The Einstein-Elevator

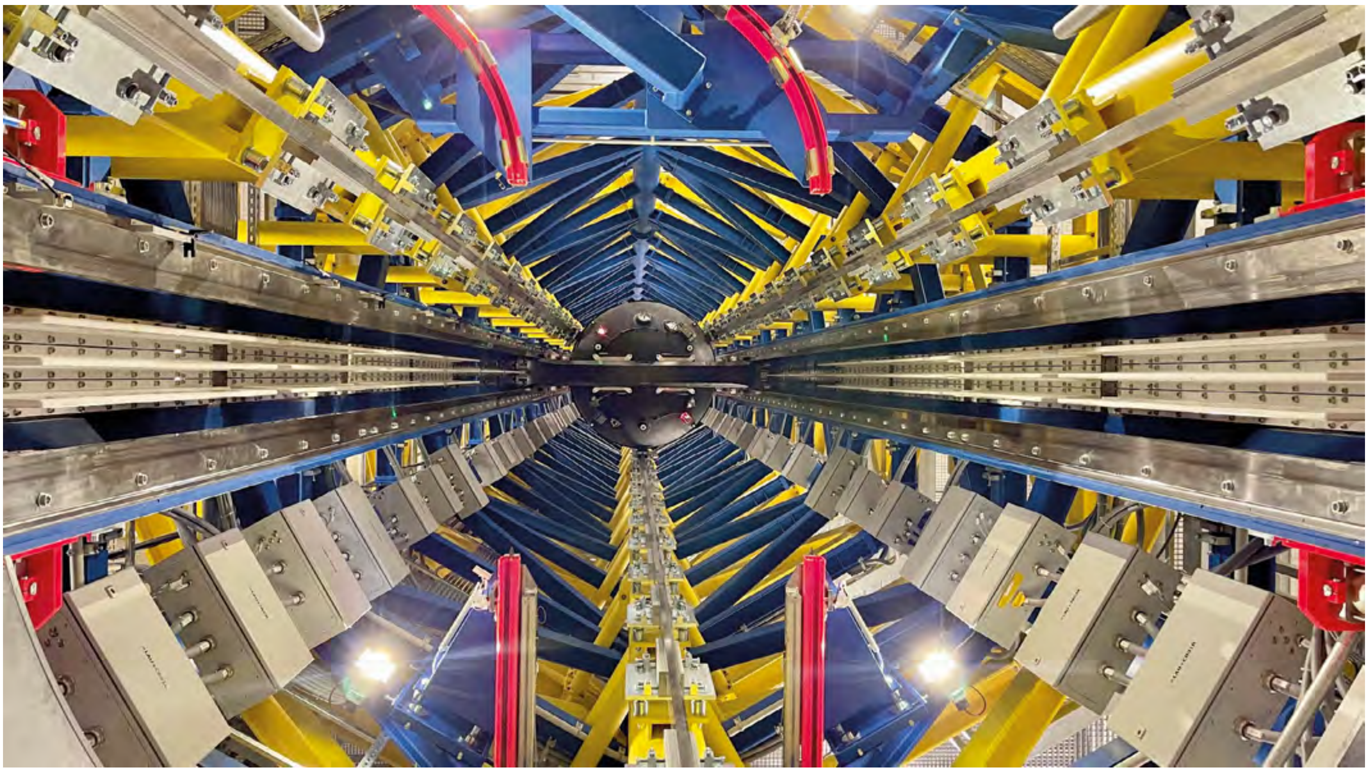
Space Experiments at the new Hannover Center for Microgravity Research

Christoph Lotz[1], Baptist Piest[2], Ernst Rasel[2] and Ludger Overmeyer[1] – DOI: https://doi.org/10.1051/epn/2023201
[1] Leibniz University Hannover (LUH), Institute of Transport and Automation Technology
[2] LUH, Institute of Quantum Optics

Development of space proven technologies, fundamental research in microgravity and preparation of future space missions all benefit from next generation drop tower facilities like the Einstein-Elevator. The facility is being made available within a DFG core facility center in Hannover.

One key aspect of next-generation drop towers is characterised by a free floating experiment inside an actively driven chamber. The experiment becomes weightless like a person in a falling elevator cabin. To avoid long evacuation times of a large vacuum tube, as applied in classical drop towers, this concept uses a chamber slightly larger than the experimental setup. These concepts also allow a high level of automation to achieve high repetition rates of several hundred drops/flights per day. The Einstein-Elevator is the first next-generation drop tower in operation worldwide (figure 1). It provides 4 s of microgravity for large experimental setups at up to 300 flights per day. Additionally, it offers also hypo- and hypergravity simulation as well as extensive technical equipment for high-tech experiments. [1] The setup is mounted on a carrier system with payload volume of 1.7 m in diameter and a height of 2 m. The total payload weight is limited to 1,000 kg. This carrier will be centered automatically inside a small vacuum chamber, the so-called gondola. Its vertical movement inside the 40 m high tower is performed by a linear direct drive. After the acceleration with 5 *g* (4 *g* dynamic plus 1 *g* earth gravity) the experiment carrier lifts about 50 mm from the gondola's floor. The microgravity phase starts immediately. While floating the experiments can •••

▼ **FIG. 1:** Experiment execution – Gondola accelerated to 20 m/s within 5 m (Credit: Leibniz University Hannover/ Christoph Lotz)



▲ FIG. 2: Arrangement of the Einstein-Elevator in the Hannover Institute of Technology. (Credit: Leibniz University Hannover/ Christoph Lotz)

be performed. Thanks to the absence of shock accelerations and low safety requirements, the Einstein-Elevator allows to conduct experiments with a low technology readiness level (TRL). After a coupled deceleration the gondola comes to a standstill at starting level. The next execution starts after a short preparation phase of less than 4 min. After completion of the campaign, a quick experiment exchange ensures a fast project turnaround time.

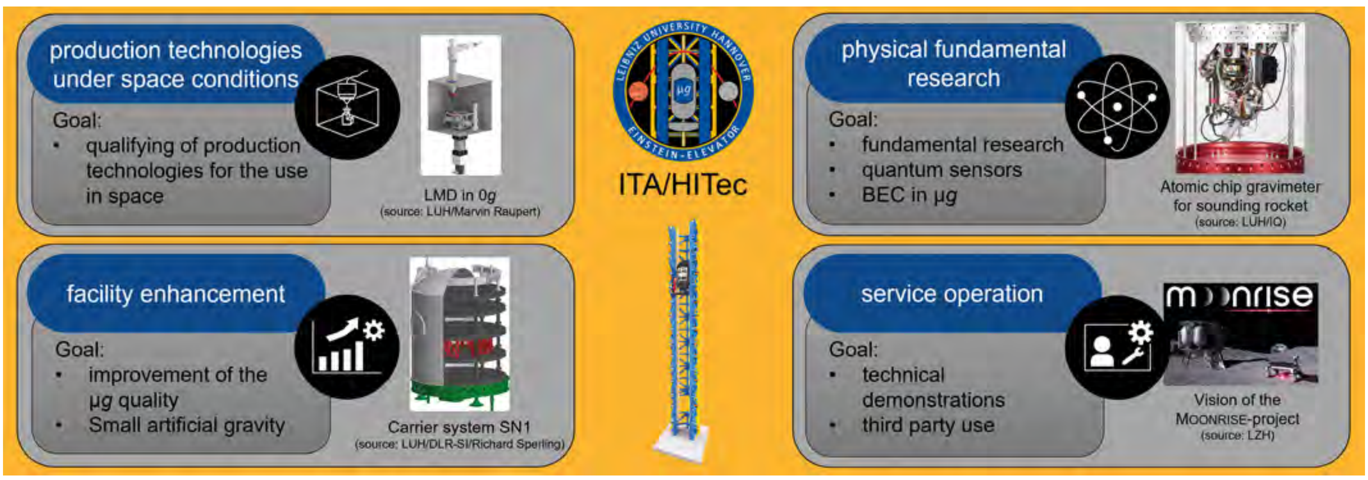
Core Facility Center

The "Hannover Center for Microgravity Research" (figure 2) supports external experiments and researchers with infrastructure to provide an excellent research environment. In addition to the mounting levels required to integrate the experimental setups into the experiment carrier system, other technical equipment can be used to operate the experiments inside the Einstein-Elevator. Highspeed and thermal camera systems as well as an advanced data acquisition system are tested for the use under the advanced acceleration conditions. The operation of the experiments is quite easy and fast due to its automation level. But the preparation of highly sensitive setups for high quality results is still time-consuming. In most cases, the personnel expenses required significantly exceeds the costs of performing the experiments. This is why the core facility center is so important for the support of external experiments. Depending on the project, the project consortium and the project sponsor, different types of cooperation can be established. Joint project application, project participation within work packages but also a pure service contract is possible. Everything starts with contacting the Einstein-Elevator operation team which is also in charge for the operation of the core facility center.

Future Trends and Current Research Issues

The Einstein-Elevator at the Hannover Center for Microgravity Research offers new research opportunities for a wide variety of research disciplines and topics. It provides access, technical support and equipment for external researchers. Therefore, the facility can be used across a range of topics and follow the trends of international research in the field of In Situ Research Utilisations (ISRU) technologies as well as high-precision quantum sensors are reflected in the focus of own research of the Leibniz University Hannover (LUH) own research (figure 3). An example is the idea to establish a permanent human presence on the Moon or even Mars, driven forward internationally by private companies and governments. Essential components for a sustainable conquer of space include reducing the financial expenditure for transportation through the reusability of rockets and the possibility to build self-sustaining stations. The first issue has gained a lot of progress in the last 10 years due to privatisation in the U.S. space industry. However, for self-sustaining stations, there is a great need for international research in this area and many initiatives have been formed around this topic. Essentially, this involves material development, production technology, energy technology, nutrition sciences, but also key technologies in the field of sensors, robotics and AI.

▼ FIG. 3: Research in the Einstein-Elevator: division of research topics (Credit: Leibniz University Hannover/ Christoph Lotz)



Another example is gravity field mapping of Earth from orbit using new types of high-precision measuring instruments. Technologies for fundamental physics experiments on board the ISS like Bose-Einstein condensates in the Cold Atom Laboratory are also progressing massively. Many newly developed research instruments are available, for example Bose-Einstein condensation on an atom chip, waiting to be used in future space missions. These sensor systems, classical as well as quantum-based, are currently gaining the necessary TRL for widespread use.

A new research group at LUH, emerged from the Institute of Transport and Automation Technology (ITA), the Institute of Quantum Optics and the QUEST-Leibniz Research School, is working on production technologies for use in new space missions such as powder-based additive manufacturing processes applicable on the Moon for production with the resources available on site, as well as metal powder processing in a microgravity environment to enable production of spare parts on board the ISS. The ITA/LUH have also been involved in the proposal of the large-scale research center "ERIS" (European Research Institute for Space Resources [2]). Its goal is to achieve great innovation leaps in solving terrestrial problems by researching the challenging environmental conditions of the Moon. Members of the ITA/LUH are also a founding member of ERIS e.V., which emerged independently from the funding of the large-scale research center, to promote progress in ISRU, among other things.

In close collaboration with colleagues from the Institute of Quantum Optics, the QUEST Leibniz Research School and the new DLR Institute for Satellite Geodesy and Inertial Sensing, quantum sensors are being developed for geodetic applications as well as the fundamentals for high-precision surveying of Earth and space with support of the area "physical fundamental research". Current projects on fundamental research in quantum physics at the Einstein-Elevator are concerned with the search for dark energy, the demonstration of a source of entangled atoms in microgravity, and the development of low-noise sensors based on nanomagnets.

Acknowledgements

The authors thank the DFG and the Lower Saxony state government for their financial support for building the Hannover Institute of Technology (HITec), the Einstein-Elevator (NI1450004, INST 187/624-1 FUGB), and the DFG for funding the "Hannover Center for Microgravity Research" (INST 187/801-1). This paper was prepared among other projects in the context of Quantum-Frontiers (Cluster of Excellence). ■

References

[1] Lotz, C.; Froböse, T.; Wanner, A.; Overmeyer, L.; Ertmer, W.: Einstein-Elevator: A New Facility for Research from µg to 5 g, *Gravitational and Space Research* **5**, 11 (2017), *Nr.* 2,

[2] Grigoleit, J.: ERIS – European Research Institute for Space Resources: Homepage, https://space-resources.de/en (06.09.2022)