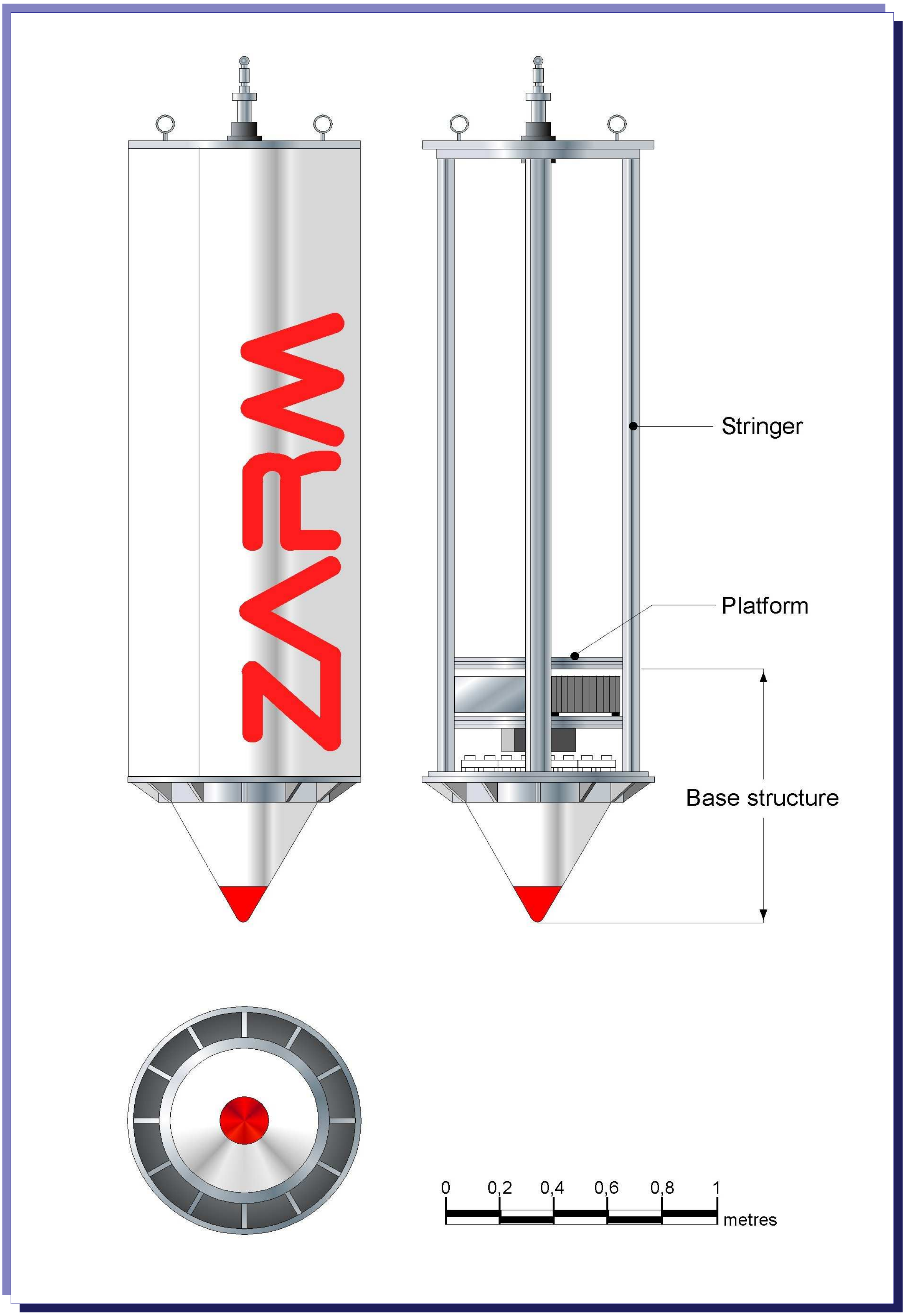

Figure 3-8: Standard drop capsule – Long version (with and without pressurising cover)

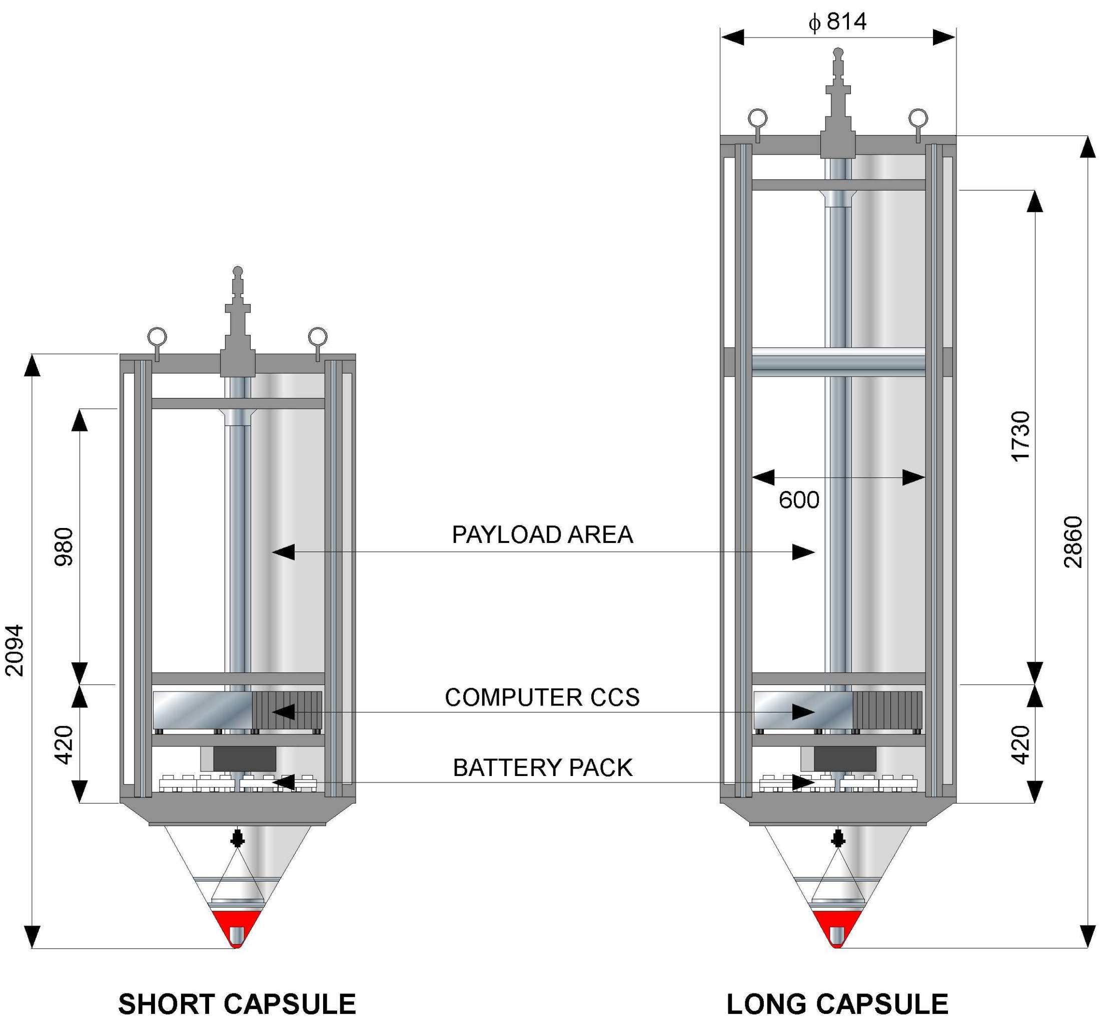

Figure 3-9: Dimensions of the Short and Long drop capsules

3.4.1.1 Experiment Platforms

The experiment platforms (see Figure 3-10) used to integrate experiments into the drop capsule are made of an aluminium/plywood/aluminium compound sandwich material. These platforms can withstand the deceleration forces encountered in the ZARM drop tower and also provide rapid damping of release-induced oscillations. Experimental parts can be fixed safely on or underneath the platforms. Users are also allowed to drill holes into the platform if large assemblies require this. Users cannot construct platforms of their own, and must use those provided by ZARM.

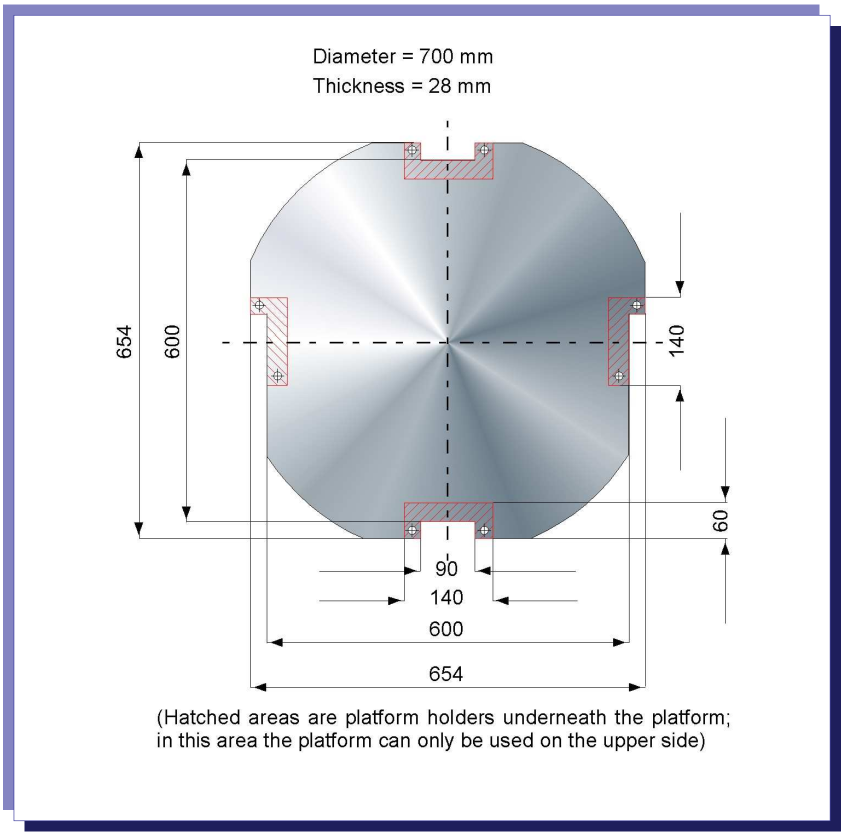

Figure 3-10: Experiment platform

3.4.2 Electrical Aspects of the Drop Capsule

The experiment power supply can either be provided by the capsule's 28V rechargeable Experiment Battery or by the High Current External Power Supply (see: Available Facilities and Resources). The onboard battery-pack is of the lead-gel type, with a nominal capacity of 25 Ah. The experiment is connected to the battery-pack via the Experiment Power Control unit (EPC).

3.4.2.1 Experiment Power Control Unit (EPC)

The EPC unit provides nominal 28V DC power to the experiment. During the evacuation period the battery is buffered with a maximum of 10 Amperes by the Battery Load Power Supply, which is disconnected about 90 seconds prior to the drop command. Three output channels with up to 40 Amperes each can be switched via telecommand. If power switching is required, 3 Digital-Out channels of the CCS are needed. The channels are protected by slow 40 Ampere fuses. This is only to protect the batteries against short circuits. The protection of the user hardware with proper fusing is the responsibility of the user.

Experimental hardware connected directly to the power supply must have the following limitations:

- Operational voltage range: 26.4 V to 35 V DC;
- Maximum current per channel: 40 Amps;
- Electric strength: 38V DC.

The actual voltage of the battery results from the initial charge status and the actual discharge as a function of time. For cases in which input sensitive hardware is used, DC-DC converters are recommended. All power consuming items must be grounded to one identical point on each platform.

3.4.2.2 Electromagnetic Compatibility

The electromagnetic emission levels of the experiment should be as low as possible. It is in the user's own interest to reduce susceptibility and emissivity by following these simple design guidelines:

- Avoid ground loops;
- Separate alignment for power, data and switch commands;
- Twist and/or shield emissive or susceptible lines;
- Shield emissive or susceptible experiment components;
- Avoid sparks and rapid electric charge transitions.

3.4.3 Electronic Aspects of the Drop Capsule

3.4.3.1 Experiment Control

Experiment control is enabled via the Capsule Control System (CCS). The engagement of the CCS into experiment control is mandatory. The CCS operates like a storage-programmable logic controller including data handling and the telemetry/telecommand management. The CCS offers virtual serial interfaces to enable embedding of user delivered electronic hardware. In cases where the performance of the CCS is not appropriate, e.g. in terms of sampling rate or resolution, the user is requested to implement the needed hardware into his set-up. Triggering of the user hardware (all mechanical or electronic elements) is to be done by the CCS. The timeline programme for automatic experiment control will be developed on site in close co-operation with the user. The specially developed software package SEPPEL (Scientific Experiment Process-control Programming Environment Language) is easy to use and enables the implementation of conditional logical operations related to all in and out channels of the CCS. This includes also the housekeeping data channels. The SEPPEL-Compiler then produces the operation software controlling all hardware elements. The SEPPEL-programme is a cyclic programme. The time for one cycle, which is the response time to changes of experiment conditions or interactive experimenter commands, depends on the length of the programme and is typically below 10 milliseconds. The number of user programmes running in parallel and independently is not limited. The definition of common variables allow for synchronisation of the programmes. After loading of the SEPPEL-script into the CCS, the telemetry/telecommand line can be interrupted without affecting the programme operation. Access to the CCS is password protected to prevent from unauthorised interference with the programme.

3.4.3.2 Capsule Control System (CCS)

After integration of the experiment into the mechanical structure, the experiment becomes connected to the CCS. The CCS is a modular system configured according to the experiment requirements. The definition of 'out' and 'in' channels is from the CCS point of view. Therefore 'out' means signals from the CCS to the experiment, and 'in' means signals from the experiment to the CCS. Connection to the CCS is established via digital and analogue channels. The digital channels are for experiment control and display the status of digital elements (switches). The analogue channels are for experiment and housekeeping data acquisition. Analogue out channels can also be used for experiment control (e.g. mass flow controllers).

3.4.3.3 Virtual Serial Interface

Two serial interfaces of the RS232 specification are available for the experiment. The interfaces enable serial data transmission between experiment and external equipment at the ground-station. The transmission parameters can be adjusted at the ground-station.

3.4.4 Safety Requirements

Even though the safety requirements for drop tower experimentation are minimal, the user must examine the set-up to identify potential hazards.

The major rules to be applied are summarised below:

- Gaseous fuels and oxidizers must be stored in different containers. Ignitable premixture storage is prohibited;
- There are no general pressure limits for gas reservoirs, but pressurised reservoirs must be certified by the technical survey of the user's country. In case this does not exist or the request is inappropriate, the user must be able to handover the technical standards related to the design on request;
- If hazardous gases are used, an appropriate gas detector to monitor leakages must form part of the set-up;
- The release of toxic, corrosive, explosive or biohazardous, contaminating matter into the capsule or to the outside of the capsule is prohibited. The user is in any case requested to nominate potential hazards for the drop tower crew's safety;
- Solenoid valves must be implemented into pressurised liquid circuits containing hazardous matter;
- The use of mercury or unstable mercury containing mixtures is generally prohibited;
- Batteries must be of the dry or gel type. Liquid electrolytic batteries will be refused;
- The centre of gravity of the set-up shall be on the vertical axis of the capsule;
- Change of motion of masses during free-fall must be avoided. If this cannot be achieved, accelerations must be compensated for by accelerating counter-weights on or around the identical axis;
- Experiments that are mechanically weak and cannot be reinforced on-site will be refused;
- Every electrical element (valves, detectors etc.) subjected to hazards or hazard control must be connected to the CCS. As any computer, the CCS is not totally failsafe. Therefore the experiment shall be in general designed as failsafe as possible.

3.5 Available Facilities and Resources

At the ZARM drop tower, facilities and special equipment can be made available to the users upon request. They include the following:

3.5.1 Laboratories, Workshops and Workplace

ZARM has various laboratories and laboratory equipment that are placed at the disposal of the users. The laboratories include a laser-lab, a bio-lab, a chemistry-lab and a crystallography-lab. There are two major workshops:

- A fine mechanics workshop with state-of-the-art machinery that can be used by scientists to carry out changes, repairs and adaptations to their hardware;
- An electronics laboratory that is equipped to develop and build space proof hardware.

Any drop tower user will be provided with an integration area consisting of workbenches, tools and Electronic Ground Support Equipment (EGSE). The EGSE allows users to perform ground experiments, which follow the same procedures as in the tower, under identical conditions (except for weightlessness), as often he/she requires.

3.5.2 Accommodation

ZARM offers reasonably priced onsite accommodation in the form of an apartment. The apartment is equipped with a shower, phone, satellite-TV and a kitchen. Alternatively, ZARM-FABmbH can make hotel, guesthouse or vacation-house bookings on behalf of users at special prices.

3.5.3 CCD-cameras, VCRs, Lenses

Colour CCD-cameras and appropriate lenses are available onsite. The cameras are aimed at complementing the experimental hardware during integration or during the drop campaign. The cameras are of the CCIR-standard. Only PAL-standard VCRs are available. Video standards used are video8 or Hi8.

3.5.4 Digital High speed CCD systems

A digital (non-standard) video recording system is available at ZARM.

3.5.4.1 Camera Specifications

- DALSA CA-D1-0256 A;
- Area-Scan Camera, 256x256 pixel;
- 1x8-Bit Digital RS422- Out;
- A/D-Board L244, 1x15MHz Data rate;
- Maximum 225 Hz frame rate (internal or external trigger);
- Pixel size 16µm square;
- Frame-Transfer-Sensor.

3.5.4.2 Recorder Specifications

- DigVid;
- Housing (H x W x D): 180mm x 250mm x 450mm (including space for connectors);
- Mass: 2 kg;
- BIT Run-PCI-24 digital interface board, 32 Bit RS422 Input 30MHz;
- BIT CONN-RUN CAM2D, Adaptor for a second camera with up to 16 Bit and differential interface;
- Frame rate: maximum 225 frames/s with one or two synchronised cameras;

- Maximum recording time with two cameras and maximum frame rate: 1 minute;
- Interface for external start-stop Trigger and single image triggering;
- Control software for parameter settings of grabbing and play function;
- Power supply for two cameras and DigVid included.

3.5.5 Non-standard Voltage/Current supply

The High Current Power Supply supplied by ZARM, can be used as an external power supply providing 28V DC with up to 100 Ampere. Switching of current is performed with ramps. This power supply is disconnected from the capsule about 90 seconds prior to the drop command.

3.5.6 Vent-Line

Experiments releasing gases (e.g. from cryogenic devices or combustion exhausts) can be connected to a vent-line. The connector is located at the cover plate. The gases can then be guided to the outside of the drop tube or released to the ambient vacuum. To avoid thruster effects during free-fall, the vent-line must be closed prior to release of the capsule. During the free-fall, gases must be stored in onboard containers (provided by the user). Non-contaminating cryogenic gases or combustion exhaust gases that are free from particulates (e.g. soot, PIV-tracers) can be released inside the capsule during free-fall.

3.5.7 Pressurised Air Reservoirs

Pneumatic elements of an experiment can be powered via special stringers, designed to serve as reservoirs for pressurised air. This avoids using additional volume-consuming reservoirs.

3.5.8 Micro-g Centrifuge

Experiments that require data to be obtained during accelerations between 0g and 1g can make use of a specially designed onboard micro-g centrifuge. The centrifuge consists of a rotating platform, with adjustable rpm level, equipped with a number of slip-ring transducers for electrical power and signal transmission between the rotating platform and capsule.

3.5.9 Free-Flyer

Experiments that require levels of residual accelerations less than 10^{-6} g can be installed onto a free-flyer module, which is mounted within the drop capsule. The free flyer is released after the release of the drop capsule and is captured again just prior to deceleration.

3.5.10 Combustion Research Laser Diagnostics

The drop tower is equipped with a laser diagnostic system (see Figure 3-11) for combustion experiments. It enables users to perform PLIF-diagnostics with a repetition rate of up to 250 f/s during a drop. It consists of:

- A tuneable laser system attached to the upper end of the drop tube;
- A mirror and a pointing system for the establishment of a stable light sheet in the capsule throughout the drop period;
- An intensified digital high-speed camera system (8bit conversion rate) onboard the capsule.

Accurate synchronising of the camera gating with the laser pulses is done onboard of the capsule. The laser delivers tuning in the 193nm, 248nm and 353nm bands. Within each band, pulse-to-pulse switching of the excitation wavelength is possible by means of an oscillating grid attached to the tuning unit of the laser. For more information users should visit the following web site:
http://www.zarm.uni-bremen.de/combustion.html

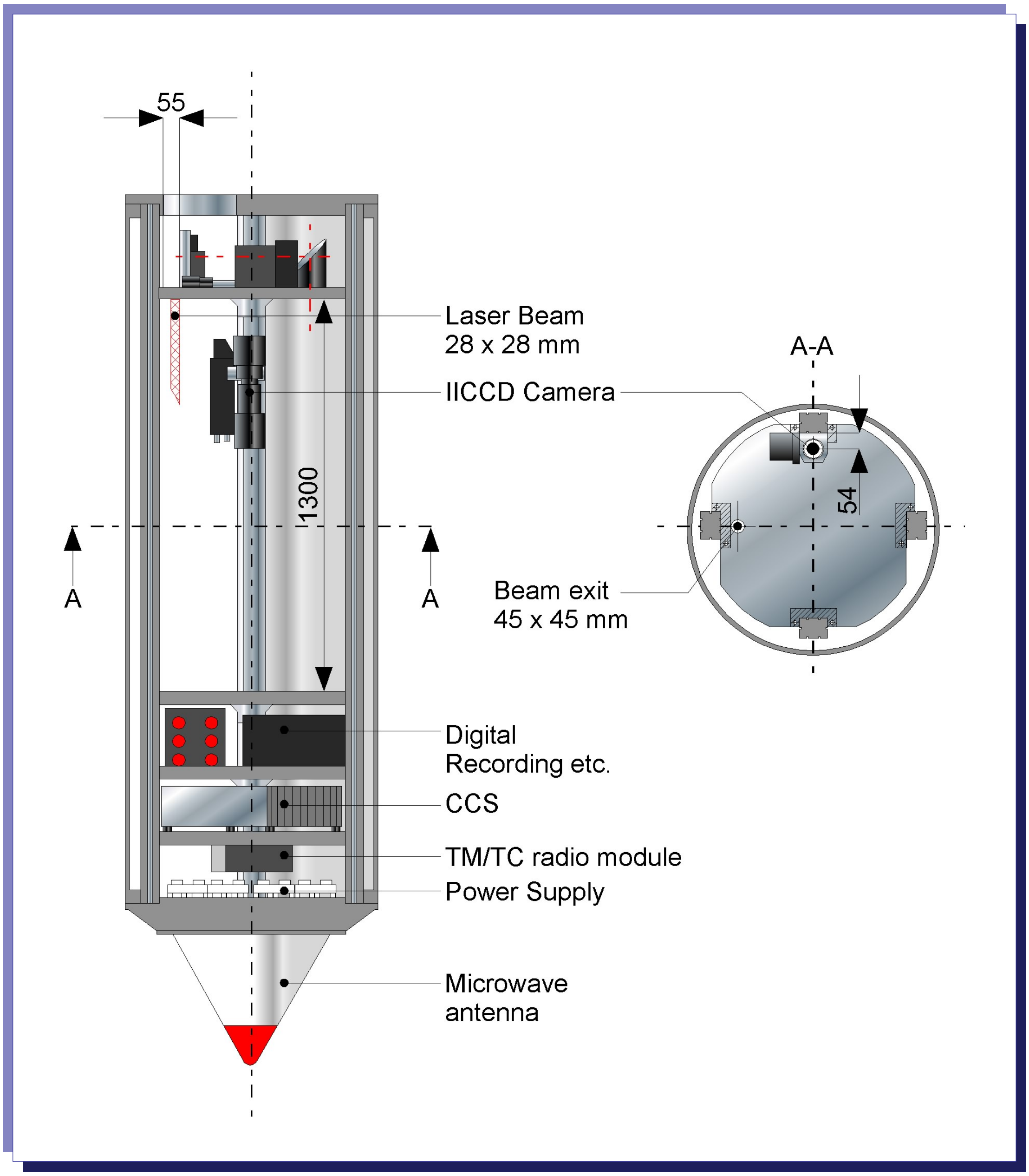

Figure 3-11: Laser diagnostic capsule. Payload area limited to a height of 1300mm

3.6 Payload Life Cycle and Major Milestones

The payload life cycle varies from experiment to experiment, and depends strongly on the complexity of the hardware as well as the channel through which access has been obtained to execute experiments in the ZARM drop tower. Based on the data relative to campaigns carried out in the past, the period that elapses from the moment in which the scientist contacts ZARM for the first time to the execution of the first drop varies between 4 weeks and 12 months. But, from an analysis of past experiments, an average period of 6 months can be considered as a reference value. Also, experiments, which are not being carried out for the first time, will have a reduced integration time.

Figure 3-12 represents a typical timeline of an experiment, aimed at providing users with an overview of the major milestones. The user must keep in mind that, although the tasks displayed in the timeline are standard, the periods are based on a generic case, and will differ, as described above, from experiment to experiment. The timeline is given in terms of weeks with respect to the start of the tower drops (L).

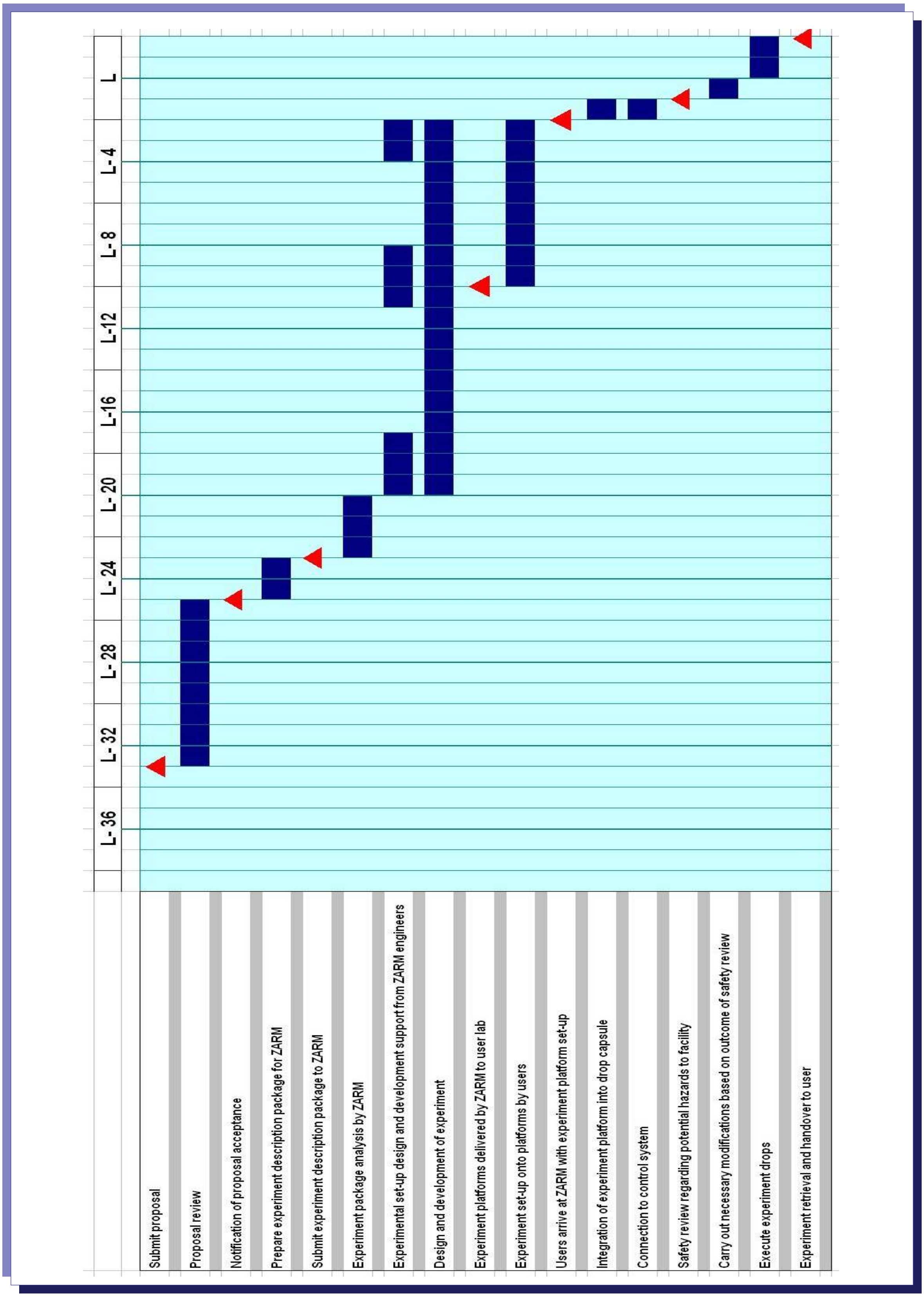

Figure 3-12: Typical timeline for an experiment in a drop tower campaign

3.7 Utilisation/Operational Cycle of the ZARM Drop Tower

The following is a general outline of the main utilisation and operational events involved in a campaign at the ZARM drop tower.

- Users prepare and submit a research proposal on the basis of the information provided in section 2;
- Once a proposal is accepted, ZARM-FAB mbH is contacted and given a description of the intended research (text, schemes, drawings);
- The ZARM-provided experiment platform(s) are shipped to the user's lab;
- Preassembly of platforms is carried out by the users;
- After the campaign has been scheduled, the user is expected at the drop tower at least 10 working days before the first drop. This time is needed for integration and ground testing;
- The drop tower is operated with three drops per day (not necessarily with the same experiment);
- Each week has 4 operation days – the Monday is reserved for system maintenance;
- Each drop sequence, which is defined as the period between handover of the capsule to the operator and then back to the user, lasts 4 hours including safety margins. The handover times are 8 a.m., 12 a.m., and 4 p.m. A handover delay of more than 30 minutes caused by the user will lead to cancellation of the drop from the schedule, and will count as a performed drop. Therefore, users are encouraged to carefully monitor the preparation time required before scheduling a campaign;
- After handover of the set-up to the operator, the capsule will be closed;
- Experiments requiring a drop (as opposed to the catapult) are connected to the winding mechanism and lifted to the top of the tower. During this process the user will not have access to the experiment for about 15 minutes;
- After reaching the top end of the tower, the telemetry/telecommand line is checked and remote access is established. The experiment is now connected to all interfaces;
- About 2 hours after handover to the operator, the evacuation process will terminate, having achieved a final pressure of < 10 Pa within the drop tower. The user now takes over operation and can drop the assembly whenever ready. The user and operator work at the same desk and can discuss the procedure together;
- During the drop, all the data can be stored onboard, otherwise it can be downloaded for evaluation after the drop via the telemetry line;
- After the drop the tower is reflooded with air;
- About 45 minutes later, the capsule is retrieved, opened and handed back to the user. The user team will then do a final check of the hardware;
- A single campaign is usually made up of 8 to 24 drops (1 to 3 weeks, two drops a day). This varies from experiment to experiment;
- For a new experiment it is suggested to first carry out a shorter campaign, review the experiment and then move on to a longer campaign. This enables the user to optimise the hardware and thus the scientific output;
- At the end of the campaign, the user team and operator team dismantle the set-up. All parts developed at ZARM will be stored for a possible successive campaign.

The utilisation cycle is summarised graphically in Figure 3-13.

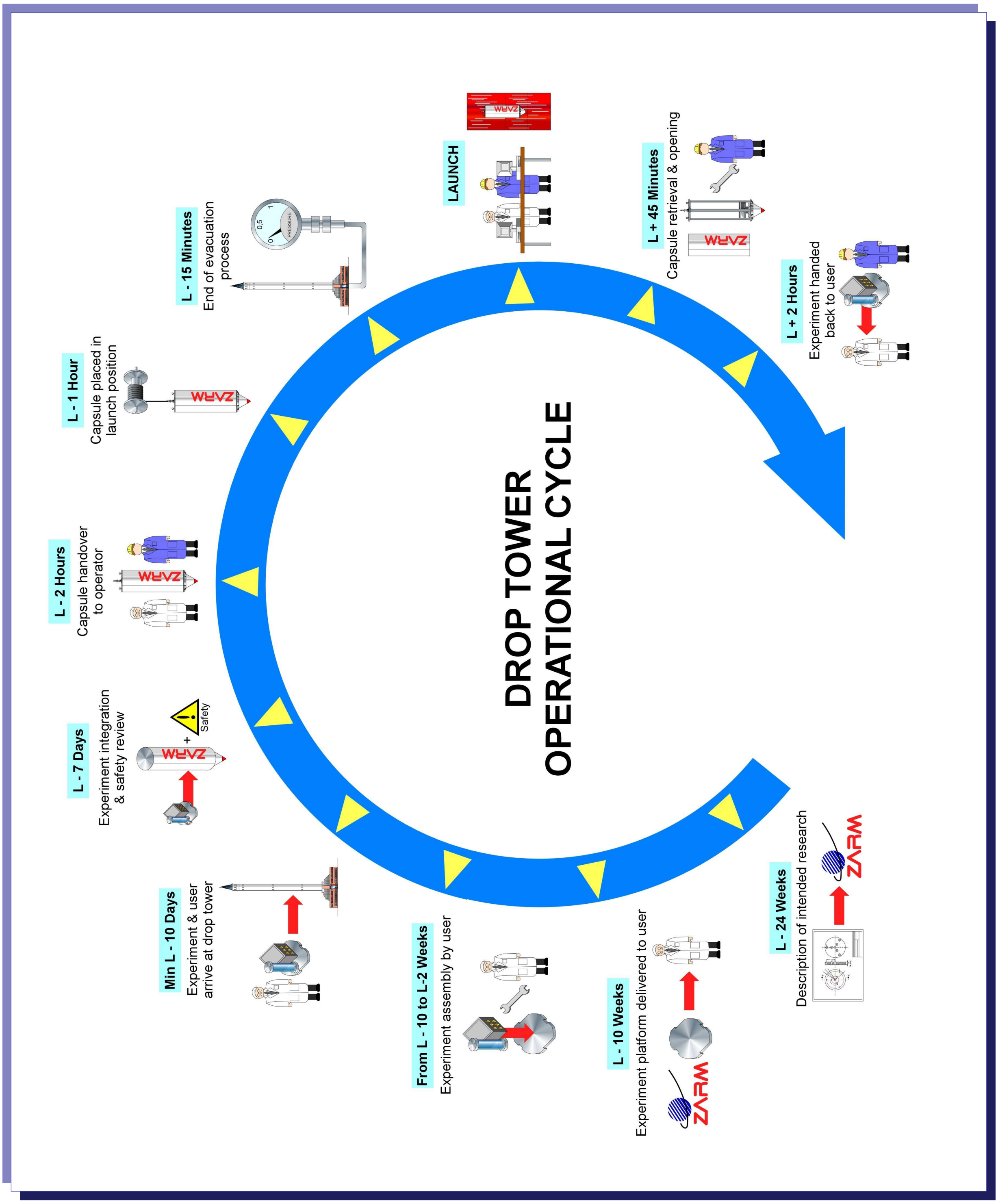

Figure 3-13: Drop Tower utilisation/operational cycle

3.8 References

Users can refer to the following documents and web addresses for further information regarding the ZARM drop tower and relative research.

1. ZARM Internet Home Page - http://www.zarm.uni-bremen.de/
2. "ZARM Drop Tower Bremen User Manual", Version 10, July 2003, Drop Tower Operation Service Company ZARM FABmbH, Bremen
3. "ZARM Drop Tower Bremen General Information", Version 28, April 2000, Drop Tower Operation Service Company ZARM FABmbH, Bremen
4. "A world without gravity", G. Seibert et al., ESA SP-1251, June 2001
5. Erasmus Experiment Archive (EEA) Internet address: http://www.spaceflight.esa.int/eea
6. Erasmus User Information Centre Internet Home Page: http://www.spaceflight.esa.int/users/
7. "Facilities for Microgravity Investigations in Physical Sciences supported by ESA", ESA SP-1116, March 1995.