

Creating Microgravity

Europe's Drop-Tower for Microgravity Research

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Introduction

The drop-tower at the 'Centre for Applied Space Technology and Microgravity' (Zentrum für Angewandte Raumfahrt Microgravitation, ZARM) in Bremen (D) is unique in Europe and

provides up to 4.75 s of microgravity for experiments. ESA is currently supporting four European teams using this facility for

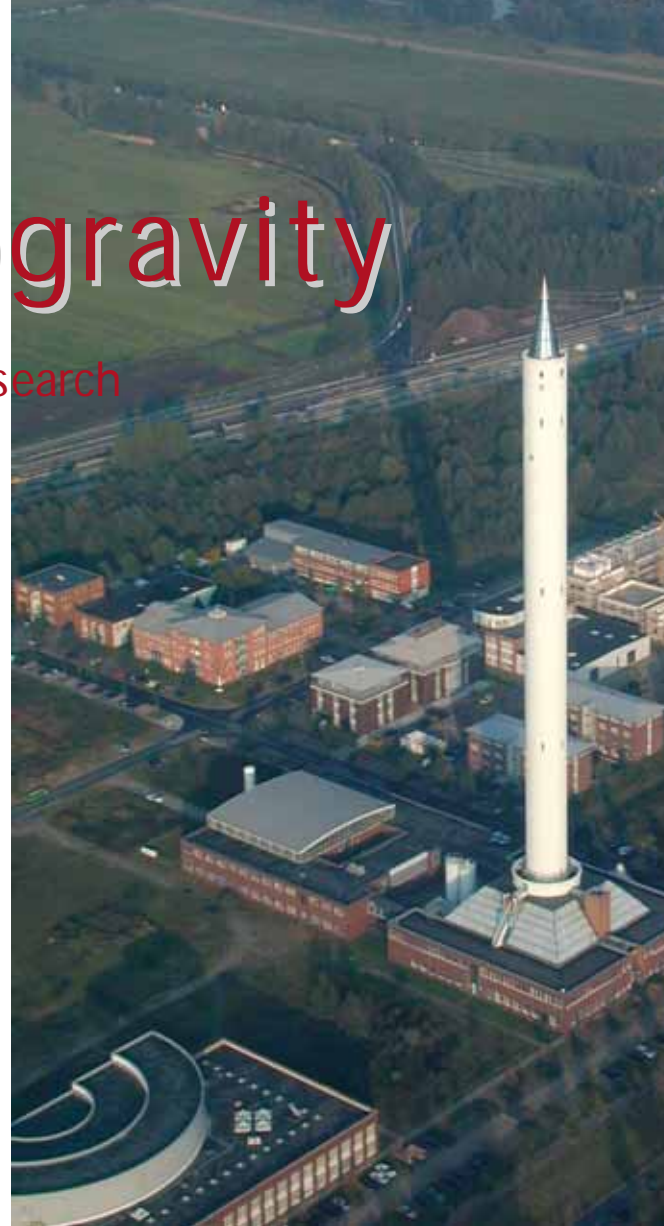
The 146 m ZARM tower in Bremen provides scientists with brief periods of microgravity ...

research into soot formation, droplet evaporation, material combustion, thermophoresis and diffusiophoresis. Gravity affects such physical phenomena on time

scales from seconds to weeks. In particular, gravity-driven instabilities set in within a matter of seconds during experiments involving steep density gradients. So drop towers and their free-fall periods lasting a few seconds are powerful research tools.

Microgravity durations offered by drop towers are inescapably limited by the height of the free-fall being proportional to the time squared. About 2 s are achieved in 20 m-high facilities, typically using drops through air at ambient pressure using a drag

shield to protect the experiment from air friction and drag. For 10 s of microgravity, a 500 m-tall vertical facility is required. In order to reach the terminal speed of about 100 m/s without air drag affecting the quality of microgravity, the experiment is carried in an evacuated capsule that is propelled by gas thrusters as it speeds downwards. Braking the capsule requires another few hundred metres. Typically, old mine shafts are exploited for such facilities: a 10 s shaft was operated in Hokkaido,



The ZARM drop tower.

Japan, until last March and a new facility is being built in Saskatchewan, Canada.

The best microgravity quality ($10^{-5}g$) is achieved by dropping capsules in vacuum to exclude aerodynamic influences, with the experiment hardware rigidly installed inside. ZARM, with Europe's largest drop facility, has such an evacuated shaft.

The Drop-Tower at ZARM

In building the drop-tower, ZARM focused on reducing the residual accelerations during the fall. The team designed a free-standing 110 m-high, 6 m-



Preparing the experiment 'Soot Particle Growth of a Diffusion Flame' using laser-induced incandescence.



The set-up for studying how materials burn in space. The windtunnel (arrowed) simulates typical airflow aboard the Space Station.



diameter vacuum chamber as the drop shaft, protected from weather perturbations by a 146 m-tall concrete tower. Eighteen pumps create a vacuum level of 10^{-5} Earth-atmosphere in about 1.5 h so that the residual drag on the capsule is less than $10^{-5}g$ by the end of the fall. The capsule is braked in an 8 m-deep tank of polystyrene pellets. Equipment is mounted on platforms specifically designed to minimise oscillations at release and to hold steady during the short braking time. The whole shaft is then repressurised to recover the capsule. Up to three drops can be carried out in a day.

When the capsule is at the top of the tower hanging over the shaft, all of its functions can still be checked and its parameters re-set. Release is triggered either by the operator or the experiment itself. All of the experiment and housekeeping data are stored onboard.

A unique excimer laser shining down from the top of the tower can illuminate experiments as they hurtle down the shaft. The capsule's automatic alignment system maintains

the position of the experiment zone relative to the laser. This is particularly valuable for combustion experiments because it allows the quantitative measurement of the concentration of various gaseous species and solid particles. Such measurements are crucial to understanding combustion processes.

By the end of this year, a catapult will become operational to fire capsules up from the bottom of the shaft, thereby doubling the free-fall time. This will make the tower even more interesting to the scientific community.

ESA-Funded Experiments

ESA continues to promote use of the Bremen tower Bremen among European scientists. It has enabled scientists to complete self-standing projects as well as complementing larger programmes employing aircraft parabolic flights, sounding rockets and the Space Station. The tower is so important to ESA and Europe that, on 2 October, a contract was signed with the ZARM FAB operating company to designate it as an ESA External Facility.

Preparing research programmes for the ISS is now in full swing at the tower; four teams are

being supported by ESA at the moment. One team is investigating the soot concentration and primary particle sizes in flames by laser-induced incandescence. Related experiments aim at understanding the production of soot during combustion in order to help develop cleaner diesel engines and to improve the production of carbon black. A second programme is looking at the combustion properties of partially premixed fuel sprays, including fuel droplets, droplet arrays and spray vaporisation. The results are of interest to companies producing turbine engines such as aircraft engines and power plant turbines.

A third team is studying the combustion properties of materials intended for space applications, as well as laminar flames representing fires in space. The scientists are developing methods to qualify space materials and to fight fires on microgravity platforms. Finally, a fundamental-physics programme is studying thermophoretic and diffusiophoretic effects by using digital holography, with the long-term goal of understanding how planets form.

Conclusion

The ZARM drop-tower is an indispensable tool for Europe to perform microgravity investigations on the ground. It is used to develop experiment hardware for other microgravity platforms such as sounding rockets and the Space Station, and its excellent microgravity quality provides highly interesting scientific data. By that, it complements ground studies, contributes to the development of numerical modelling tools, helps to define key parameters for long-duration space experiments and helps to evaluate results from other microgravity platforms. ■



The capsule is dropped down the shaft.

The research team for 'Phoretic Experiments using Digital Holography', which looks at the motions of paraffin and sodium chloride particles in nitrogen.