

→ 4 DROP TOWER

This chapter provides a guide to the ZARM (Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation – Centre of Applied Space Technology and Microgravity) drop tower, located in Bremen, Germany, which was officially declared an ESA External Facility on 2 October 2003. The chapter begins with a brief introduction to drop towers and drop tubes.



Image 4-1: ZARM drop tower in Bremen

Drop tower

9.3 s microgravity time
 10^{-6} g low gravity environment
400 drops/year
20 experiments/year
264 kg max payload mass

4.1 Introduction

4.1.1 What are drop towers?

Drop towers are ground-based research facilities with which free-fall conditions can be achieved. In the case of the ZARM drop tower, up to ten seconds can be achieved.

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 and friction forces. 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.

4.1.2 What do drop towers offer?

Drop towers provide:

- facilities for experiments that require relatively short microgravity time;
- precursor opportunities for carrying out research in preparation for long-duration missions;
- low-cost access to research in microgravity 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;
- relatively easy to handle safety requirements;
- a high quality low gravity environment ($< 10^{-6}$ g in the case of the ZARM drop tower);
- a platform for new ideas in the field of microgravity research.

4.1.3 Why use drop towers?

The main reason for using 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 moving on to more costly, long-duration missions. Even though the time of weightlessness to perform experiments is only in the order of seconds, the level of microgravity obtained is of extremely high quality, providing good scientific data.

4.1.4 Principal characteristics of the ZARM drop tower

The ZARM drop tower is a 146 m tall concrete tube shaft (Figure 4-1), which provides near weightlessness up to three times a day, for experiments dropped from the top of the tower (4.74 seconds of microgravity) or catapulted upwards from below the tower (9.3 seconds), respectively. In September 2004, a catapult system was inaugurated at the ZARM drop tower (Figure 4-2), which doubled the standard drop microgravity time,

and is located in a chamber 10 metres 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 400 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 and operation mode chosen. Inserted platforms, held in aluminium frames, form the modular drop tower 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

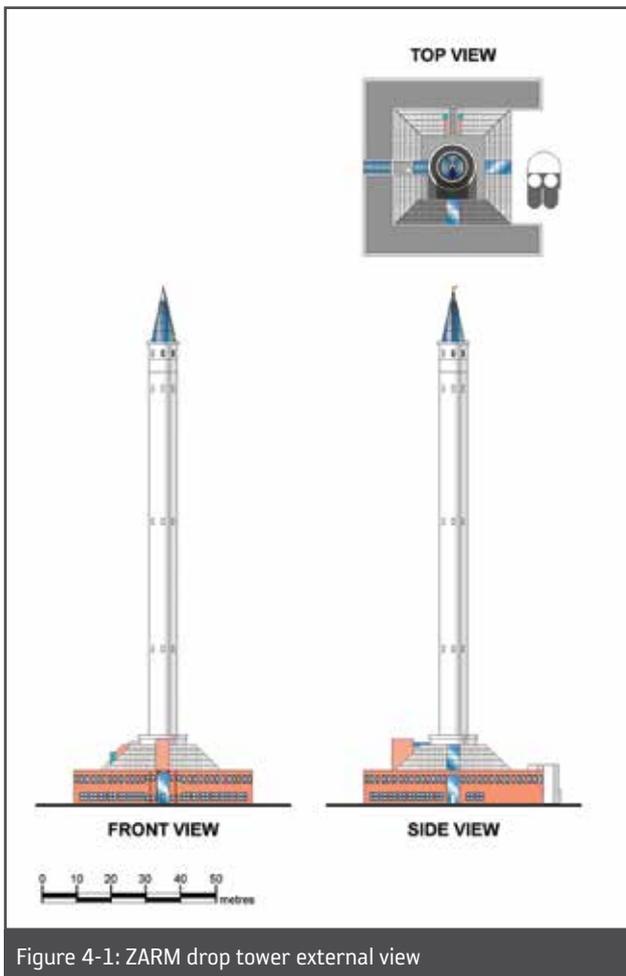


Figure 4-1: ZARM drop tower external view

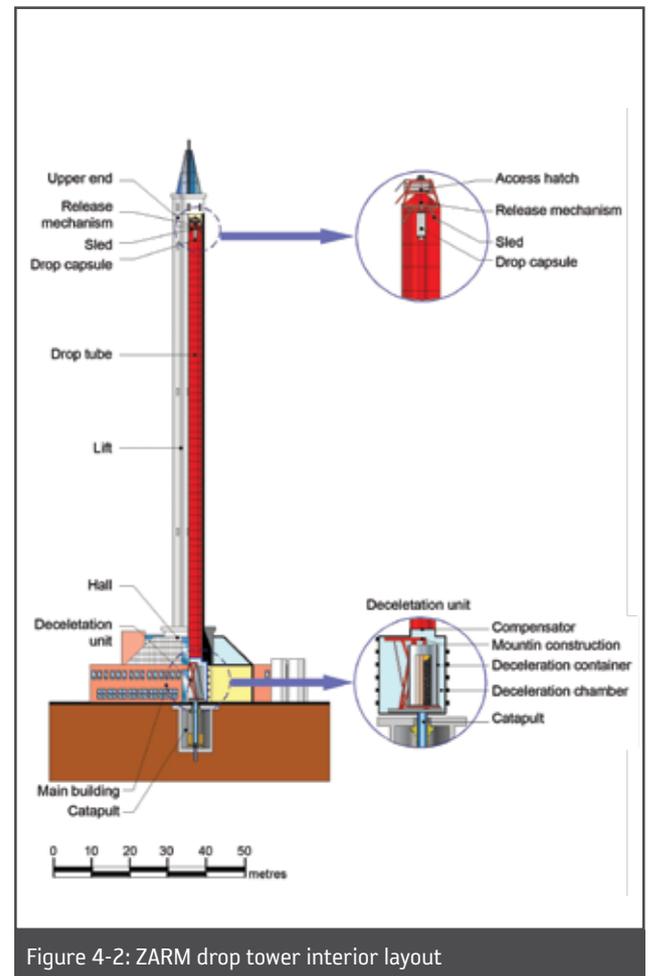


Figure 4-2: ZARM drop tower interior layout

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 catapult launch and the capsule is released/ catapulted at a residual pressure of 10 Pa. The internal tube, which has a volume of 1700 m³, 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 catapult launch, an ultimate microgravity quality with a residual acceleration of 10⁻⁶ g can be detected. At the end of the experiment, an 8 m high deceleration unit, filled with polystyrene pellets, decelerates the vehicle.

4.2 Physical environment

4.2.1 Pressure environment

The drop tower 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 or catapult launch 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 4-1: Drop tower environment pressure parameters

PARAMETER	VALUE
Nominal capsule pressure (p)	1013 hPa
Pressure loss (dp)	< 1 % in 3 hours
Safety range (p)	980 hPa – 1300 hPa

4.2.2 Thermal environment

The temperature of the interior of the capsule is continuously monitored and is in general maintained at room temperature. 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 room temperature. 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 launch command. An onboard heat exchanger with about 1 kW power can be made available.

Table 4-2: 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

4.2.3 Accelerations

Accelerations are relevant in three aspects:

- transition from 1 g to 0 g (drop mode) / Transition from approx. 30 g to 0 g (catapult mode)
- residual accelerations
- acceleration / deceleration forces

a) If experiment initiation is required to be prior to the drop, the experimenter is requested to keep in mind that the transition from 1 g to 0 g (drop mode) might be of disturbing effect to the experiment. The release mechanism has been designed and revised over the years in order to achieve a smooth transition. Nevertheless, for some experiments it might still be of relevance (e.g. for levitation systems, experiments with long relaxation times, hardware like interferometers that might become misaligned if not loaded by 1 g).

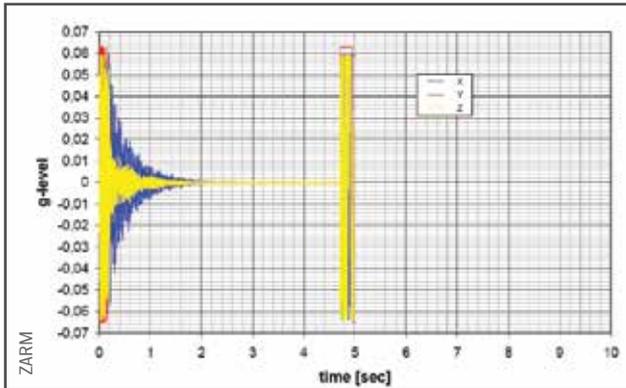


Figure 4-3: Typical drop experiment, residual accelerations, Y is drop axis, X and Z are cross axes.
 Note: The high sensitive acceleration sensors are overloaded at the beginning, after about 0.2 seconds they are within the measurement range

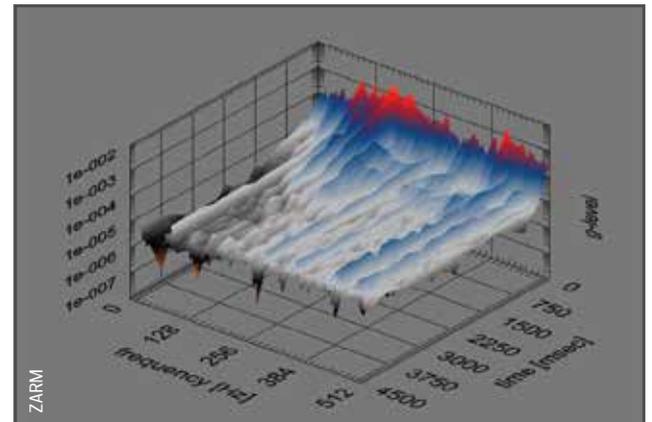


Figure 4-5: Waterfall amplitude spectrum of drop axis, free fall (ref. Fig. 4-3)

This is more if the catapult is applied with an initial transition from 30 g to 0 g.

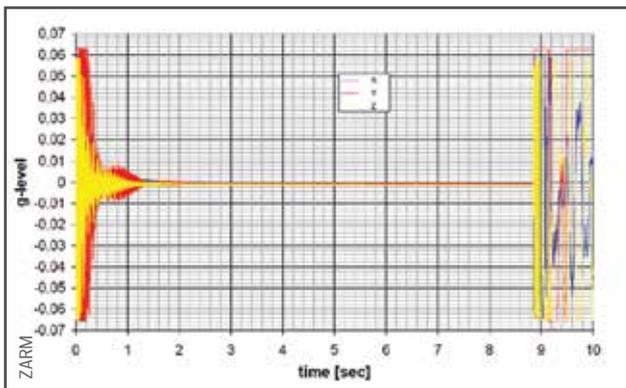


Figure 4-4: Typical catapult launch, residual accelerations, Y is drop axis, X and Z are cross axes.
 Note: The high sensitive acceleration sensors are overloaded at the beginning, after about 0.2 seconds they are within the measurement range

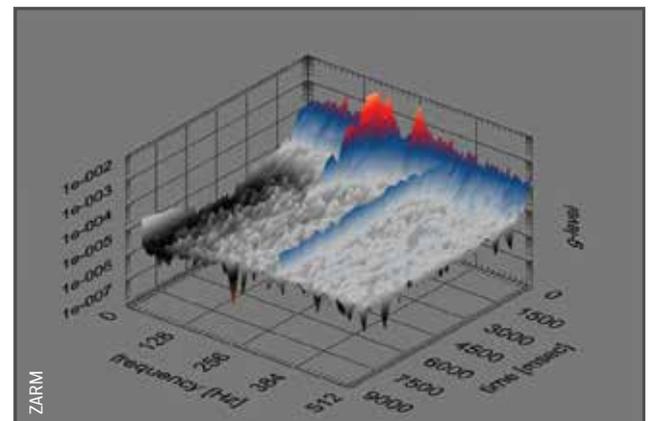


Figure 4-6: Waterfall amplitude spectrum of drop axis, catapult launch (ref. Fig. 4-4)

As shown in Figures 4-4, 4-5 and 4-6, the residual acceleration and damping rate during the flight phase of a catapult experiment is not worse than in a drop experiment.

b) The residual accelerations (microgravity quality) during the flight are as low as 10^{-6} to 10^{-5} g. This is to the best values amongst the microgravity facilities. Figure 4-3 depicts the residual accelerations during the experiment. The data as well as those from the Fourier spectrum were grabbed during a drop of a capsule without experiment. The capsule was equipped with batteries, running CCS, data transmission system, sensor platform and platforms loaded with screwed steel plates of an experiment comparable mass. These data can serve as reference environment data.

c) The experimental hardware must be designed and mounted enabling to withstand the acceleration/deceleration forces. The following graphs depict typical acceleration/deceleration curves of Bremen drop tower. As can be seen (Fig. 4-8), the deceleration lasts for about 200 ms. The average value is 25 g, the peak value is about 50 g. For design purposes, these values must be handled as quasi-steady accelerations.

The introduction of a safety factor of two is strongly recommended. Therefore the experiment shall be able to withstand acceleration up to 100 g.

Please keep in mind, that qualification equipment is not available at stores. All given shock resistance values are in accordance with military standards. These were tested against shock (<11 ms) and oscillations which are incomparable to quasi-steady accelerations. The drop tower acceleration/deceleration forces are of minor effect compared to oscillatory accelerations of the same order of magnitude. In contrast, military standard approved equipment might fail as shock absorbers are often implemented. In the drop tower case, shock absorbers might lead to an amplification of accelerations. The best design is to fit all elements together (and to the platforms) as rigidly as possible. No damping elements are recommended.

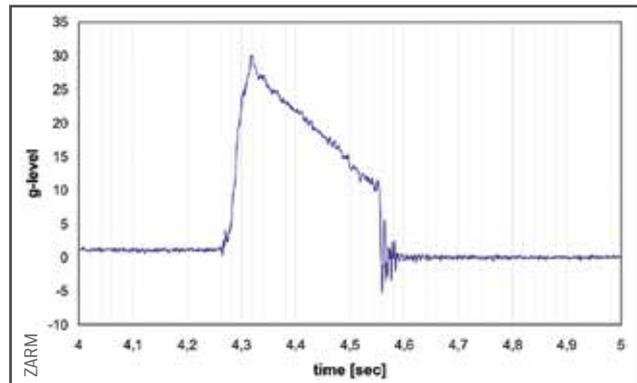


Figure 4-7: Typical acceleration plot, capsule is launched by the catapult system. Note: The delay time of about 4 sec after initialization of launch

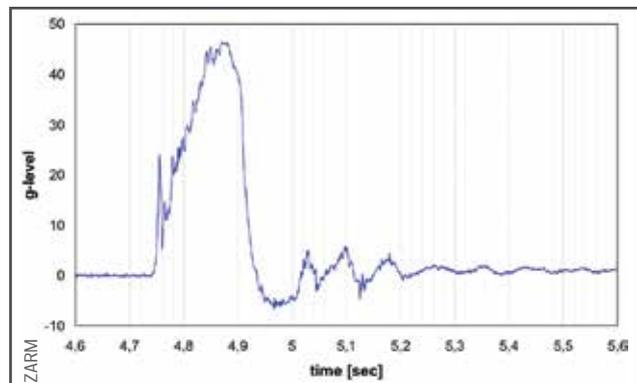


Figure 4-8: Typical deceleration plot, capsule slowing down inside the deceleration container

4.3 Scientific research topics suitable to the ZARM Drop Tower

Figure 4-9 highlights 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.

For more information on drop tower experiments please visit the Erasmus Experiment Archive at the following web address: eea.spaceflight.esa.int



Image 4-2: Integrating an experiment in the drop capsule

FUNDAMENTAL PHYSICS

Complex plasmas and dust particle physics

- Aerosol particle motion
- Frictional interaction of dust and gas
- Thermophoresis

MATERIALS SCIENCE

Thermophysical properties

New materials, products and processes

- Polymers
- Melt processing
- Metallic foams

FLUID AND COMBUSTION PHYSICS

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

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

BIOLOGY

Cell and developmental biology

- Gravitaxis and gravikinesis

Figure 4-9: Research fields carried out in the drop tower, based on past experiments

4.4 Payload accommodation

4.4.1 Mechanical aspects of the drop tower capsule

The user experiments are accommodated in a specially designed drop tower bus, which is pressurised to atmospheric pressure and is shockproof to withstand the deceleration forces.

The base structure (see Figure 4-10 and Figure 4-11) consists of the Capsule Control System (CCS) - the electronic interface between experiment and experimenter - the switchable power supply PDU (Power Distribution Unit) and the radio telemetry/telecommand system with parabolic microwave antenna mounted within the nose cone.

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 (to the centre) may not exceed 50 kg;
- the distribution of mass should be even. The mass eccentricity should be as low as possible. If mass eccentricity is too high, additional counterbalance masses (accumulated to the payload) will be mounted to the rig at ZARM;
- due to safety requirements it is mandatory to balance the Catapult Capsule (CC). The procedure of balancing will take about 4 hours and will be performed on site by ZARM engineers after the setup has passed the test readiness review;
- 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 1,730 mm (long capsule). See Table 4-3;
- 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 4-3: Masses and dimensions of the drop tower capsules

VERSION	SHORT	LONG	CATAPULT
Stringer length (mm)	1341	2107	1341
Maximum payload height (mm)	953	1718	953
Total area of experiment-platform (m ²)	0.359		
Base structure incl. batteries and CCS (kg)	122.8		
Top lid plate incl. video transmission unit (kg)	32.9		30.2
Pressurized cover incl. clamping rings and thermal isolation cover (kg)	38.5	61.1	38.5
4 Stringer (kg)	36.8	57.4	36.8
Nose cone including connection rod (kg)	4.6		10.2
1 Experiment-platform including brackets (kg)	15.5		
Capsule net weight (kg)	235.6	278.8	238.5
Capsule gross weight (kg)	500		400*
Max. payload mass (kg)	264.4	221.2	161.5

* Actual limit, enhancement up to 500 kg in future depends on evolution progress

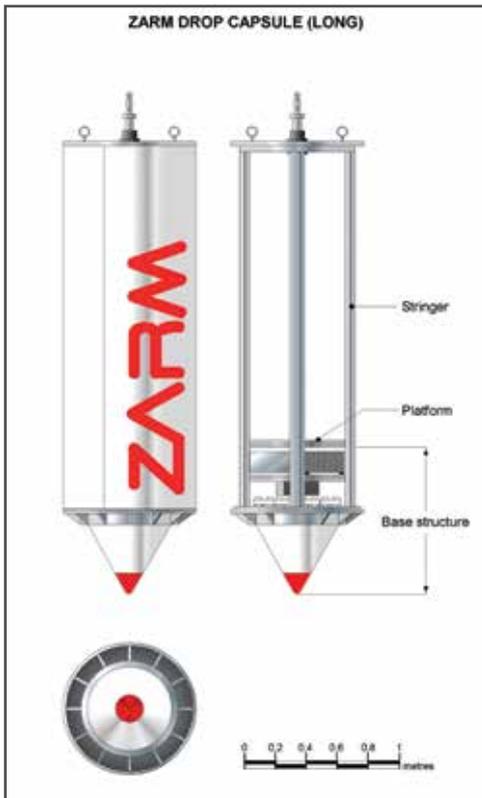


Figure 4-10: Long capsule version (with and without pressurising cover)

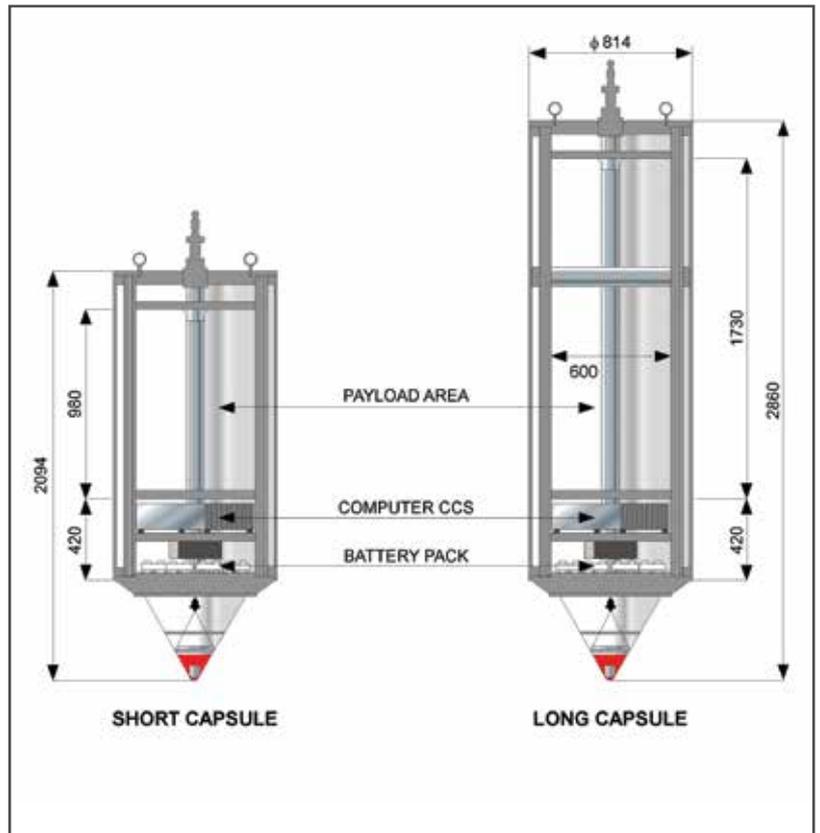


Figure 4-11: Dimensions of the drop tower capsules

4.4.1.1 Experiment platforms

The experiment platforms (see Figure 4-12) used to integrate experiments into the drop tower 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.

4.4.2 Electrical aspects of the drop tower capsule

The experiment power supply can either be provided by the capsule's 24V rechargeable experiment battery or by the high current external power supply (see: 4.6 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 Power Distribution Unit (PDU).

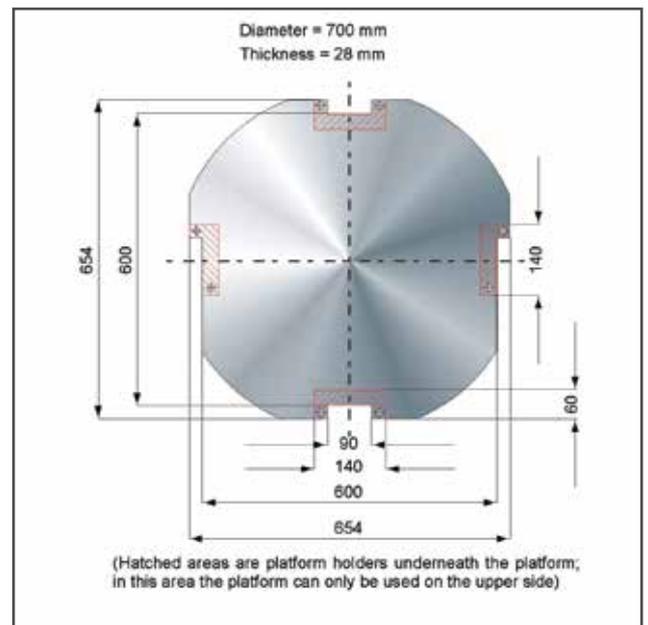


Figure 4-12: Experiment platform

4.4.2.1 Experiment Power Control (EPC) unit

The PDU unit provides nominal 24V 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 launch command. Three output channels with up to 40 A 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 A 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: 22.6 V to 30 V DC;
- maximum current per channel/ pair: 40 A;
- 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. In all cases where input sensitive hardware is used, DC-DC converters are recommended. All consumers must be grounded to one identical point on each platform.

4.4.2.2 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.

4.4.3 Electronic aspects of the drop tower capsule

4.4.3.1 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. In cases where the performance of the CCS is not appropriate, e.g. in terms of sampling rate or

resolution or communication interfaces, the customer is requested to implement the needed hardware into his setup. Triggering of the customer hardware (all mechanical or electronic elements) is foreseen to be done by the CCS.

The specially developed software package "Kapsel-Boden" (https://www.zarm.uni-bremen.de/fileadmin/images/droptower/downloads/Kapsel_Boden_Reference.pdf) is easy to use and enables the implementation of conditional logical operations related to all inputs and outputs of the CCS. This includes also the housekeeping data channels. To automatize and control a drop capsule experiment, an "ExperimentVI" (https://www.zarm.uni-bremen.de/fileadmin/images/droptower/downloads/ExperimentVI_Reference.pdf) will be developed on site in close cooperation with the scientist. This VI (Virtual Instrument) will be implemented under the rules of National Instruments™ programming language G (see "G Reference Manual" of National Instruments™). Any hardware I/O is provided to ExperimentVI as global variables by the capsule program (Kapsel). Used globals includes all data and will be transmitted via wireless LAN to the ground programme (Boden) where all acquired data can be permanently stored to the corresponding user account. For data files and global variables description see "Kapsel-Boden Reference" and "ExperimentVI Reference" (see links mentioned above). As a first approach please keep in mind, that the interface to your experiment is the CCS and it is important for the electronic interfaces of your experiment to match the interface specifications given hereafter. Wiring between the experiment and the CCS must be done on-site.

4.4.3.2 Capsule Control System (CCS)

After integration of the experiment into the mechanical structure, the experiment becomes connected to the CCS. The CCS is based upon a National Instruments™ PXI Chassis 1000B-DC with Real Time Controller 8145 RT equipped with PXI-6031E (Dev1), PXI-6527E (Dev2), PXI-6713 (Dev3) and a second PXI-6031E (Dev4). Connection of experiment digital and analogue I/O channels to the CCS is performed via the interface board. Definition of 'in' and 'out' is from the CCS point of view. So 'in' stands for signals from the experiment into the CCS and 'out' stands for signals from the CCS towards the

experiment. 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).

4.4.3.3 Virtual serial interface

Two serial interfaces of the RS-232 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.

4.4.4 Safety requirements

Even though the safety requirements are low, as compared to other micro-g facilities, some aspects are essential and to follow these rules is mandatory for a safe and successful operation. In general, these rules do not exceed those to be applied to the same research performed in a ground-based laboratory.

It is the experimenter's responsibility to care for a safe operation of their equipment. It is the experimenter's duty to implement safeguards into the equipment. The experimenter shall examine the setup to identify potential hazards. ZARM-FAB GmbH must become informed about any potential hazards identified by the experimenter in order to enable the installation of appropriate countermeasures.

The rules to be applied are summarised below:

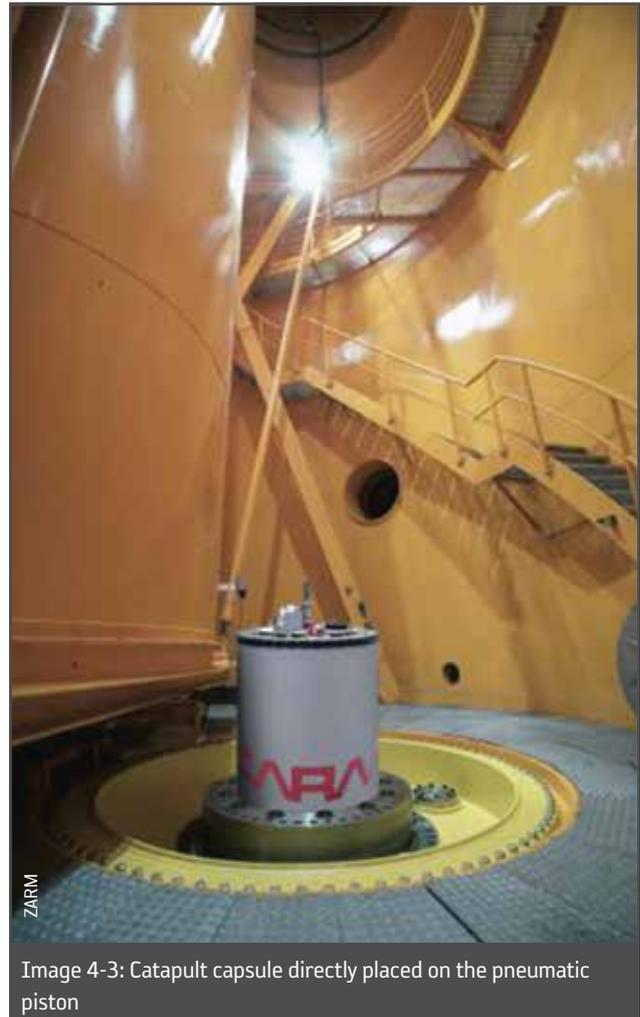
- gaseous fuels and oxidizer must be stored in different containers. Ignitable pre-mixture storage is prohibited;
- there are no general pressure limits for gas reservoirs but pressurised reservoirs used must be certified by the technical survey of the customer's country. In case this does not exist or the request is inappropriate, the customer must be able to hand over the technical standards related design calculations on request;
- if hazardous gases are used, an appropriate gas detector to monitor leakages must be part of the setup;
- the release of toxic, corrosive, explosive or bio-

hazardous or other contaminating matter into the capsule or to the outside of the capsule is prohibited. The customer is in any case requested to declare potential hazards for the drop tower crew's safety;

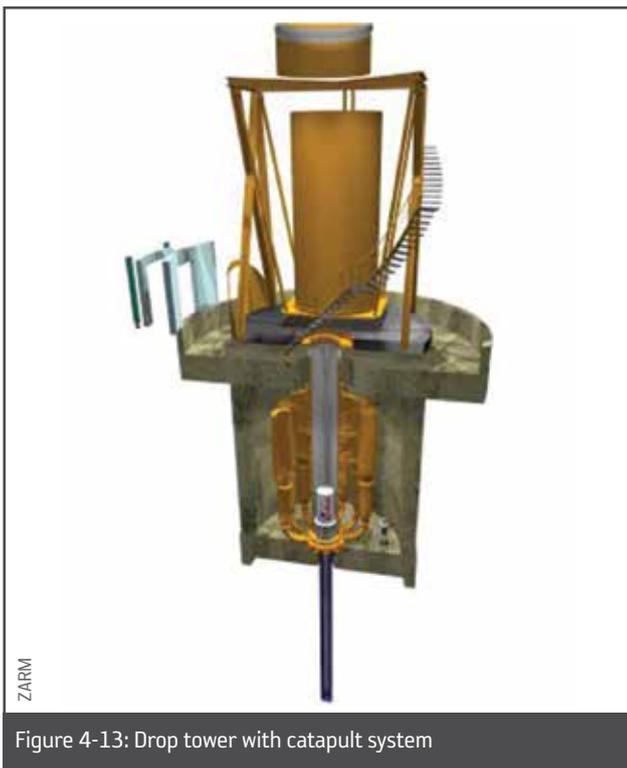
- solenoid valves must be implemented into pressurised liquid circuits containing hazardous matter. The switching power of the valves will be connected to the PDU with a g-switch. In case of CCS failure, the valves can be closed by dropping the capsule;
- the use of mercury or unstable mercury containing mixtures is prohibited generally;
- batteries must be of the dry- or gel-type. Liquid electrolytic batteries will be refused;
- the centre of gravity of the setup shall be on the vertical axis of the capsule. Slight deviations from that can be compensated on-site through attaching passive counterbalance masses to the stringers. If this is impossible because of positioning or exceeding the maximum mass of the capsule, the experiment can be refused. Please make sure masses are evenly distributed;
- change of motion of masses during free-fall shall be avoided. If this cannot be achieved, accelerations must be compensated by accelerating counterweights on- or around the identical axis. If the customer does not know about the exact location of the COG (Centre of Gravity) of the complete capsule in a particular direction a pendulum test of the fully integrated capsule will be made on-site;
- experiments that are mechanically weak and cannot be reinforced on-site will be refused. Please ensure that your equipment meets the conditions given by the deceleration forces;
- any electric element (valves, detectors etc) subjected to hazards or hazard control must be connected to the CCS. The CCS is not totally failsafe - therefore the experiment shall be in general design as failsafe as possible;
- if potential hazards are not reflected above, it does not necessarily mean that these hazards do not exist. Final approval is subjected to a last safety check at the end of integration. This may lead to a request for remedial measures. In case of any doubt, the customer is strongly encouraged to contact the ZARM drop tower staff.

4.5 The catapult system

With the inauguration of the catapult system in December 2004, ZARM entered a new dimension of ground-based microgravity research. This innovation meant that scientists could extend the experiment period to more than 9.3 seconds. In order to achieve this doubled experiment time, the catapult system has been installed in a chamber 10 metres below the base of the drop tower. This chamber is almost completely occupied by twelve huge pressure tanks. These tanks are placed around the elongation of the vacuum chamber of the drop tube. The pneumatic piston in its centre accelerates the drop capsule 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. After only a quarter of a second the drop capsule achieves its lift-off speed of 175 km/h. With this exact speed, the capsule rises up to the top of the tower and afterwards falls down again into the deceleration unit which has been moved over the catapult chamber and under the drop tube in the meantime.



The catapult system accelerates capsule masses from 300 kg up to 500 kg to a speed of 48 m/s within 0.28 seconds. A drop tower of approximately 500 m would be necessary to achieve the same experiment time of 9.3 seconds as it is available now in the ZARM drop tower.



4.6 Available facilities and resources

At the ZARM drop tower, facilities and special equipment can be made available to the users upon request. Available facilities and resources are mentioned in the following section.

4.6.1 Laboratories, workshops and workplace

ZARM has various laboratories and laboratory equipment that are placed at the disposal of 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 as they require.

4.6.2 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 FAB GmbH can make hotel, guesthouse or vacation-house bookings on behalf of users at special prices.

4.6.3 Special equipment

In general, experiments are expected to be fully equipped with all necessary sensors.

Some special equipment that cannot be expected to have been available by the experimenter can be hired temporarily (throughout a drop campaign) from ZARM FAB GmbH.

4.6.4 CCD-Cameras, VCRs, lenses

Colour CCD-cameras and associated lenses can be made available onsite. The cameras aim to complement the

experimental hardware if, during integration or during the drop campaign, additional optical access or data is desirable. The cameras conform to the CCIR standard. Recorders are of the DVCam™ standard as depicted.



Image 4-4: DVCam™ recorder and CCIR camera with zoom lens



Image 4-5: DVCam™ recorder, front panel



Image 4-6: DVCam™ recorder, rear panel

4.6.5 Digital High-Speed CMOS Imaging System

A digital high-speed video system (Photron Fastcam MC-2) can be made available. It is based on light sensitive CMOS imaging sensors and offers the following performance:

- two remote camera heads (35mm x 35mm x 35 mm; 90 g; without lens);
- 512 x 512 pixel resolution;
- 2000 f/s recording rate at full image resolution, for both camera heads and 4 s recording time;
- 1000 f/s recording rate at full image resolution, for both camera heads and 8 s recording time;

- up to 10.000 f/s with reduced image resolution (512 x 96 pixel);
- global electronic shutter from 20 ms to 6 μ s;
- colour (24 Bit) or monochrome (8 Bit);
- cameras precisely synchronised to an external source;
- lens mount: C-mount;
- remote camera heads with 3m cable allows easy positioning at hardly accessible space;
- processor unit (H: 195 mm x W: 159 mm x D: 130 mm; 5 kg);
- live video during recording, NTSC, PAL;
- ethernet camera control;
- Start, End, Centre and Manual Trigger Modes;
- saved formats: JPEG, AVI, TIFF, BMP, PNG, FTIF.

The live video output can be transmitted to ground prior and during the experiment time. The high-speed data is stored onboard. The bandwidth of the transmitted data is the same of that of a standard video.



Image 4-7: Photron Fastcam MC2 with dual camera head

4.6.6 Heating and cooling devices

Experiments can be connected to a thermal liquid circuit. This circuit is connected to a thermostat outside of the drop tube. Through a closed loop regulation, temperature can be adjusted between -20 °C and +60 °C. The circuit is disconnected about 90 seconds prior to the drop command.

Technical data of the thermostat:

- forerun temperature: -20° C - +60° C;
- liquid: Glycole/Water-Mixture;
- heating power: max. 2 kW;
- cooling power: at +20° C: 2,3 kW, at -20° C: 1.2 kW;
- volume of bath: 19-27 l;
- max. pressure: 0.6 bar.

A heat exchanger with about 1 kW power (forerun temperature dependent) can be made available.

4.6.7 Non-standard voltage-/ current-supply

One more recent feature is the High Current Power Supply, to be used as an external power supply providing max. 28 VDC with up to 100 A. Switching of current is performed with ramps. This power supply is disconnected from the capsule about 90 seconds prior to the drop command.

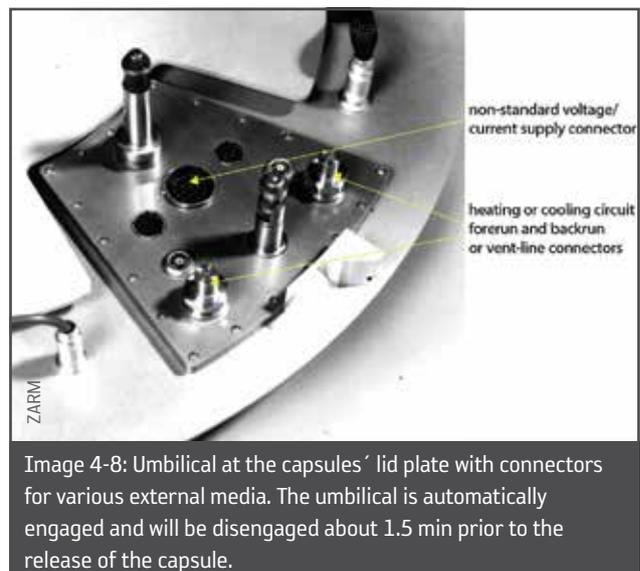


Image 4-8: Umbilical at the capsules' lid plate with connectors for various external media. The umbilical is automatically engaged and will be disengaged about 1.5 min prior to the release of the capsule.

4.6.8 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 from there be guided to the outside of the drop tube (alternative use of the connectors of the heating and cooling circuit up to 90 seconds prior to release of the capsule) 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 (delivered by the experimenter).

Cryogenic gases of non-contaminating nature or combustion exhaust gases that are free from particulates (soot, Particle Imaging Velocimetry [PIV] -tracers) can be released to the inside of the capsule during free-fall.

4.6.9 Micro-g centrifuge

Experiments requesting data from accelerations between 1 g and 0 g can make use of a specially designed onboard micro-g centrifuge. The centrifuge consists of a rotating platform equipped with a number of slip-ring transducers for electrical power and signal transmission between the rotating platform and capsule.

- total height without experimental setup: 340 mm;
- turntable diameter: 540 mm;
- fixation: T-slots 10*4 mm, slot nut M5;
- maximum load on turntable: 18 kg;
- revolutions: 0-400 rpm;
- the turntable's rotation speed is fully programmable and controllable but in order to prevent the capsule from counter-rotating the rotation speed should not be changed during free fall;
- in order to prevent the capsule from tumbling during free fall, the turntable's load shall be balanced. For electric connection of hardware elements 30 slip ring transducers are available, four of which are designed for coaxial (BNC) connections;
- micro-g-centrifuge is not applicable for catapult operation.



Image 4-9: Turntable loaded with several fish tanks with individual illumination and camera observation

4.7 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 final drop varies between four weeks and 12 months. From an analysis of past experiments, an average period of six 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 4-14 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 drop tower launch (L).

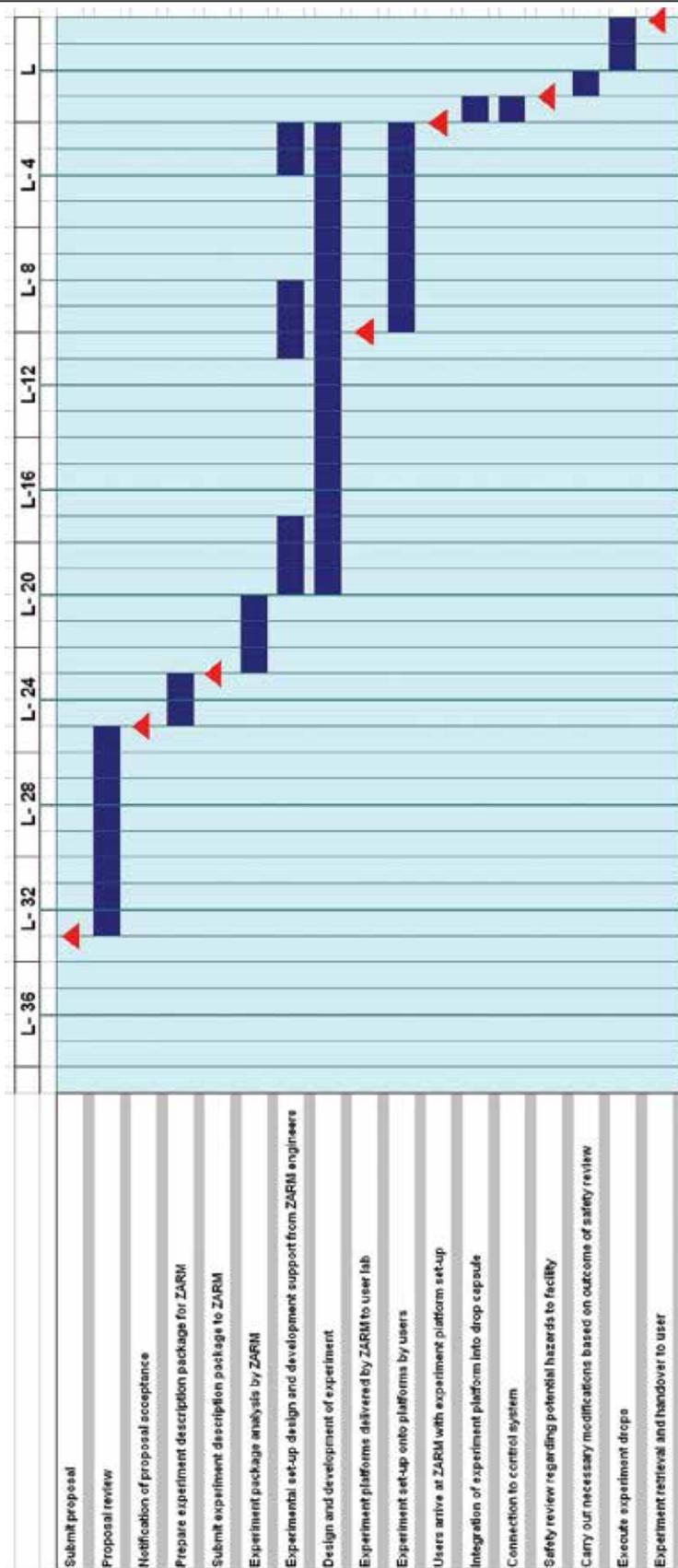


Figure 4-14: Possible timeline for an experiment in a drop tower campaign

4.8 Utilisation/Operational cycle of the ZARM drop tower

The following list is a summarised 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 chapter 2;
- once a proposal is accepted, ZARM-FAB GmbH 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 ten working days before the first launch. This time is needed for integration and ground testing;
- the drop tower is operated with three launches per day (not necessarily with the same experiment);
- each week has four 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 four hours including safety margins. The handover times are 08:00, 12:00 and 16:00. A handover delay of more than one hour caused by the user will lead to cancellation of the launch from the schedule, and will count as a performed launch. 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 1.5 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 microgravity phase, all data can be stored onboard, otherwise it can be downloaded for evaluation after the free fall via the telemetry line;
- after the free fall, the tower is refilled 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 (one to three 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 4-15.

For more information on drop towers please visit the following web pages:

www.esa.int/Our_Activities/Human_Spaceflight/Research/Drop_Towers

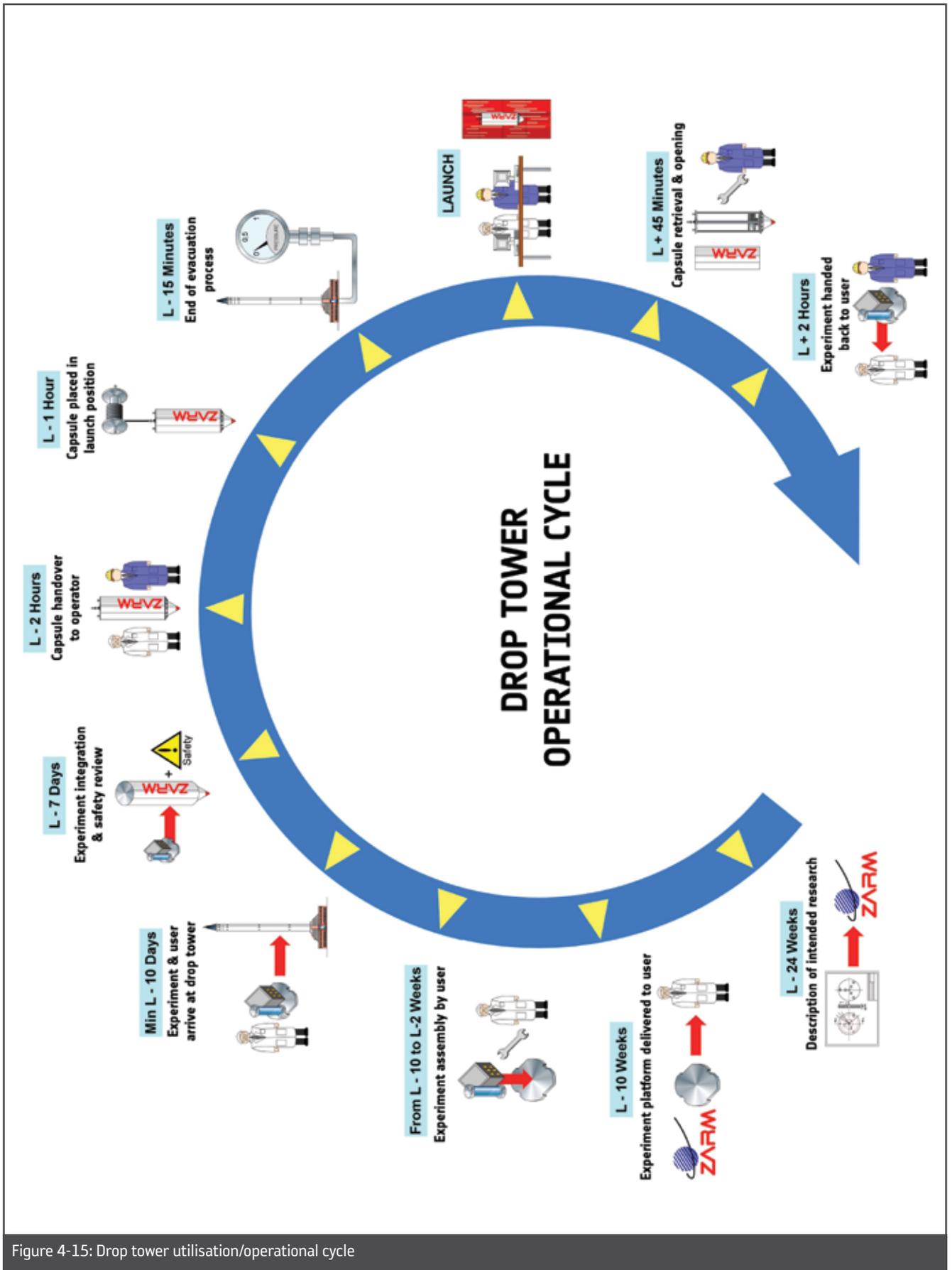


Figure 4-15: Drop tower utilisation/operational cycle

4.9 References

1. “A world without gravity”, G. Seibert et al., ESA SP-1251, June 2001.
2. Erasmus Experiment Archive (EEA) internet address: eea.spaceflight.esa.int
3. ESA Drop Towers web pages:
www.esa.int/Our_Activities/Human_Spaceflight/Research/Drop_Towers
4. “ZARM drop tower Bremen User Manual”: www.zarm.uni-bremen.de/drop-tower/downloads
5. ZARM internet home page: www.zarm.uni-bremen.de

